OT–P–30–79–05

**BART Impact Program**

# ENVIRONMENTAL IMPACTS OF BART



**FINAL REPORT**

**APRIL 1979**

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16. Abstract

This report is a summary of the results and accomplishments of the Environment Project of the BART Impact Program. The study consisted of a detailed assessment of BART's current environmental impacts, including direct (i.e.,wayside) impacts as well as indirect impacts (resulting from development in BART station areas) and effects on the system's patrons. Assessment was made using both technical impact evaluations (e.g., noise measurements) and surveys of the responses of those affected. In addition, indications of BART's construction impacts and future impacts associated with the system's full-service level of operations are described and evaluated.

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DOT-OS-30176

BART IMPACT PROGRAM

# ENVIRONMENTAL IMPACTS OF BART
# FINAL REPORT
## DOCUMENT NO. DOT-BIP-FR 7-4-77

PREPARED BY

**GRUEN ASSOCIATES, INC.**

**DE LEUW, CATHER & COMPANY**

UNDER CONTRACT WITH THE

**METROPOLITAN TRANSPORTATION COMMISSION**

FOR THE

**U. S. DEPARTMENT OF TRANSPORTATION**

AND THE

**U. S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT**

UNDER

**CONTRACT DOT-OS-30176**

**TASK ORDER 204**

## 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.

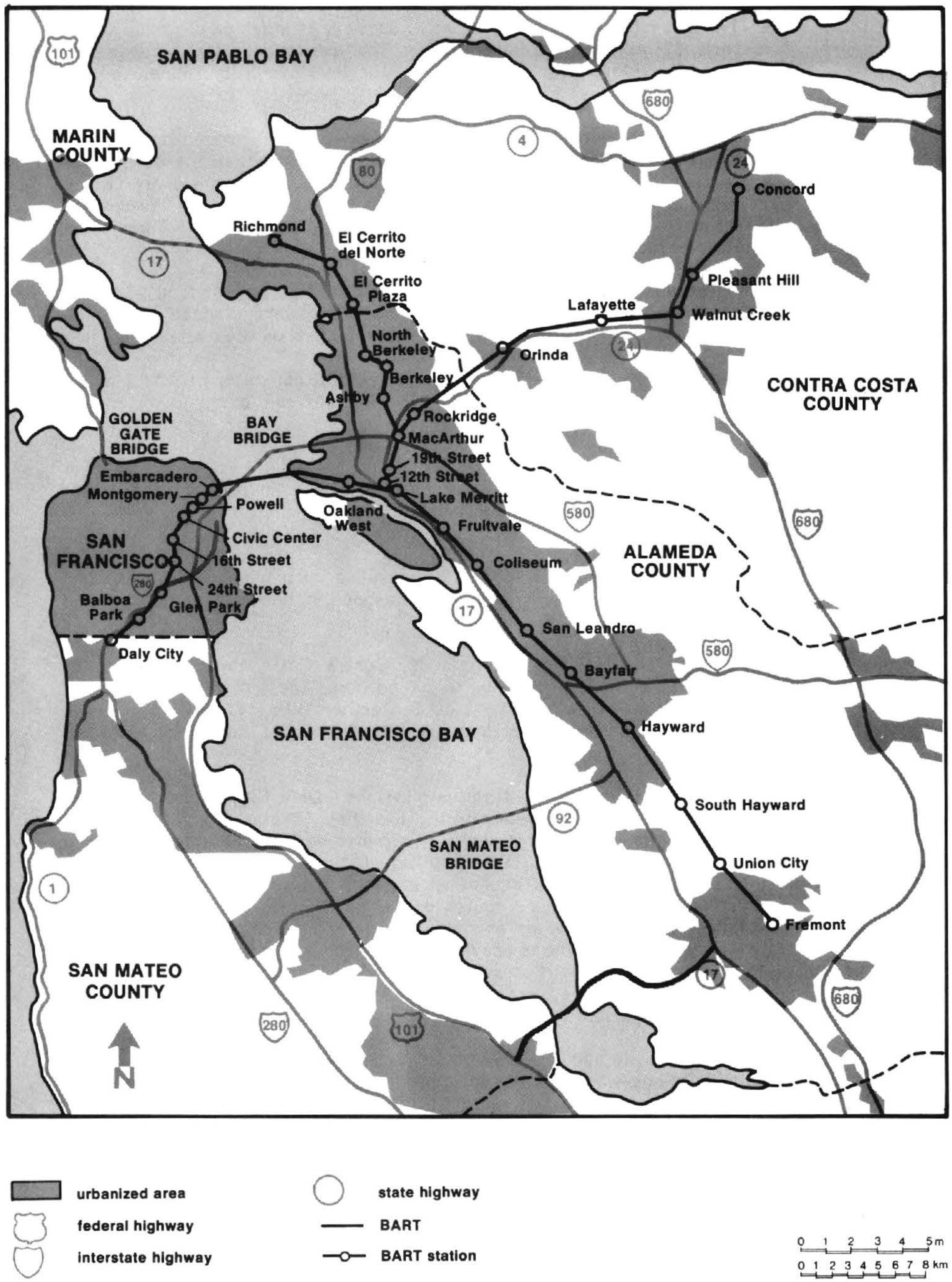
McDonald & Grefe, Inc., "The Economic and Financial Impacts of BART," MTC, 1979.

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.


SAN PABLO BAY
MARIN COUNTY
Richmond
El Cerrito del Norte
El Cerrito Plaza
North Berkeley
Berkeley
Ashby
Rockridge
MacArthur
19th Street
12th Street
Lake Merritt
Oakland West
Fruitvale
Coliseum
San Leandro
Bayfair
Hayward
South Hayward
Union City
Fremont
Concord
Pleasant Hill
Walnut Creek
Lafayette
Orinda
CONTRA COSTA COUNTY
ALAMEDA COUNTY
GOLDEN GATE BRIDGE
BAY BRIDGE
Embarcadero
Montgomery
Powell
Civic Center
16th Street
24th Street
Glen Park
Balboa Park
Daly City
SAN FRANCISCO
SAN FRANCISCO BAY
SAN MATEO BRIDGE
SAN MATEO COUNTY
N
101
680
4
80
24
17
580
280
92
1
urbanized area
federal highway
interstate highway
state highway
BART
BART station
0 1 2 3 4 5 m
0 1 2 3 4 5 6 7 8 km

**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.

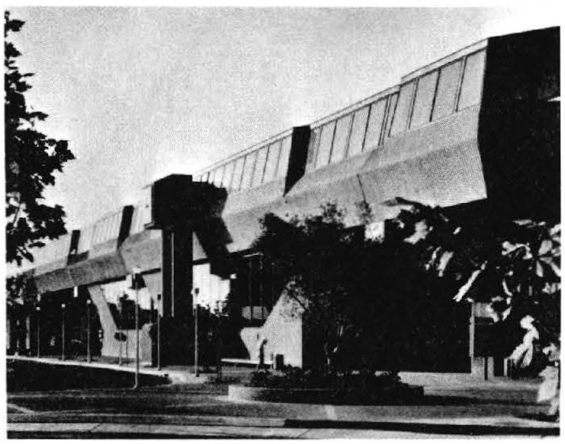
**Cost:** BART construction and equipment cost $1.6 billion, financed primarily from local funds: $942 million from bonds being repaid by the property and sales taxes in three counties, $176 million from toll revenues of transbay bridges, $315 million from federal grants and $186 million from interest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

March 1978

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

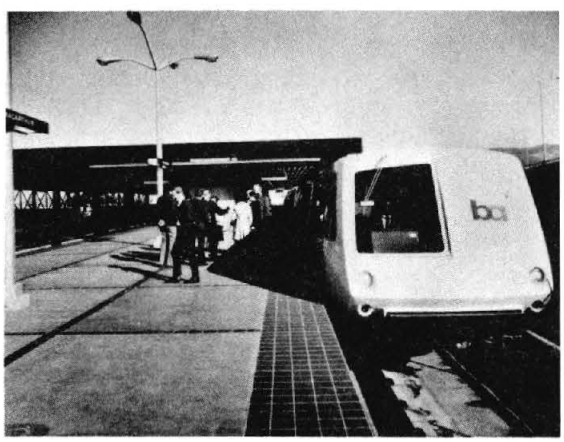
Aerial line.

Maintenance yard.



Station exterior.


Station concourse.



Station platform.

Train interior.

**VIEWS OF BAY AREA RAPID TRANSIT SYSTEM**

Photos supplied by BART

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# SUMMARY

This final report of the BART Impact Program's Environment Project provides an overview of the BART system's environmental impacts. Consideration is given in turn to the past effects of its construction, the current impacts of its facilities, operations and associated land use changes, and future changes in impact. Impacts on the environment outside BART are the study's primary emphasis, although the impacts of the system on its users are also reported.

Each of this summary's sections states a key conclusion from the study, briefly outlines the supporting findings, and concludes with implications for rapid transit planning and design in other cities. The body of the report presents more detailed findings, conclusions, and implications. Further details of methodology and findings are provided in a series of published technical memoranda, which are referenced at the end of the report.

## OVERALL LEVEL OF IMPACT

**BART has not had much impact on its environment.** This conclusion is particularly significant in view of the system's large size, the intensive local activity it generates at stations, its variety of configurations, and the diversity of environments through which it passes. Moreover, it was planned and largely completed before environmental concerns had attained their present importance in public policy.

There are exceptions: impacts vary throughout the system, both in degree and nature, depending on variations in BART itself and in its surroundings. However, the system's environmental impacts—both during construction and through its early operations—have been small enough in most places to require careful study even to detect. This "low profile" of impact is confirmed by surveys of BART users and nearby residents.

This demonstrates that it is possible to build a large rapid transit system with a generally low degree of environmental impact, although specific attributes of both the system and its surroundings are key factors in such a result.

## MOST SIGNIFICANT IMPACTS AND CAUSES

**The disruption of traffic and other activities during subway construction, traffic and parking problems at suburban stations, and train noise along aerial lines have been the most serious environmental impacts of the BART system. Beneficial impacts include its landscaping, linear park, encouragement of downtown street improvements, and generally excellent provisions for its riders.** Subway construction caused enough inconvenience in some places that its effects are still remembered by nearby residents today, years after its completion. The disruption of traffic, pedestrian movement and retail trade was worsened by the long construction period, which extended over five years in some locations.

Train noise problems occur along about ten percent of the line and are confined to a narrow band (about two blocks), but are significant to many of the persons whose homes are affected. Although the trains are quiet compared to most other rapid transit vehicles now in use, their high speeds combine with the sound transmission qualities of the elevated trackways to generate sound which exceeds background levels in quiet neighborhoods.

Overflow parking at several suburban stations located in residential neighborhoods is the system's most serious continuing environmental problem. This is caused by the dominance of automobile access to BART stations everywhere but in the city centers. The high levels of BART access by automobile result in part from the lack of effective feeder bus service and other alternatives for station access and in part from a long-standing orientation to car travel among the Bay Area population. Overflow parking problems are especially severe at terminal stations, where a high level of patronage is drawn from large outlying areas.

On the other hand, BART has helped to improve some of its urban and suburban settings through extensive landscaping and encouragement of downtown street and sidewalk improvements near its stations. Other positive aspects include the high environmental quality of the BART travel experience. This is virtually without peer, particularly in the design and function of the stations and trains. These benefits are substantial and widely recognized.

From the BART experience it appears that many of a transit system's adverse environmental impacts can be avoided. BART's success in avoiding or minimizing adverse impacts could be improved upon in future systems by faster subway construction methods, train noise barriers, locating lines away from sensitive areas, providing adequate parking, and good bus access to suburban stations. In addition, BART has demonstrated that rapid transit can enhance environmental quality by stimulating urban beautification.

## IMPACTS OVER TIME

**BART's future operational impacts, both beneficial and adverse, are not expected to change much from those to date.** Impacts experienced in the early stages of rapid transit operations are generally representative of the effects to be expected in later years under more stable conditions. As BART service expands and patronage grows, some current problems such as access to suburban stations will spread to more stations and become more serious at stations already experiencing problems. The growth of BART patronage could be discouraged by such problems unless more parking and better bus feeder service is provided.

It also is possible as well that environmental benefits might result from future land use impacts of the system. If the potential for relatively intense development near stations in outlying areas is realized, the amount of land consumed by urban expansion could be reduced. Such station-area development might also bring the economic and environmental advantages of a more compact transit-oriented urban structure. These "indirect" impacts could become the system's most significant environmental benefits.

## UNREALIZED FEARS AND EXPECTATIONS

**Many expected environmental impacts of BART, both beneficial and adverse, have not materialized.** Contrary to some fears expressed during the planning process, BART has not generated significant automobile-related air pollution or noise at its suburban stations. Likewise, crime (especially crimes against persons) has not been a significant problem, either to patrons or to station-area neighborhoods. There is also no indication that the above-ground trackway functions as a serious barrier to cross-line movement. The natural ecosystems near BART facilities have suffered no impacts; vibration from passing trains is not a problem; and the visual impacts of BART facilities have not been significant.

Some anticipated benefits have also not appeared. As is now generally recognized, an urban rapid transit system such as BART contributes only marginally to regionwide traffic reduction and related energy savings and air quality improvement. In addition, BART's effect to date on urban development patterns appears to be minimal. The areas near BART experiencing the greatest development are downtown San Francisco and Oakland, but many factors other than BART contributed to development in these areas. Very little land use change has occurred around stations. The system has not served to check urban sprawl by encouraging redistribution of low-density development into higher-density station-area development. In general, the system's overall environmental impacts, both good and bad, have been less than expected.

A new rapid transit system is not likely to solve a city's commuter traffic-related problems to any significant degree nor to cause a wide array of serious localized dangers. This study's specific evidence of BART's limited impacts should help to reduce both overoptimism and undue apprehension concerning environmental impact in the planning of future rail rapid transit systems.

## LOCATIONS AND PERSONS AFFECTED

**BART's environmental impacts affect some of the people living very near its lines and stations; most of these are not members of ethnic minorities or persons of low income.** All impacts are limited to an area within four blocks of BART, with the nearest block by far the most strongly affected. The impacts, including various minor ones and more severe train noise problems, have occurred along about a sixth of BART's line mileage (12 miles) and around most of its stations. About 46,000 persons, or about one-fourth of those living within a few hundred feet of the lines and stations, were adversely affected either by BART's construction or operations. Since the completion of construction, fewer than 13,000 continue to be disturbed.

Construction impacts fell primarily on densely settled areas near subway construction sites (where about one-half of the population are members of ethnic minority or lower-income groups) and to a lesser extent around the suburban stations with large parking lots (typically affecting middle-income households). Operational impacts were found to affect fewer people, mostly non-minority middle- and lower-middle-income groups living along the aerial lines and near outlying stations. Much of the system is in lower-income areas in its central city portions, where it is underground. However, the greater portion of its total length, which is above-ground, is in suburban middle-income neighborhoods. Suburban neighborhoods are relatively more sensitive to these impacts because previous levels of traffic, noise and other environmental disruptions which mask BART's effects were low. No one social group was found to be more or less sensitive to impact than others. The overall level of concern about impact reported by residents interviewed was not high; 18 percent were unhappy about BART's effects in and around their homes; the rest were either pleased or indifferent.

Above-ground line construction appears to generate fewer impacts than subway construction, but the above-ground features have greater impacts due to the system's operation. In future transit planning special attention should be given to locations and methods of proposed subway construction, particularly in inner-city areas where many people may be affected.

## TRANSFERABILITY

A number of significant conclusions have been drawn in this study concerning BART's environmental impacts, their specific causes, and the populations on whom they fall. These conclusions have led to implications for possible application elsewhere. Despite the obvious value of such implications, however, a word of caution concerning their application is in order.

BART's impacts depend heavily on specific sensitivities of its surroundings, as well as on certain attributes of BART itself. These environmental sensitivities were found to vary widely along the BART lines and among its stations, resulting in major differences in impact. Since other cities and their alternative system routings also differ in sensitivity to impact, the BART experience can be "transferred" only with caution and a clear understanding of how closely BART's setting, as well as its own attributes, are representative of those in other (proposed) situations. However, it does appear that in any setting the environmental impacts of greatest concern in the planning of a rail rapid transit system will be those associated with subway construction, train noise along aerial line segments, and increased traffic and associated parking demands in outlying station areas.

An even more important determinant of the overall level of impact to be expected is the "null alternative," or how the region's transportation facilities and their use would most likely have developed without the transit system. The impact of a transit system is the difference in the whole regional environment with and without the system, not just around its lines and stations. If by building such a system other major environmental disruptions such as freeway expansion are avoided, the result may be environmentally favorable, even though the system itself has some adverse effects. The "no-BART alternative" employed in the BART Impact Program was defined as the transportation system judged most likely to have evolved in the absence of BART. Based on an analysis of the political and economic decision history of the Bay Area, it stipulated no significant changes to the area's existing freeway and bridge system. Therefore, no major highway-oriented disruption was avoided by building BART. As a result, BART's net environmental effects are mostly adverse. Elsewhere, the balance could be much different. The BART experience does show, however, that even without such "benefits by avoidance," a rapid transit system's environmental impacts need not be large.

Changes in the environment due to a transit system's land use impacts might also figure prominently in its balance of environmental effects. Such land use impacts might involve the generation of a more compact urban development pattern which would require less use of land, energy, and travel time. However, since no significant land use changes due to BART have been identified to date, this study's results reflect no such effects. This might well be different in another city, and the environmental effects of land use impacts should be considered in any study of transit options.

Within this context, the conclusions and implications presented here represent the major lessons drawn from the study of BART's environmental impacts. They are intended to be balanced in the BART Impact Program Final Report against other factors such as cost and levels of service, and to aid others in making decisions about transit development.

# I. INTRODUCTION

## THE BART IMPACT PROGRAM

As the first regional rapid transit system built in the United States in more than 50 years, the San Francisco Bay Area Rapid Transit System (BART) is a potential learning model for metropolitan areas now considering investments in transportation facilities. It is of additional interest to the Federal Government in allocating financial aid for local transportation improvements, urban development and environmental protection in urban areas. The BART Impact Program is designed to meet immediate needs for accurate information on the BART investment and to provide input for future transportation decisions in the Bay Area and throughout the nation.

The BART Impact Program is a comprehensive, policy-oriented study and evaluation of the impacts of the BART system. It covers the entire range of possible rapid transit impacts and includes major impact studies of the Bay Area's transportation systems, travel behavior, land use and urban development, the environment, the regional economy, social institutions and lifestyles, and public policy. The impacts are defined, then measured and analyzed by their effects on population groups, local areas, and economic sectors. Finally, the benefits of BART are weighed against the negative impacts and system costs in order to arrive at an evaluation of the BART investment in meeting the overall needs and objectives of the metropolitan Bay Area and its people.

## THE ENVIRONMENT PROJECT

Within the BART Impact Program, the Environment Project has conducted impact studies focusing on two related phenomena:

- Direct and indirect effects upon the physical environment brought about by the BART system.
- Social and psychological consequences of these changes in the physical environment.

The issues of primary concern to the Environment Project's study of these phenomena are readily translated into a set of questions:

- What aspects of the physical environment are affected by BART?
- Where and why do these impacts occur?
- Who are most affected by BART's impacts?
- How can this information best be used by decision-makers?

Several characteristics make the Environment Project unusual among environmental impact studies. First, it examines an existing transportation system rather than a planned or hypothetical one. Second, it has sought out all existing environmental impacts instead of being limited to a set of hypotheses or predetermined impact types. Finally, the Project has studied not only BART's physical impacts, but also the persons affected and their responses to the impacts. It is hoped that the Environment Project studies will become a cornerstone for better forecasting of the environmental impacts of transit systems and will result in more reliable guidance of public and private decisions in transportation planning and design, environmental protection, and urban planning.

The studies were accomplished in two phases. During Phase I (April 1974 to August 1975) a detailed research plan was designed. BART's direct physical effects were defined and assessed, the population groups affected were identified, and a baseline for study of impact changes over time was established. The Phase I studies are documented in a report published in January 1976.[1]

Phase II studies (October 1975 to August 1977) have focused on three main issues: (1) how people living near BART perceive and respond to its impacts, (2) the environmental experience of the BART patron within the system, and (3) BART's indirect physical effects, i.e., the impacts resulting from BART-associated changes in urban development and activity patterns. In addition, supplementary studies of BART's direct impacts were conducted.

Both the Phase I and the Phase II studies are the basis of this report. The study's complete documentation is shown at the end of this report.

## REPORT CONTENT AND ORGANIZATION

The purpose of this report is to present a detailed summary of the full range of Environment Project findings, conclusions, and implications. The organizational intent is to convey a full and concise picture of past, present and projected BART impacts in a form that is useful to planners and designers of transit systems as well as to decision-makers and public administrators.

The general findings, conclusions and implications reached from all studies are consolidated into one Summary section at the beginning of the report. The descriptions of general study concepts, strategies and methods in the Study Design chapter (Chapter II) are supplemented by the specific methodology information in each of the four chapters on findings (III-VI).

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1 Gruen Associates, Inc. and De Leuw, Cather & Company, **Environmental Impacts of BART: Interim Service Findings,** Document No. DOT-BIP-FR 2-4-75. Berkeley: Metropolitan Transportation Commission, January 1976. Prepared as part of the documentation for the Environment Project.

The chapter on Construction Impacts (III) assesses the past impacts of building the BART system. Chapter IV (Direct Impacts) incorporates the technical assessment of current direct impacts with the Resident Response Survey results, presenting the full scope of BART's direct environmental impacts regionally (as they affect the entire Bay Area) and locally (as they affect residents near BART lines and stations). Chapter V examines the current indirect environmental impacts of BART, and Chapter VI discusses the BART patron's travel experience. Theoretical projections of BART's future impacts and their implications for the Bay Area are presented in Chapter VII. The final chapter (VIII) addresses the question of how the findings can be used by decision-makers by focusing on conclusions and implications.

# II. STUDY DESIGN

## BASIC CONCEPTS

In this study the term **environment** encompasses a broad set of characteristics ("impact categories") organized under a five-component classification of the human environment, as shown in Table II-1. By screening various environmental impact classificiation schemes, the impact categories of potential relevance to a rail rapid transit system were selected for inclusion in the study.

### TABLE II-1
### ENVIRONMENTAL COMPONENTS AND IMPACT CATEGORIES

| nvironmental omponent | Acoustic | Atmospheric | Natural | Social | Visual |
|---|---|---|---|---|---|
| ıpact ıtegories | • Sound<br>• Vibration | • Regional air quality<br>• Local air quality<br>• Microclimate | • Biota<br>• Soils and geology<br>• Drainage and water | • Barriers<br>• Safety<br>• Security<br>• Visual exposure | • Visual quality<br>• Illumination<br>• Shadows |

The term **impact** in this Project refers to the effect of a given BART stimulus or emission (e.g., train sound) on an adjacent environment. Environmental impacts can arise **directly** from BART attributes such as its structural facilities and train operations. Impacts may also arise **indirectly** through intervening factors, such as BART-caused changes in travel behavior and land use, which lead to environmental impacts at least partially attributable to BART's presence. The term **response** carries the idea of impact a step further to encompass the various ways in which people perceive, interpret and react to the environmental impacts.

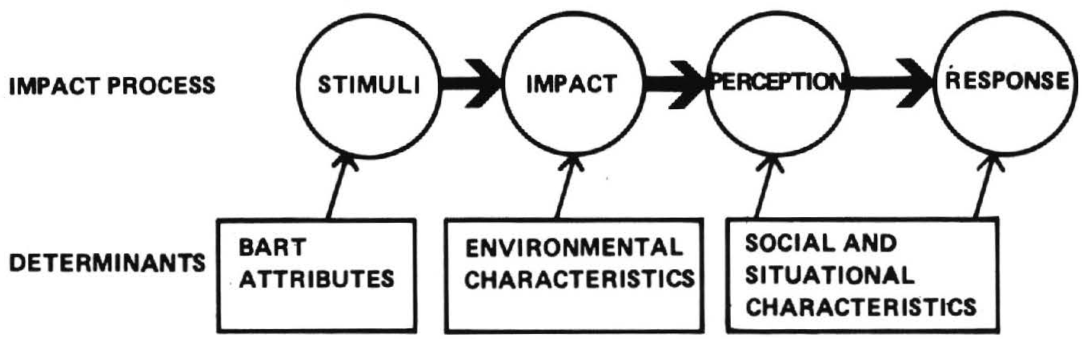
## IMPACT PROCESS

The Environment Project not only identifies and assesses impacts, but also relates those impacts to their origins and to their effects on people.

The **analytical scheme** used in the study follows a general model of the impact process (Figure II-1) in which specific BART attributes (e.g., train speed) are sources of environmental **stimuli** (e.g., sound). These stimuli interact with characteristics of the nearby environment (e.g., background sound level) to produce a distribution of **impacts** across a given area. The impacts in turn are **perceived** by persons in the environment, who **respond** to them.

The process **determinants** are the causes of impact occurrence, location and extent. Determinants include impact origins (**BART attributes** and their indirect effects) and modifiers of impact (**characteristics of the surrounding physical environment** which influence its susceptibility to impact). Also included are **social and situational characteristics** (e.g., age, ethnicity, income, sex) of the persons affected, which may influence the ways they receive and respond to a given impact.

**FIGURE II-1**
**IMPACT PROCESS AND DETERMINANTS**




## RESEARCH STRATEGY

### Study Scope

Since BART is not yet at its planned level of service, a total emphasis on its present environmental impacts would produce a misleading and soon obsolete report. In addition, some observers contend that the system's long-range indirect environmental impacts—those arising from its ultimate effects on the region's pattern of development—will prove to be much more significant than its direct impacts. In consideration of such concerns, the Environment Project has sought to examine BART's environmental impacts throughout its expected life, rather than only those occurring at the present time. These include environmental effects of construction, current interim operations, future full-service operations, and possible long-term influences of the system on urban development.

Since only the current situation is available for detailed empirical study, the system's most recent impacts are the basis of the study. However, the limited available information has been used to provide indications of BART's construction impacts, and the basic study's detailed findings on impacts of current BART operations have been adjusted for future system changes to yield predictions of the system's full-service level of operations. Finally, without actually predicting BART's impact on land use,[1] the system's maximum likely land use effects and associated environmental impacts were estimated. This provided a basis for discussion of the possible importance of such impacts relative to the system's direct impacts.

1 This is the task of the BART Impact Program's Land Use and Urban Development Project.

The assessment of BART's current environmental impacts, which are the basis for these projections, included direct (i.e., wayside) impacts as well as indirect impacts to date and effects on the system's patrons. For both direct impacts and effects on BART patrons, surveys of those affected were conducted in addition to technical impact evaluation.

In the first of the Environment Project's two phases, the focus was on BART's direct wayside impacts. Effects of specific impact determinants were assessed at sites selected for their representation of the BART system's most characteristic conditions. The occurrence of these conditions throughout the BART system was inventoried, and from this base the overall degree of impact and effect of each determinant was estimated.

In Phase II, the Project's concern shifted to the human response to these impacts. In addition, studies evaluated indirect impacts; changes in impacts over time and with changes in BART service, and impacts on BART users. Where a need for further study had been identified in Phase I, additional assessments of specific direct impacts were also undertaken in Phase II.

The estimation of future impacts focused on "dynamic" impacts—those most likely to change with anticipated or temporary adjustments in BART service and use. It made use of the Phase I impact findings, as well as data on the changes in impact determinants (e.g., BART train frequency and hours) which are currently projected.

### The No-BART Alternative

An important aspect of any evaluation is its control strategy—in this case, the means by which BART's impacts are distinguished from the effects of other trends and events.[1] The BART Impact Program's approach has been to construct a hypothetical scenario of Bay Area transportation and related characteristics "most likely" to have evolved had BART not been built.[2] The control strategy was then to compare the existing situation with this hypothetical "No-BART Alternative" (NBA), defining the differences between the two as BART's impacts. This concept is illustrated in Figure II-2.

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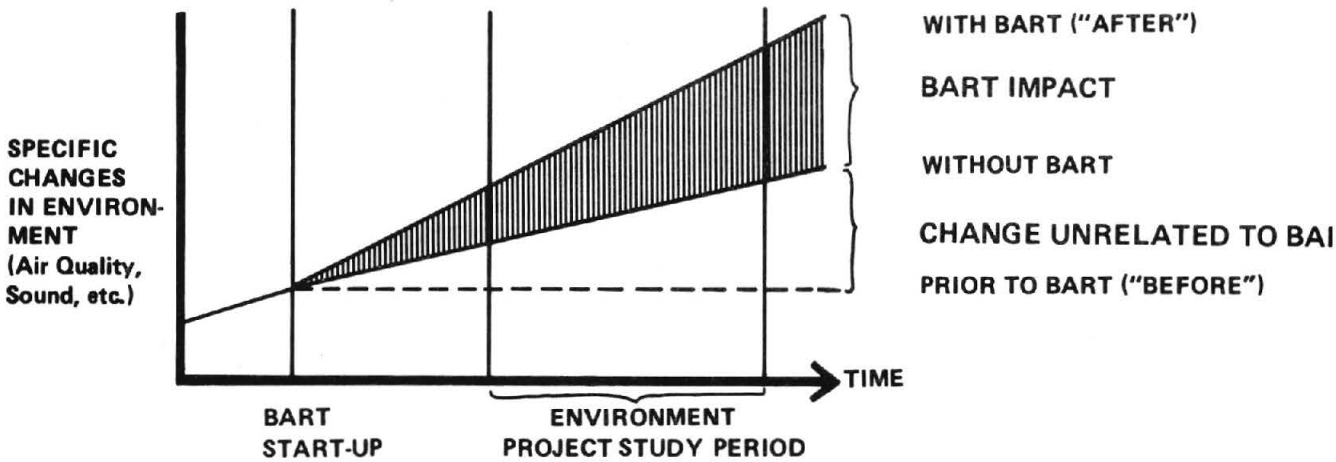
1 In recent years there have been major advances in evaluation strategy and tactics to recognize and minimize situational threats to the validity of evaluation findings. These advances are only beginning to be applied in transportation research. For an excellent discussion of threats to evaluation validity and approaches to them for "real-world" experiments, see Cook and Campbell, "The Design and Conduct of Quasi-Experiments and True Experiments in Field Settings," in M. D. Dynnette (ed.), **Handbook of Industrial and Organizational Research.** Chicago: Rand McNally, 1976.

2 McDonald & Smart, Inc., **A Generalized No-BART Alternative Transportation System,** Document No. DOT-BIP-FR 1-14-75. Berkeley: Metropolitan Transportation Commission, May 1975. Prepared as part of the documentation for the BART Impact Program.

**FIGURE II-2**

**ISOLATION OF IMPACTS**




Within this conceptual framework, the Environment Project's task was to identify the environmentally-relevant aspects of the NBA and use these as a base against which to define BART's impacts on the Bay Area environment. This was done in two steps. First, actual-versus-NBA differences in BART's immediate surroundings were considered to establish a basis for identification of BART's own localized effects. This was the emphasis of the study's first phase (1974-75). Second, differences elsewhere between the actual and NBA transportation systems were sought in order to allow the estimation of environmental changes (both in specific locations distant from BART and also at a regional scale such as for air quality) prevented by the decision to build BART. Most of this took place in Phase II (1975-77), along with continued monitoring and updating of the study of BART's localized environmental impacts.

BART's Localized Impacts

In the first step, estimation of BART's localized impacts involved several control tactics. For some impacts it was possible to isolate and measure current BART and "without-BART" effects directly. Community sound levels, for example, could be measured when no BART trains were passing and then compared with aggregated sound levels, including the sound of trains.

For other impacts, historical trends or current conditions in nearby control sites (similar but without BART) were used. In several cases, combinations of approaches were used in order to minimize the overall threat to validity. Traffic accidents, crime and local air pollution were some of the effects estimated through combinations of trend and control site studies.

Because of their susceptibility to error, simple comparisons of pre-BART versus current conditions were avoided. They were used to estimate BART's impacts only where historical data and interviews with local officials indicated little or no likelihood of other relevant changes during the study period if BART had not been built.

Impacts Elsewhere in the Bay Area

During Phase II of the study, BART Impact Program management provided more explicit details of the No-BART Alternative in order to allow its use in specific impact studies. The Environment Project's concerns centered on whether any major construction of other transportation facilities would have occurred without BART. Also of interest was whether differences in the region's flow of vehicles, particularly buses, but also total traffic volumes, would have resulted. Both of these kinds of travel and transportation impacts could have significant environmental effects.

The NBA specified a reliance on peak-period express buses in lieu of BART, generally using the reserved lanes already in existence. This bus service was estimated to be similar in scale to that existing in 1973 before BART's transbay service began. This level of service used approximately the number of buses currently in service with BART, since many former express buses were shifted to local and BART feeder service. Such shifts were concluded to have no appreciable effect on environmental impact, since most localized concentrations of bus traffic remained.

Total transbay traffic volumes were determined to have possibly dropped slightly due to BART. This could have influenced BART's environmental impact, notably in regional air quality, and the Environment Project included study of such effects. Otherwise, the NBA as defined was concluded to be basically a "null" alternative to BART for purposes of environmental impact estimation, and therefore it is not further discussed in this final report. However, it should be stressed that a most likely "no-build" alternative to rapid transit in another metropolitan area may involve major environmental changes. Obviously such changes must be carefully considered in any evaluation of transit alternatives despite their apparent insignificance in BART's case.

One NBA option had envisioned the construction of an additional transbay bridge, the "Southern Crossing," which had, in fact, come close to realization in the early 1960s. This bridge and its approaches, including major new freeway segments along the bay shores, would have had substantial environmental effects. However, it was decided that this bridge would not have been built even without BART, and consequently the NBA included no major differences in freeway construction or in other transportation facilities. Therefore, no further study of its possible environmental impact was made.

## RESEARCH METHODS

Because of the variety of impacts under study, a broad array of research methods was employed. These included direct observation both on site and from the air, interviews with many local officials and BART personnel, review of published and unpublished statistics and other documentation, instrument measurements, and process modeling. In some cases, new methods were required, even though development of methods was not a major study objective. A particularly innovative approach was developed and used in the assessment of BART's acoustic impacts.[1]

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1 Bolt Beranek and Newman Inc., **Acoustic Impacts of BART: Interim Service Findings,** Document No. DOT-BIP-TM 16-4-76. Berkeley: Metropolitan Transportation Commission, March 1976. Prepared as part of the documentation for the Environment Project.

Wherever possible, several independent research methods were used to approach a given research question. For example, in the study of traffic safety impacts around BART stations, approaches included interviews with officials, as well as BART station attendants and local patrolmen, direct observation by trained personnel, and study of statistics on traffic accident rates. The following paragraphs briefly describe the study approach and methods used in each of the Project's four major studies: direct wayside impacts, residents' responses to those impacts, indirect impacts, and impacts on the BART user. Additional methodology descriptions are found in Chapters IV through VI of this report, and full methodological detail for interested specialists is contained in the various technical reports listed in the Documentation section.

### Direct Wayside Impacts

BART's environmental impacts on areas alongside its lines and around its stations were identified by direct physical measurements (noise, vibration, local air quality), by review of existing data and interviews with specialists, local officials and BART personnel (natural environment, safety, security), by examination of pre- and post-BART photography (barriers, shadows, privacy), from staff observations and judgments (visual quality, micro-climate), and by process modeling (regional air quality). Generalizations from study sites to the entire system were made by relating impact type and intensity to specific source characteristics, and then inventorying these sources by location systemwide.

### Responses of Nearby Residents

The study of environmental impacts as viewed by nearby residents who are exposed to those effects focused on site-specific case studies. Home interviews, observations and other data collection activities were conducted in ten small residential neighborhoods along BART. All abutted the transit right-of-way, and most extended to about four blocks away. Each was selected primarily for its representation of conditions commonly found both in the Bay Area and elsewhere. From about 50 to over 100 interviews were conducted in each site for a total of approximately 700. Analysis was statistical, comparing response patterns between sites with different causal conditions, by distance from BART lines or stations, and among individual groups with different lifestyles, general attitudes, and socioeconomic characteristics.

### Indirect Environmental Impacts

Changes in land development near stations were identified by comparing 1965 and 1975 aerial photography, through site inspection, and by discussions with local planning officials. Public policy changes were identified through contact with local jurisdictions. In assessing the environmental impacts of the identified changes, most of the information was derived from secondary data sources (particularly recent environmental impact reports) and interviews with locally knowledgeable persons. Information about street improvement programs was gathered primarily through site visits and interviews with city officials and project representatives. News clippings and project-related publications supplied additional information.

### Users' Experience

The study of the BART travel experience—the immediate effects of BART as an environment for its users—utilized a variety of assessment methods, including: direct observation, instrument measurements, review of existing technical studies, and interviews with BART managerial personnel, BART travelers, and station attendants.

Each step in the travel sequence was evaluated: finding and arriving at the BART station, entering and using the station facilities, waiting on the platform, riding on the BART train, and exiting from the BART system. For each step in this sequence, several general categories were used as a convenient means to identify and group the many specific factors in the BART environment which are of importance to transit system users. These categories included orientation, reliability, convenience, safety, security, comfort, enjoyment, and non-travel services.

## ASSESSMENT OF STUDY STRATEGY AND METHODS USED

It is probable that impact studies will be conducted on other new transit systems. Such studies are already beginning in Washington, Atlanta, Miami and Buffalo, where systems are being designed or constructed. Other studies can be expected, both in this country and abroad, since national and local officials will continue to need evaluative information in making decisions on whether, where and how to extend newly operating transit systems. To assist the designers of these future impact evaluations in achieving the best possible results most economically, a few comments on the methods used in the BART Environment Project are presented here.

### Strategic Considerations

- **Conceptualization.** It was found that the simple impact process model developed and used in this study (Figure II-1) is a useful reminder of the relationships between impacts and their determinants. This model is based on an exhaustive review of environmental and psychological literature; future studies should not have to repeat this process.[1]

- **Issue Scope.** There are many conceivable types of environmental impact and methods for categorizing them. This study's results indicate the impacts most likely to be important and also verify the comprehensiveness of the typology used throughout the Project. However, in any impact study an early activity should be a field and key informant reconnaissance, followed by a listing of issues (and hypotheses where relevant) arising both from the reconnaissance and from knowledge of local concerns. This may lead to a slightly different set of impact categories than that used here.

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1 Frances Carp, **Theory Background for Study of BART's Impacts on Human Perception and Response,** Document No. DOT-BIP-WP 23-4-76. Berkeley: Metropolitan Transportation Commission, 1976. Prepared as part of the documentation for the Environment Project.

- **Timing of Impact.** Although data concerning the current situation or recent past are the most readily obtainable, impacts which occur at other times in the transit system's life are equally and sometimes more important. While conclusions about past impacts may be sketchy due to limited data, and those about future impacts are necessarily speculative, it is still possible to draw useful conclusions about impacts from the time of construction through the system's maturity.

### Methods of Study

- **Perishable Data.** In anticipation of impact studies, data on changing conditions such as construction should be preserved. Without such data on dislocation, accidents, traffic delay and pre-construction conditions, for example, the research must rely heavily on subjective recollections of those involved. Although some success is possible with such techniques, they are not recommended.

- **Assessment Versus Surveys.** The close agreement found between this study's technical impact assessments and the surveyed perceptions and attitudes of residents affected suggests that expensive, large-scale home interview surveys may not be required. This appears to be particularly true for quantifiable impacts such as noise, but perhaps less so for impact assessment requiring a judgmental value such as visual quality. A program of informal group or telephone interviews to verify important assessment findings may suffice; if a number of unanticipated responses are encountered, a larger and/or more formal survey might then be designed and undertaken.

- **Use of Parallel Methods.** The Environment Project's use of parallel methods, including data review, observation, key informant interviews, and sometimes the collection of new data, was found to be essential in assessing "soft" or subjective impacts such as traffic safety and visual quality.

- **Aerial Photography.** The BART study relied heavily on aerial photos taken both at vertical and oblique angles. Existing photos were the prime source of pre-construction information and were readily compared with post-construction photos to indicate impacts such as barrier effects and land use/landform changes. Oblique color photos were also found to be an invaluable tool for site reconnaissance, for inventories of relevant system characteristics and land uses, and in presentations of results.

- **Train Sound.** This impact is complex and can be costly to assess accurately. The Environment Project's use of on-board measurements calibrated to a few wayside data points and compared with ambient levels was demonstrated to be an effective and economical method of assessing wayside sound impacts systemwide. An assessment of subjective sound variables (e.g., reverberation because of overpasses, perceived sound effects on upper floors of buildings or hillside houses above the line) made from on-site comparative judgment and/or survey data would provide valuable additional input for designers of future systems.

- **Site-Specific Studies.** The Project's use of site-specific, in-depth studies when system-wide data collection was not feasible was found to be effective. With sites chosen for representativeness, results can be generalized to the full system and relied upon with only minimal verification effort. However, several sites must be carefully selected for studying each specific impact, rather than studying all impacts at each of very few sites. While the Environment Project studied impact occurrence within four blocks of BART, major impacts were found to extend to only two blocks' distance from BART facilities; unless preliminary reconnaissance indicates that larger areas are affected, future local impact studies could safely use these established impact-area limits in deciding where to concentrate their efforts.

# III. CONSTRUCTION IMPACTS

## INTRODUCTION

This description of the environmental effects of BART's construction is necessarily brief because of limited detailed data. However, important lessons may still be drawn from BART's construction experiences. The presentation is based on information sources such as summaries of news articles and BART comment files, interviews with BART and contractor personnel, review of aerial photos before and after construction, and responses from residential interview surveys.

Information from BART public comment files for the period 1963 to 1973 and Bay Area news reports for the years 1967 and 1970, as summarized by BART staff, were used to identify behavioral responses to impacts. In addition, persons knowledgeable about the construction impacts were interviewed to obtain an overview of the magnitude of effects.

Response data from two surveys conducted in 1972 and one conducted in 1976 provided information about residents' perceptions of construction impacts. In one of the 1972 surveys, a 2,500-case sample of persons living within one mile of BART was interviewed. (This will be referred to as the 1972 Systemwide Survey.) In addition, residents living within two blocks of BART at 27 "special sites" were surveyed and asked the same questions as the Systemwide Survey respondents. The results of both 1972 surveys were summarized in the **Analysis of Pre-BART Urban Residential Environment Survey.**[1]

In 1976, as part of another residential survey, the BART Wayside Impact Survey, residents were asked to recall construction impacts. For this survey, ten sites near above-ground non-downtown BART facilities were selected, and residents living within four blocks of BART were interviewed. Site samples were designed to include more residents adjacent to BART than persons further away. Survey results were summarized in the BART Impact Program report entitled **Responses of Nearby Residents to BART's Environmental Impacts** (1977).[2]

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1 De Leuw, Cather & Company, **Analysis of Pre-BART Urban Residential Environment Survey,** Document No. DOT-BIP-WP 24-4-76. Berkeley: Metropolitan Transportation Commission, March 1976. This report is based on material from the Urban Residential Environment Study (URES), a part of the University of California "BART II" portion of the BART Impact Program.

2 De Leuw, Cather & Company, **Responses of Nearby Residents to BART's Environmental Impacts,** Document No. DOT-BIP-TM 25-4-77. Berkeley: Metropolitan Transportation Commission, July 1977. Prepared as part of the documentation for the Environment Project.

**Organization**

In the following pages, general effects of BART construction are first summarized. This is followed by a more detailed description of construction operations and impacts in several types of situations: downtown subway areas, suburban station locations, and areas adjacent to the above-ground BART lines. The chapter ends with an assessment of the BART attributes and situations found to be most influential in producing construction impacts, and an indication of the size, locations and characteristics of the population affected. (*Where resident survey results are discussed, the eliciting questions are italicized and set in parentheses within the text. Each question is displayed only once; subsequent discussions identify the question by number and refer readers to the page on which it appears.*)

## GENERAL EFFECTS AND RESPONSE

**Some of BART's construction impacts appear to be more significant than many of the continuing operational impacts.**

Examination of data sources indicates that in downtown San Francisco the long period of cut-and-cover subway station construction[1] had a substantial adverse effect on access and traffic safety. In some locations this lasted for five years or longer. Access was affected in Oakland and Berkeley downtown areas as well, but to a lesser extent.

This project's 1976 survey (BART Wayside Impact Survey) found that a majority (50 percent to 77 percent) of respondents in the study sites exposed to construction and living directly adjacent to suburban stations and aerial line segments remember construction as having "bad" or "very bad" effects. (*Q14B. "Would you say the BART construction process had a very bad effect, fairly bad, fairly good, very good effect, or no effect at all on this neighborhood?"*) Dust and dirt was the impact mentioned most often by the suburban station respondents, while residents living near the aerial line mentioned noise as well as dust and dirt most frequently. (*Q14C. "For each of these things—noise, truck traffic, dust and dirt, streets blocked/dug up, homes removed, places for kids to play, and duration of the construction process—was the effect of BART construction very or somewhat good, half and half, somewhat or very bad, or was there no effect?"*) However, other available sources indicate that disruption in these areas was minor compared to that in downtown locations.

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1 Downtown construction was made up of three sequential projects. The first project was the construction of the basic BART system. The second project was the construction of mezzanine extensions and beautification of Market Street. The third project involved construction of the Embarcadero BART station.

## DOWNTOWN SUBWAY CONSTRUCTION

**BART's subway construction impacts were substantial and continued for several years despite major efforts to reduce their effect.**

### Operations

Most of the downtown subway stations were built by cut-and-cover construction methods, while the subway line segments were generally tunneled. One major exception is the subway line construction in Berkeley, where nearly all of the construction was cut-and-cover. This judgment was based on the opinion that the very wide streets and availability of off-street rights-of-way for BART would allow room for both construction and traffic.

In downtown areas, duration of heavy construction was from about two to five or six years and was greatest in San Francisco. The cut-and-cover station construction was a daytime-only operation; line tunneling occurred throughout the day and night. During construction in San Francisco, the streetcars, diesel and electric buses, and automobiles were frequently rerouted from one side of the street to the other, and diesel buses and automobiles were also moved onto adjacent streets. In Oakland, several downtown streets were made one-way in order to limit and simplify traffic flow through the construction sites.

Storage of construction materials usually took up at least one lane of traffic. Downtown San Francisco sidewalks were narrowed from 22 feet to between 10 and 15 feet in many locations. In addition, in some areas (particularly Oakland, where streets were narrow and soil unstable) retaining walls directly against buildings were used to bound the construction areas. These extended from below the bottom of the excavation to as much as four feet above the sidewalk level. Fenced temporary sidewalks were suspended above the excavation, with catwalks extending into stores. The retaining walls often blocked the view from these sidewalks into stores.

### Efforts to Minimize Impact

According to BART personnel and consulting construction engineers, several steps were taken by BART and the contractors to minimize negative impacts, particularly in downtown areas. These steps can be classified into three general types: pre-construction coordination with cities, operational tasks, and community relations.

In all the downtown areas there was pre-construction coordination by BART and its contracting engineers with local city representatives. Most of this coordination dealt with developing and managing a traffic plan to minimize disruption. In San Francisco, BART personnel worked directly with city employees in these efforts. This included plans for relocating buses to a parallel street (Mission) south of the construction sites. In Berkeley, the contractor hired a former city policeman to work out a traffic control system. In Oakland, the city hired a person as liaison between contractors and city hall prior to and during the construction period.

**PLATE III-1**
**CUT-AND-COVER CONSTRUCTION, DOWNTOWN SAN FRANCISCO**

Many construction activities were designed to minimize community disruption. Some of these included:

- A policy limiting the amount of construction materials placed around station sites.
- Installation of timbers over station openings to allow traffic movement over the stations during construction.
- Use of sidewalk ramps to provide access to businesses and safety to pedestrians.
- Daily use of water trucks to reduce dirt and dust from cut-and-cover construction (Berkeley only).

BART's community relations program was extensive in all areas where construction occurred. All complaints were given quick and personal attention. BART kept a daily complaint file, and, where applicable, complaints were assigned to the construction engineers for decisions about follow-up action. In some cases, engineers visited complainants to observe, or even take instrument measurements, of impacts and to talk about the complaints. In other cases complainants or community representatives were invited to visit construction sites to see the efforts which contractors were making to limit disruption. Also, many repairs to homes and businesses were made on the basis of good will, even when there was no absolute proof of BART-related activity being the cause of damage.

During construction in San Francisco, contractors took the initiative in checking with Market Street merchants to identify construction problems and working to improve conditions wherever possible.

## Impacts

### Neighborhood Travel

**An analysis of newspaper reports, interviews, BART comment files and study team observation suggested that BART construction had an adverse impact on traffic safety.** Police complained about hazards of narrowed sidewalks according to the BART complaint files. San Francisco newspapers reported that police considered construction traffic regulation a "dangerous maze"; news articles cited five BART-related pedestrian accidents within a few weeks' time.

Observation in downtown San Francisco supported police comments about the maze of traffic controls. It was also noted that frequent changing of the allowed direction of traffic flow added to the confusion. More definitive conclusions about traffic safety impacts could not be drawn because BART-related accident data could not be obtained.

**There is evidence to suggest that barrier effects were also significant.** A review of BART comment files and news articles indicates that there were frequent complaints about blocked access in downtown station areas. News articles reported that San Francisco business representatives met with BART and local government officials to argue that businesses were losing money because of construction barriers.

Further, the 1972 Special Sites Survey indicates that negative effects were perceived by a number of persons living near one of the two downtown stations included in the survey. Five or more of 20 respondents in the Mission-24th Street station area noted that parking, getting to and from work/stores/schools, and going places on foot were negatively affected by BART construction. (*Q44C. "Has BART construction made any of the situations listed on this card worse for you or your family?" List included 15 items covering such variables as traffic, mobility, crime, noise, dust/dirt, privacy, neighborhood appearance, and resident uses of home and neighborhood.*)

### Security

**The use of retaining walls may have had some negative impact on crime control.** A BART spokesman stated that the Oakland police complained about the fact that the wall blocked the view into stores. Police stated that this blockage tended to prevent them from detecting crime occurring in the stores. However, significant and unique increases in crime reported in these areas did not occur.

### Acoustics

**Noise effects were minimal in downtown areas.** Sonic pile drivers were used to make that operation relatively quiet. In addition, vaults were built to house some of the heavy construction machinery and thus to reduce the noise.

### Earth and Water Systems

**The complete underground utility mapping accomplished during the construction process is a major benefit to San Francisco.** During construction there were isolated incidents of flooding, broken gas mains and electrical circuitry problems in downtown San Francisco. Part of this problem resulted from the previous incomplete mapping of utilities. As a result, the location of all utility lines, some of them many years old and unrecorded, was completely documented for future use by the city and all utilities involved.

### Dislocation

**In downtown areas, several merchants lost basement space which was located underground in the public right-of-way.** In San Francisco about 50 merchants claimed they lost space valued up to about $600,000. However, in general, this space had not been legally authorized in the first place. Apparently, no residential dislocation occurred in downtown areas.

### Historic Preservation

**Artifacts discovered during construction may have been lost.** A news article reported that two San Francisco museums complained that artifacts dug up during BART San Francisco subway construction vanished before historical value could be determined. The article also stated that, in general, during BART construction there was no coordination between prime contractors and historians. However, BART and its construction management contractors' personnel interviewed indicated no knowledge of potentially important finds or losses due to lack of coordination.

## SUBURBAN STATION CONSTRUCTION

**Suburban station and parking lot construction had widespread impacts, but of less severity and duration than those of subway construction.**

### Operations

Most suburban stations were built in relatively quiet areas with little traffic in comparison to the downtown areas. However, in some locations, housing dislocation was substantial[1] because of the large size of parking lots (two to eight acres). Also, in many cases construction of the station and the parking lot paving was accompanied by major changes in traffic circulation systems adjacent to stations.

The most disruptive period of station area construction averaged about six months. This involved demolition, site grading and heavy concrete construction. All construction was accomplished during daytime hours.

**PLATE III-2**
**SUBURBAN STATION CONSTRUCTION, CONCORD**

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1 The full extent of this will be documented by the Land Use and Urban Development Project of the BART Impact Program.

Often there was coordination between BART and cities in developing circulation plans for areas adjacent to stations. BART also conducted a public information program, including warning residents of upcoming construction, as well as the same public relations efforts already described in the section on downtown station construction.

## Impacts

### Neighborhood Travel

**Survey results indicate that in suburban station areas there may have been some minor reductions in traffic safety and access.** A substantial proportion (20 percent) of the 1972 Special Sites Survey respondents stated that traffic safety was reduced and that the reduction had negative effects on them and their families (*Q44C; see page III-5*). Many of the BART Wayside Impact Survey (1976) respondents who lived near the Daly City and Concord stations during BART construction recalled that truck traffic created bad effects (about 40 percent of the affected respondents at each site) and that bad effects resulted as well from blocked and dug-up streets (recalled by 54 percent of those at Daly City and 40 percent of those at Concord) (*Q14C; see page III-2*).

### Acoustics

**Survey responses suggest that adverse noise impacts were perceived in residential areas near suburban stations.** Between 25 percent (El Cerrito Plaza) and 46 percent (Daly City) of the surveyed station-area residents who were exposed to BART construction stated in 1976 that the noise effects of construction had been bad or very bad (*Q14C; see page III-2*). Respondents whose homes were directly adjacent to stations during construction apparently experienced the severest noise impacts.

### Atmosphere

**Dust and dirt was mentioned as a negative effect of BART construction by a significant number of respondents in all of the suburban station sites surveyed.** This result was found in the 1972 Special Sites Survey, where 27 percent of the respondents reported adverse dust and dirt effects (*Q44C; see page III-5*). In addition, of the BART Wayside Impact Survey station-site respondents who were exposed to construction, 41 percent in Daly City, 50 percent in Concord and 33 percent in El Cerrito recalled adverse dust and dirt impacts (*Q14C; see page III-2*). This impact received more mention than any other type of impact.

### Housing Dislocation

**Demolition of housing to clear the land for BART parking lots was a source of disruption near suburban stations.** Land clearance for suburban stations with parking lots in residential neighborhoods was disruptive because of the large size of the parking lots. These lots, which in some cases provided for 1,400 parking spaces, took as many as four blocks of land or more. Also, one source noted that the sequence of events which occurred during the land clearance had a negative effect on displaced residents as well as the remaining neighborhoods in some areas. Housing demolition rapidly followed each condemnation, and therefore several to-be-relocated persons were still in their homes as other houses around them were being demolished.

Residents were given higher-than-market prices for the homes taken. However, at that time there were no substantial efforts to relocate persons in similar areas with the same relative access to services. According to one informed source, displacement was particularly hard on elderly people, most of whom had lived in their residences for many years.

The Land Use and Urban Development Project of the BART Impact Program has estimated that 3,000 housing units were removed for construction of BART's stations and lines. This represents about 7,000 to 7,500 people affected and is a significant factor. However, compared to freeway construction the number is modest. The Grove-Shafter Freeway in Oakland (approximately three and one-half miles in length) caused displacement of about 3,000 households. Considering that BART has 48 miles of above-ground trackage and 23 stations with large parking lots, BART's displacement is relatively small.

## ABOVE-GROUND LINE CONSTRUCTION

**Construction of BART's at-grade and aerial trackways was rapid and caused relatively little impact, although nearby residents were disturbed by the effects.**

### Operations

The construction of **aerial** line segments occurred in several steps. First, interfering utilities were relocated, then street configuration changes were made. Next, the aerial structure support columns were installed, and the precast girders were placed. Finally, the track was laid, sometimes considerably after completion of the structure. Later, if cities agreed, landscaping was added under separate contracts. During the **at-grade** construction, the major activity was the trucking of soil for earth berm construction. According to BART and its construction management contractors' sources, the most disruptive period of aerial line construction usually lasted about two months. Disruption from at-grade construction usually occurred for a matter of a few weeks only.

Since much of the above-ground line was built parallel to active railroad tracks, there was a major coordination effort with the railroads. This resulted in minimal effects on railroad operations and no additional effect on other nearby activities.

## Impacts

### Neighborhood Travel

**A substantial number of residents who lived near the aerial line while it was being built perceive that construction adversely affected neighborhood travel.** In the five aerial line sites of the BART Wayside Impact Survey, between 19 percent (Albany E.) and 36 percent (Albany W.) of the respondents exposed to BART construction recalled that associated truck traffic created bad effects (*Q14C; see page III-2*). There is no survey response information identifying these specific effects, but it may be assumed that noise, dirt and perceived danger were the main effects.

**PLATE III-3**
**AERIAL LINE CONSTRUCTION, WALNUT CREEK**

BART Wayside Impact Survey results also indicate that persons living near some of the aerial line segments were affected by reduced access. At least one-third of the respondents exposed to construction at three of the five aerial line sites stated that blocked and dug-up streets resulted in bad or very bad effects (*Q14C; see page III-2*). However, as already noted, these effects apparently lasted for only brief periods compared to downtown subway construction.

Atmosphere

**Dust and dirt was perceived to be a construction-related problem by persons living near aerial lines.** From 29 percent (Albany E.) to 46 percent (Albany W.) of the BART Wayside Impact Survey respondents exposed to the impacts and living within four blocks of BART aerial line sites recalled adverse dust and dirt impacts (*Q14C; see page III-2*). In most of the 1976 sites, people remembered adverse atmospheric impacts more often than any other type of impact.

Acoustic

**Survey responses suggest that adverse noise impacts may have occurred particularly in residential areas near aerial lines.** Substantial proportions (from 31 percent in Oakland to 48 percent in San Leandro) of the respondents who lived in aerial line sites during BART construction stated in 1976 that the noise effects of construction were bad or very bad (*Q14C; see page III-2*). Again, however, this exposure to impact was brief.

## CONSTRUCTION IMPACT CAUSES

**Construction impacts were found to depend largely on differences in configuration and setting.**

In downtown San Francisco and the Mission District near downtown, where cut-and-cover construction of stations occurred in heavily traveled areas, the adverse impacts on access were significant. In most other downtown areas, the impacts were less acute because construction time was shorter, because there was less street activity, or because tunneling was used. Tunneling was a much more expensive process but, according to BART and contractor sources, caused virtually no disruption.

In some suburban station areas, the substantial housing displacement for large parking lots, the dust and dirt from construction, and the changing of traffic circulation systems had the most adverse effects, but these were much briefer than in downtown areas.

Relatively minor impacts are associated with at-grade construction. The widespread negative response to construction impacts in aerial line areas seems to outweigh what actually occurred. The survey questions may have encouraged unduly extreme responses. Also, it may be that in these areas residents' attitudes toward BART's operation effects are reflected in their recall of construction impacts.

Finally, it is apparent that BART and contractor public relations efforts and coordination with cities were effective in minimizing public reaction to construction impacts. As described earlier, such efforts were given high priority throughout the construction process.

## LOCATIONS AND POPULATION AFFECTED

**BART's most severe construction impacts were around its subway stations and lines, where shoppers and merchants, office workers, and low-income and minority residents were most affected.**

The long period of BART's excavation and construction along Market Street in San Francisco caused delay and inconvenience to commuters who customarily used or crossed Market Street in traveling between home and job. It can be assumed that about half of the estimated 170,000 downtown office workers were subjected to these effects. Downtown shoppers were also affected. Similar problems in other downtown construction areas (Mission Street, Berkeley, Oakland) also affected many shoppers and workers.

Effects on residents are of greater concern in this study because of the more continuous exposure of all family members to construction. The populations thus affected are described in Table III-1. Inconvenience was probably greatest for residents near BART construction on Mission Street because of the street's heavy traffic, its narrowness, the long construction period, the high density of population in the area, and the concentration of convenience shopping facilities there. Difficulty of access to stores may have forced many area residents to shop elsewhere. As many as 13,000 persons (the population within two blocks of the BART line under Mission Street) may have been so affected. Most are of Spanish heritage. Median incomes in the area are substantially below the regional average.

The Market Street corridor also had a high population. In 1970, over 6,000 persons lived within 500 feet of the subway construction. This was a very low-income population living primarily in older residential hotels. However, impacts on residents here appear to have been much less severe than on Mission Street because most of the area's convenience shopping and housing was on the side streets rather than on Market Street itself.

Other downtown areas where subway construction is judged to have had substantial impacts include Berkeley's Shattuck Avenue and Oakland around the 12th Street, 19th Street and Lake Merritt stations. The Lake Merritt station area alone had a 1970 population of about 1,500 within 500 feet of the BART station and headquarters construction site, predominantly Oriental and low-income families. Outside these downtown areas, populations subjected to subway construction effects were smaller and varied in both ethnic and income characteristics.

Large numbers of residents were subjected to construction impacts at above-ground stations. At the 20 above-ground stations with parking lots, where impacts were of shorter duration and somewhat less severity than at subway construction locations, nearby residential population possibly affected (within 500 feet of the sites) totaled approximately 8,000 (Table III-1). Although most of these locations were in middle-income, non-minority suburban areas, some largely low-income ethnic neighborhoods were affected. As much as a third of this total population was of minority group status.

## TABLE III-1
## RESIDENTIAL POPULATION AFFECTED BY BART CONSTRUCTION IMPACTS

| Location and Configuration of BART | Total Population Within 500 Feet | Dominant Population Characteristics |
|---|---|---|
| *Downtown Subways** | | |
| San Francisco - Mission Street | 13,000 | Hispanic, low-income |
| San Francisco - Market Street | 6,000 | Very low income |
| Oakland | 2,000 | Oriental, low-income |
| Berkeley | 5,000 | Moderate income |
| *Other Open-Cut Subways*** | 4,000 | No dominant characteristics |
| *Above-Ground Stations with Parking Lots* | 8,000 | Middle-class, non-minority |
| TOTAL | 38,000 | |

* Open-cut lines and stations.

** North Berkeley and Ashby lines and stations; Glen Park and Balboa Park stations.

Source: 1970 Census block and tract data.

# IV. DIRECT ENVIRONMENTAL IMPACTS

## INTRODUCTION

This chapter reports on the Environment Project's central effort, the assessment of the BART system's direct environmental impacts to date.[1] Direct impacts are considered to be the immediate effects of the functioning system on its surroundings. They are distinguished from the system's construction impacts and also from the indirect environmental impacts which arise from changes in land use and urban development that are partially attributable to BART. Indirect impacts to date, as well as potential future direct and indirect impacts, are discussed in later chapters.

## METHODOLOGY

Methods of study included both technical assessments and interviews with persons affected. The technical assessments were based on instrument measurements where feasible (e.g., sound), review of relevant prior documentation such as inventory maps of the natural environment, interviews with knowledgeable officials, and systematic direct observation. These methods reflect the current state of the art of impact assessment.

The interviews were conducted to verify and extend the professional assessments. Some 700 home interviews were completed with residents living in ten sites within a few blocks of BART lines and stations. The results of these interviews confirmed the earlier technical findings, indicating that those methods could generally be relied upon to provide an accurate picture of impacts as perceived by the population whose homes were affected.

Because of the Environment Project's emphasis on these direct impacts, the study methods used deserve some explanation. Discussions of the measurement and analysis techniques used to determine impacts are presented below by impact type, followed by a discussion of the study methods used in the home interview survey.

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1 For more complete and technical discussions of these findings see the following reports: Gruen Associates, Inc. and De Leuw, Cather & Company, **Environmental Impacts of BART: Interim Service Findings**, Document No. DOT-BIP-FR 2-4-75, Berkeley: Metropolitan Transportation Commission, January 1976; also De Leuw, Cather & Company, **Responses of Nearby Residents to BART's Environmental Impacts**, Document No. DOT-BIP-TM 25-4-77, Berkeley: Metropolitan Transportation Commission, January 1977. Other pertinent documents are listed at the end of this report.

### Acoustic (Sound and Vibration)

Wayside **sound levels** were measured throughout the system by instruments placed aboard BART trains. The resulting "sound profile" of the entire 71-mile BART system was calibrated by wayside measurements taken at selected points throughout the system. In addition, community or "background" sound levels were measured at several points and estimated for the entire system based on local population density and nearness to other major sound-generating facilities such as freeways. To permit comparison, these BART and background sound levels were converted to continuous averages over BART's hours of operation and weighted according to standard criteria for the intrusiveness of sound at different times of day and night.

**Vibration** was measured at five representative sites with a velocity-sensitive vibration transducer and recorded with an analog system. Time histories of vibration velocity levels for each train pass-by were then established.

### Atmospheric (Air Quality and Microclimate)

The BART-induced reduction in vehicle-miles traveled was calculated by the Metropolitan Transportation Commission to be about three percent for the three-county BART area; this figure was applied to regional emissions estimates of CO, $NO_X$ and RHC to assess emission reduction attributable to BART and, by inference, BART's impact on **regional air quality.**

**Local air quality** impacts near station parking lots were studied at two stations chosen to represent extremes in local BART-induced vehicular traffic. For one full day, carbon monoxide readings were taken at each station and at locations downwind and upwind; comparisons were made to determine BART's effects on ambient air quality.

**Microclimate** was considered to be wind characteristics within an area of a few square meters up to a square kilometer. The impacts of BART facilities on wind conditions were assessed by a trained meteorologist.

### Natural (Biota, Soils, Water)

The study of BART's impacts on **biota** focused on vegetative communities, rare/endangered wildlife species, diversity of ecological communities, plant/animal productivity, and nutrient cycling. The **soils and geology** study reviewed BART-adjacent slope stability, geological resources, unique geological features, impermeable strata, and weathering. Geological processes with potential effects on BART (i.e., consolidation, seismic activity, and subsidence) were also considered. **Drainage and water system** assessments considered BART's effects on local natural water systems, including study of surface drainage, storm water flooding, water quality, sedimentation, aquifer yield, and ground water recharge. Potential impacts on BART from the leakage or failure of water impoundments were also investigated.

Bay Area geological and ecological maps were reviewed to pinpoint potential impact areas, and aerial reconnaissance was used to identify affected areas. Natural impacts were then screened through interviews with BART and community officials. Additional on-site observation and interviews with specialists focused on the impact areas identified.

**Social (Barriers, Safety, Security, Privacy)**

Data on BART-created **barriers** and changes in vehicular and pedestrian movement system-wide were gathered by comparing aerial photographs taken in 1965 and 1972 through field observations and discussions with BART and local officials.

The **safety** analysis focused on changes in accident potential and occurrence in BART parking lots and BART-adjacent areas. Data was gathered from accident reports and statistics, interviews with police and public officials, traffic and census reports, and direct observation. Broad-scale preliminary interviews were followed by detailed data collection at representative sites. Where possible, statistical comparisons were made to determine the significance of findings.

The **security** study focused on crime and crime-related activities in BART-adjacent areas. General and in-depth interviews with police officials provided information on crime and police policy. Additional data were collected through interviews with BART police and station agents, review of BART crime and accident records, and through direct observation.

To determine the loss of **privacy** resulting from visual exposure of properties along BART lines, photos of selected residential areas taken in 1972 were compared to photos taken in 1975 to find tangible resident reactions (e.g., fences, screens, and landscaping additions).

**Visual (Appearance, Illumination, Shadows)**

On a **regional** scale, the repetitive visual elements of the BART system were identified and evaluated in relation to Bay Area urban form. Professional judgments of visual quality were based on aerial and ground observation and photography, including observation aboard trains and in station areas.

**Local visual effects** were evaluated in a highly structured manner. Based on land use, building types/density and open spaces, areas along the BART system were categorized into local visual setting types. Representative study sites (about 50) were evaluated to determine BART's visual relationship to the local setting, comparing such characteristics as size, shape, mass, openness, linearity, height, and movement. Changes in visual scale and focus, architectural character and open space areas (including streets and pedestrian areas) were determined, and an evaluation was made based on urban design criteria adapted from the San Francisco Urban Design Plan.[1]

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1 San Francisco Department of City Planning, **The Comprehensive Plan: Urban Design,** San Francisco: Department of City Planning, 1971.

Observations of **lighting** effects were made at six sites during BART's nighttime operation, and photographs were taken.

Using aerial photographs and BART track charts, the prime causes of daytime **shadows** were identified and categorized by sun orientation, height and surrounding land use to determine probable areas of impact.

## Residents' Response to Impacts

This assessment involved a detailed analysis of residents' perceptions of BART impacts in ten small sites adjoining BART stations and trackways. The overall strategy combined features of statistical quasi-experimental research designs with intensive case-study methods of the social sciences.

The study's central activity was a formal home interview survey. Informal interviews with local real estate and news media personnel, census data and direct observation were used to confirm and add perspective to survey findings.

### Site Selection and Sample Design

Based on the technical study findings, case-study sites were chosen to represent a variety of impact-producing conditions characteristic of BART and potentially applicable to other urban areas. To the extent possible, sites were also selected in pairs to allow estimation of the effects of a given impact variable while holding other differences constant between two sites. The sites chosen averaged 4 x 4 blocks in size and were located near the Daly City, Concord and El Cerrito Plaza stations; aerial line segments in Oakland, San Leandro, Hayward North and Albany East and West; and at-grade line segments in Richmond and South Hayward.

The targeted total number of completed household interviews was 700. Site samples were stratified by distance, with more responses drawn closer to BART to facilitate statistical analysis of differences among persons subjected directly to impact-producing conditions.

### Field Procedures

Survey sample populations were identified by use of address maps and field inspection. Household sampling rates differed among strata and sites in order to provide the required sample sizes. Interviewing was conducted from mid-May to August 1, 1976. Each interview averaged about one hour in length. Interviewers made at least five, and as many as nine attempts to contact each sample household. The number of completed interviews was 702, with a final response rate of approximately 70 percent.

Data Analysis

The objectives of the survey analysis were to identify the nature and causes of responses to BART's environmental impacts, both under specific impact conditions (i.e., within a single site or stratum) and under different conditions (between sites). The relationships between responses and nearby BART attributes such as track configuration, characteristics of the physical environment such as density and nearness of homes to BART, and personal characteristics such as age, sex, ethnicity and use of BART were estimated.

Both direct comparisons of responses between relevant groups (through cross-tabulations) and regression analyses were used. For example, to estimate the effect of the aerial line, responses concerning noise and view were compared statistically between an aerial line site and an otherwise quite similar site next to the at-grade BART tracks. Where possible, two independent comparisons involving four sites were used in order to increase the statistical reliability of such findings. Regression analyses were used on pooled data to identify personal characteristics related to responses in order to find out whether such interpersonal differences might obscure the reported effects of BART.

## CHAPTER ORGANIZATION

The remainder of this chapter includes several major sections:

- **General Findings:** The general level of impact found by technical assessment, plus feelings about BART and its effects on them.

- **Regional Impacts:** Impacts not limited to specific locations near BART, such as the system's effects on regional air quality.

- **Station Impacts:** Those occurring within a few blocks of the stations; organized further by impact category (e.g., acoustic, atmospheric, visual).

- **Line Impacts:** Those occurring near the BART track right-of-way; organized as for station impacts.

- **Service Facility Impacts:** Those occurring near BART facilities where trains and service vehicles are maintained, repaired, and stored; also BART's administration building.

- **Causes of Impacts:** Conclusions concerning which BART attributes and situations are most influential in producing impacts.

- **Population Affected:** Estimates of who, where and how many people are affected by BART's localized impacts.

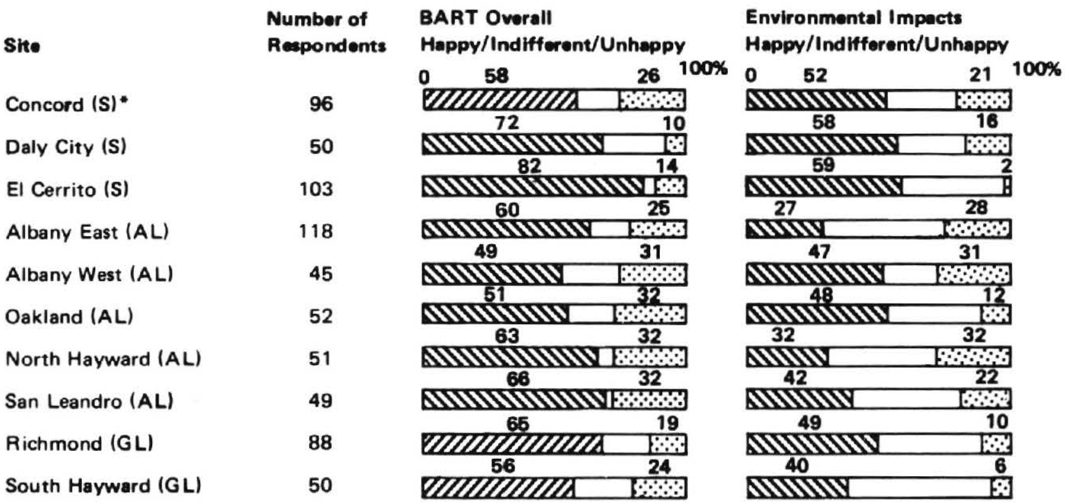
## GENERAL FINDINGS

**BART's current environmental impacts were found to be small for the system as a whole.**

This is impressive, since the system covers 71 miles and includes 34 stations, with much of the system traversing residential areas. Local impacts, however, do occur at certain sites within the system, affecting those living near the facilities. Although these local impacts tend to be more adverse than beneficial, few persons are affected, and the overall reaction of those affected is more indifferent than either positive or negative. Train noise along aerial lines and overflow parking at stations are the adverse effects most frequently found.

The technical finding of low levels of overall impact was reinforced by a mildly positive response to the BART system among the study's survey respondents, including those whose homes were subjected to some of the worst of BART's local impacts. (*Q19B. "To sum up the way you feel overall about BART nowadays—not just your life here at home but other things too like taxes, travel and anything else that occurs to you, how happy or unhappy are you that BART was built?"*)[1] Between 49 percent and 82 percent of the respondents at each of the ten sites felt happy about BART overall, and many of the remainder were indifferent. In each case the proportion of respondents who were happy about BART was substantially greater than the proportion who were unhappy (Figure IV-1, first column).

### FIGURE IV-1
### GENERAL RESIDENTIAL SURVEY RESPONSE TO BART




*S = Station, AL = Aerial Line, GL = At-Grade Line

1 Throughout the chapter where resident survey results are discussed, the eliciting questions are italicized and set in parentheses within the text. Questions are displayed only once; subsequent discussions identify the question by number and refer readers to the page on which it appears.

A parallel question concerned only environmental impacts in and around the respondent's home. (*Q19A. "How happy or unhappy are you about BART's effects just on your life here in and around your home—not counting travel, taxes, and things like those?"*) Here too positive responses outweighed negative, although to a slightly lesser extent in most cases (Figure IV-1, second column).

A low level of public action in response to BART was also found among survey respondents. Opposition to BART most often took the form of talk with neighbors, and even this mildest form of protest occurred among relatively few respondents, ranging from 10 percent at Hayward South (at-grade line) to 37 percent of the Concord (station) respondents. (*Q21. "Please tell me whether you have done anything on this list in order to support something BART was doing or to try to get something about BART changed." List included: filing a lawsuit, organizing an action group, BART-influenced voting, petitioning, writing to newspapers or public figures, attending meetings about BART, talking to neighbors about BART, and "anything else."*)

More formal public involvement (voting, petitioning, attending meetings) occurred at much lower levels at each of the sites; when respondents did sign petitions or attend meetings, it was usually to express opposition to BART. Respondents at the Daly City station had most often petitioned against BART (18 percent) and attended anti-BART meetings (15 percent). At the Albany East and West aerial line sites, voting for anti-BART candidates and petitioning reached levels of 12 to 13 percent. Fewer than 10 percent of the respondents at all other sites were involved in these sorts of public action. At Hayward South (at grade) there were no formal anti-BART actions among respondents.

An overall stability in feelings toward BART after four years of operation is further evidence of the system's low impact level. Roughly half of the respondents reported that they felt differently in 1976 about BART than they did when the system's revenue service began, but shifts in attitude were about evenly divided between those who became more satisfied and those who became less happy with the system. (*Q19C. "How do your feelings now compare with the way you felt when BART first started running here [or when you first moved here]? Would you say you felt better at the beginning or worse?"*) At no site were these reported shifts in opinion consistent enough to result in a significant change in overall response to BART.

## REGIONAL IMPACTS

**On the regional scale, BART has had few, if any, significant effects.**

In the judgment of the researchers, it has given new visual emphasis to existing urban centers and regional transportation corridors, but notice of this effect by persons interviewed is slight. BART's operation has not significantly improved regional air quality. Finally, BART has had no significant effects on the region's natural environment or on its historical and cultural resources.

**Regional Image**

The study included an evaluation of BART's effects on the appearance of the region. This led to the conclusion that BART has reinforced existing centers of population and activity visually and functionally by locating major stations in downtown areas and by inducing major municipal street improvement projects that were coordinated with BART's construction.

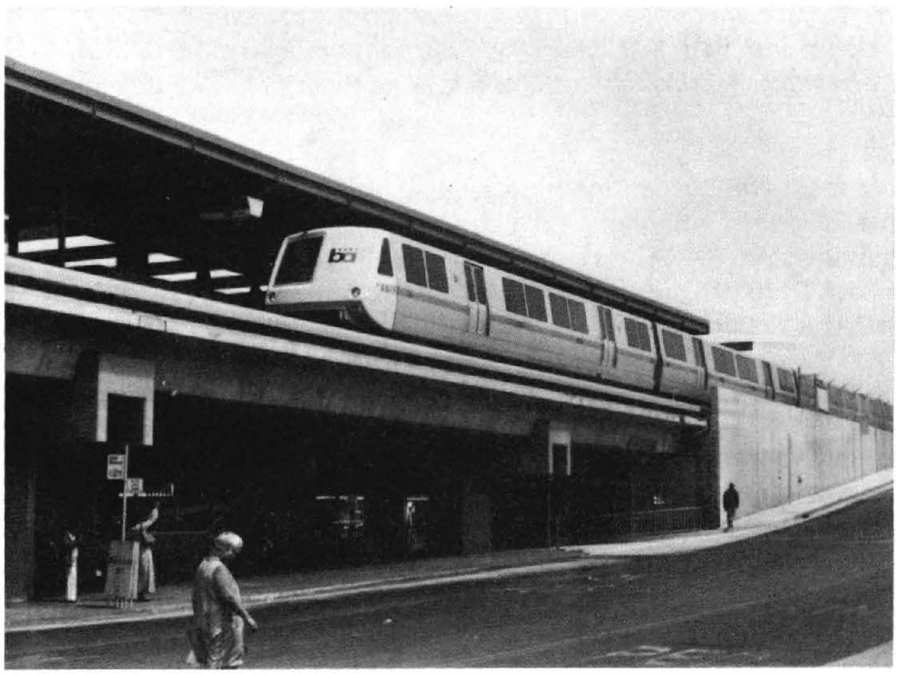


**PLATE IV-1**
**BART TRAIN AND STATION, DALY CITY**

BART's overall appearance in the region was rated highly by the residents interviewed. (*Q22E. "When it comes to overall appearance or how it looks from the outside, would you say that BART generally looks very good, fairly good, fairly bad, or very bad?"*) However, their recognition of BART's reinforcement of specific urban centers was only slight. Few persons perceived that BART has increased their knowledge of the Bay Area. (*Q22B. "Do you find that you've become more aware of different parts of the Bay Area because BART was built, or hasn't that had any effect on what you notice?"*) Notice of downtown street improvements was slight. (*Q23B, 24B. "Tell me whether you often, sometimes or rarely notice each of these when you're traveling or in places you visit often around the Bay Area." List of 10 items included "the changes they've made in the downtown streets and sidewalks in Oakland, Berkeley or San Francisco." For items noticed often, respondents were also asked whether they were especially happy or unhappy about them.*)

## Atmosphere

BART has had no significant effect on regional air quality. The 1972 survey of public attitudes toward BART showed that many residents (62 percent of those surveyed) thought the system would substantially improve the region's air quality. (*Q45. "When construction is complete and when BART is running, what kind of an effect do you think it will have on this area?" Respondents were asked to agree or disagree with each of 30 statements about possible impacts, e.g., "There will be less air pollution because of fewer cars on the road."*) In actuality, only a small improvement has occurred, and future increases in the system's use are not expected to produce a significant effect on regional air quality.

This is due primarily to the small proportion of Bay Area trips carried (or likely to be carried) by the BART system. The BART Impact Program estimates that BART will account for no more than three percent of the area's total travel, even under full forecast patronage. Many of the BART trips formerly made by car will still rely on automobiles for access to stations; since most automobile air pollution occurs during start-up and in the first few miles of travel, very little pollution will be eliminated by such shifts. Therefore, the reduction in automobile-generated air pollution due to BART is likely to be even smaller than three percent. At best, this would provide only about five percent of the EPA-required reductions in the Bay Area airshed's carbon monoxide and reactive hydrocarbons.

The possibility of an offsetting increase in pollution due to production of electrical power for BART was also checked. BART does consume a large amount of electricity; in its fully operational state this will be on the order of one percent of total Bay Area consumption. Much of this power is derived from hydroelectric facilities elsewhere in the state, and about half is generated from oil-fired plants in the Bay Area. Even assuming that BART's needs are met at the margin (i.e., by the least efficient oil-fired Bay Area plant), the resulting air pollution is insignificant in comparison with the automobile emissions eliminated, as shown in Table IV-1.

**TABLE IV-1**
**BART'S ULTIMATE EFFECTS ON REGIONAL AIR QUALITY**

| | 1972 Emissions | EPA Required Reductions | BART's Maximum Effect | Emissions From BART Power Production |
|---|---|---|---|---|
| CO | 1,073 tons/day | - 540 tons/day | - 32 tons/day | Insignificant (13 lbs./day) |
| RHC | 168 tons/day | - 131 tons/day | - 5 tons/day | Insignificant (96 lbs./day) |
| $NO_x$ | 141 tons/day | None | - 4 tons/day | + 1 ton/day |

Source: TRW, Inc., **Impacts of BART on Air Quality**, Document No. DOT-BIP-WP 20-4-76. Berkeley: Metropolitan Transportation Commission, March 1976.

Note: Carbon monoxide (CO), reactive hydrocarbons (RHC), oxides of nitrogen ($NO_x$).

### Earth and Water Systems

The building and operation of BART have caused no significant effects on the environmental components considered—soils and geology, drainage and water systems, and living things. There are two major reasons for this:

- Most of BART lies in urban areas; the few non-urbanized places traversed by BART were not ecologically unique or sensitive.
- BART's designers sought to minimize such effects.

Some minor local effects were found, including minor land slippage in a BART-related freeway excavation slope (Orinda) and temporary storm water sedimentation due to erosion in trackway embankments (Hayward). Parking lot runoff contamination is controlled by traps and has no apparent effect. No significant ecological systems or components appear to have been disturbed or damaged.

### Historical, Cultural and Other Sensitive Resources

No significant historical or cultural landmarks or sensitive areas have been disturbed by BART. BART was built before present protective environmental legislation was in force. Through map studies and discussions with local officials it was determined that BART neither damaged nor degraded the environment of any of the Bay Area's important historical or cultural landmarks. No such resources existed within the right-of-way.

Several parks, hospitals and schools constitute sensitive areas adjacent to BART. However, in all such cases BART follows an existing highway or railroad facility to which abutting uses were already adapted. No evidence was found of problems or complaints arising from BART's nearness to these sensitive areas, and direct observation revealed no cause for concern.

## STATION IMPACTS

**BART's only major environmental impact at its stations has been its high levels of on-street parking by patrons around suburban stations with no or inadequate parking lots.**

This section discusses BART's effects on the environments around its stations, as distinguished from more general regionwide effects or those related to the system's trackways (lines). Its emphasis is on above-ground stations rather than those in subway, although both types were studied. Particular attention is given to stations in residential areas.

## Acoustic Impacts

Although the study of BART's acoustic impacts dealt primarily with the effects of train sound and structural vibration along the lines, acoustic impacts near stations (arising from station-oriented traffic as well as from trains) were also investigated. While this investigation focused on stations in residential areas, observation and checks with local officials confirmed that no other station areas were sensitive to acoustic impacts.

### Sound

BART station activities, trains and traffic have not resulted in significant noise problems. The quietness of stopping trains is a major factor in the low levels of station-related noise. Trains decelerate over a 2,000-foot track segment approaching the stations, allowing a smooth and gradual stop. Typically, there is a steady decrease in sound from full speed to stop, with no squeal or other obtrusive sound; the disc brakes make virtually no sound. This is dramatically different from the high level of brake and wheel noise common to older transit systems.

Other sounds associated with stations are the train horn, the platform public address announcements, the use of trackway switches, and the sound of bus and automobile traffic entering and leaving the station. The train horn and platform announcements are clearly minor and inoffensive. Switches (at crossovers and turnouts) occur near many stations, particularly at terminals. While these generate noticeable sound when a train passes (potentially increasing BART sound by about 5 dB(A)[1] ), this alone is not a major noise impact and affects only persons living within about one block of the source.

Traffic noise related to BART is limited to morning and evening rush periods, when most station traffic occurs. A limited measurement program indicated that BART-related traffic does not significantly increase ambient noise levels, even during rush periods, because of the much greater volumes of non-BART traffic in most of these areas.

These findings were supported by the results of the residential survey. In all three station areas surveyed the majority of respondents were indifferent to any BART-related effects on neighborhood sound levels. (*Q15. Respondents were given a set of cards representing 24 environmental attributes [e.g., noise levels, wind, privacy, traffic] which might have been affected by BART facilities and operations; they were asked to sort the cards by perceived effect of BART on each attribute—very good, somewhat good, somewhat bad, very bad, half and half, or no effect. Noise variables: "noise inside your home" and "noise outside your home—in the yard, on the porch."*) However, substantial minorities judged BART's sound effects as "bad," particularly near the stations with heaviest traffic and overflow parking, Concord and Daly City, where 41 percent and 26 percent, respectively, reported adverse effects from noise. This indicates that traffic-related noise is at least potentially a problem in areas with heavy automobile access.

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1 Sound intensity measure with frequency distribution weighted to reflect human perception.

### Vibration

No vibration problems were found around the stations. The major potential source of vibration here is the train itself. However, actual effects are very slight. The heavy concrete station structure, resilient rail mounting pads, and BART's track and wheel grinding program seem to effectively eliminate any problem. As with sound, this is confirmed by the residential survey results. (*Q15; see page IV-11. Vibration variables: "vibration inside your home" and "vibration just outside your home."*) At all three station sites studied, only from 4 to 16 percent of the respondents reported unhappiness with vibration from the BART trains.

## Atmospheric Impacts

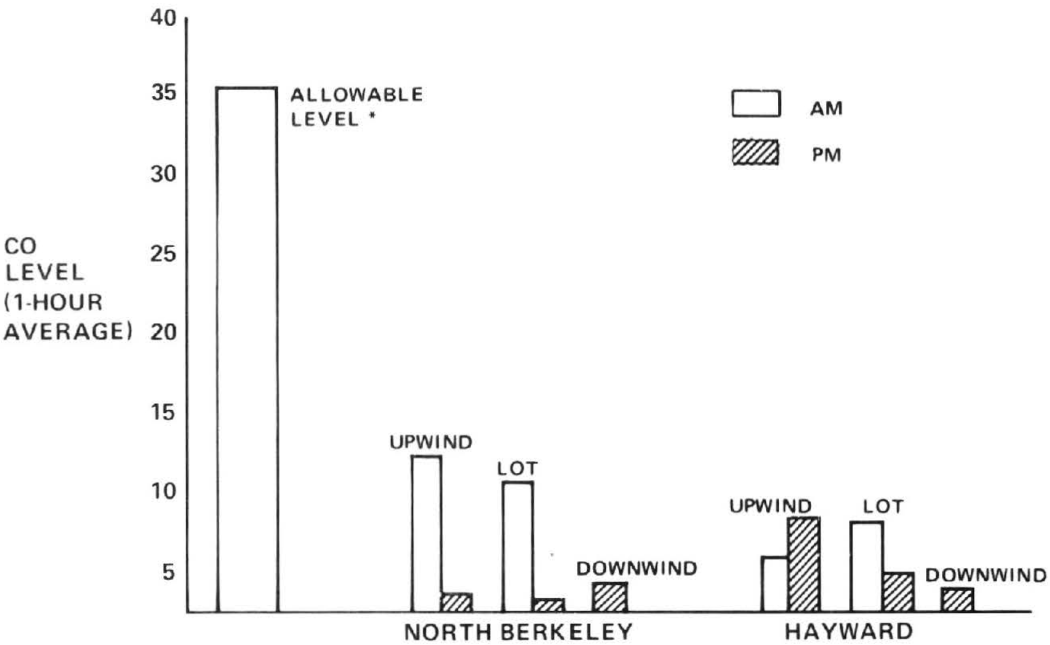
Effects of BART on wind and air quality around the stations are minor. Neither station structures nor the open areas of its parking lots have led to a major increase in ground-effect winds; this finding was corroborated by survey respondents. (*Q15; see page IV-11. Atmospheric variables: "wind around your home," "air pollution around your home," "air quality or smell around here," "television or radio reception."*) Effects on station-area air quality were of greater concern, however, since some observers had anticipated that BART-related traffic might cause significant increases in pollution. Accordingly, this topic was given careful study.

### Local Air Quality

Local air quality near BART stations has apparently not been affected significantly. Direct air sampling measurement of carbon monoxide (CO) near two representative BART stations indicated that station-area traffic and parking had produced only very low levels of local air pollution (Figure IV-2). Rush-hour CO concentrations were increased only slightly, even within the parking lots, and never did CO levels approach EPA one-hour exposure limits.

Adverse effects to local air quality were perceived by a substantial number of Daly City residents surveyed. (*Q15; see page IV-11. "Air pollution around your home" and "air quality or smell around here."*) An increase in air pollution was noticed by 25 percent of the Daly City respondents and a bad effect on air quality/smell by 18 percent. This may be related to the severe parking overflow problem in the area, which subjects residents directly to the effects of many cold-starting vehicles each evening. However, since this station adjoins a major freeway, respondents may have been incorrectly attributing its effects to BART.

FIGURE IV-2
MAXIMUM 1-HOUR AVERAGE CO LEVELS
IN AND AROUND BART STATIONS




* National Ambient Air Quality Standard—35 ppm for 1 hour
NOTE: No downwind AM measurements were taken.

### Land and Water Systems

There has been virtually no damage to living systems or soils and drainage as a result of station construction and operation. Each of BART's parking lots has from two to eight acres in paved or impermeable surface area, thereby increasing local rainfall runoff. In all cases BART construction included provision of adequate storm sewer capacity for this additional flow. Minor flooding (confined to BART property) has occurred at a few stations, generally due to temporary clogging of drainage culverts and ditches as well as inaccuracies in landscape grading. However, no significant property damage or personal danger has been noted.

A small amount of soil slippage has taken place in the Orinda Hills, where extensive slope cuts (entailing the removal of four million cubic yards of soil) were made in an unstable formation for BART station construction and related freeway relocation. Minor slippages and erosion continue to occur, although they are no worse than those common along the freeway prior to BART.

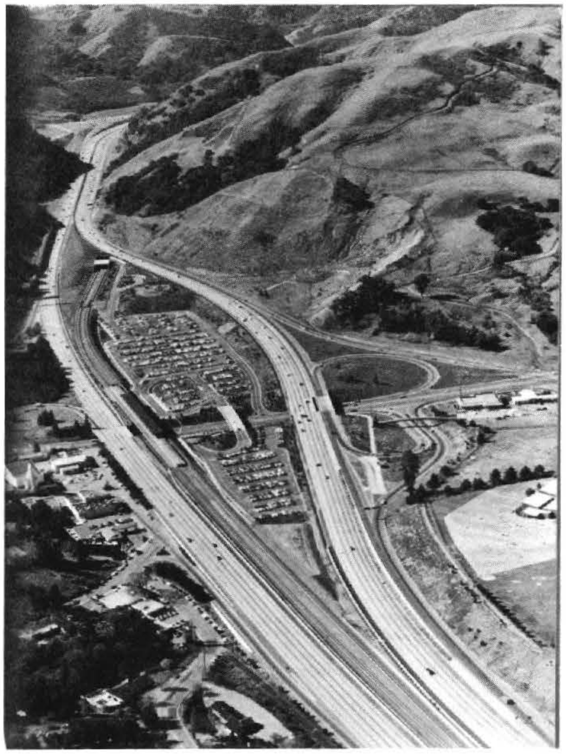


**PLATE IV-2**
**SLOPE CUTS, ORINDA HILLS**

**Neighborhood Travel**

A small reduction in traffic safety and the impairment of automobile and pedestrian travel have occurred near some BART stations. These problems were found to be of substantial concern to residents near the most heavily used BART stations surveyed. Two sources of such problems were studied: the intensity of BART-related traffic and on-street parking.

Barriers to Local Movement

Heavy on-street parking due to BART parking lot overflow is the most severe problem perceived by residents in neighborhoods adjoining the stations where it occurs. All of BART's station parking lots allow patrons to arrive and depart by bus or by automobile, providing dropoff/pickup areas in addition to parking. This mix of traffic sometimes creates potentially dangerous traffic patterns near stations, a problem sometimes compounded by the lack of clear identification of entrances and exits between parking lots and city streets.

Twelve of BART's 23 parking lots are filled daily. There is substantial parking overflow at five BART stations with parking lots and two stations without parking lots (Table IV-2). This overflow ranges from 100 to as many as 750 cars. Parking overflow occurs most commonly at stations near the outer extremities of the BART lines and is especially heavy at terminal stations (Daly City, Fremont, and Concord). At Daly City, where heavy overflow parking has caused the most serious problems, a 1,000-car, three-level parking structure is now being completed by BART to absorb the additional automobiles. Parking overflow problems can be expected to develop at the El Cerrito del Norte station when direct BART service from Richmond to Daly City begins.

**TABLE IV-2**
**FULL PARKING LOTS AND ON-STREET PARKING AT BART STATIONS**

| Station[a] | Parking Lot Capacity and Use[b] | Estimated Number Of Cars On Street[c] |
|---|---|---|
| Daly City | 675 | 625 |
| Fremont | 735 | 525 |
| Concord | 1,074 | 575 |
| Glen Park | No Parking Lot | 725 |
| Balboa Park | No Parking Lot | 750 |
| Oakland West | 403 | 250 |
| Lake Merritt | 225 | 150 |
| Union City | 816 | 0-100[d] |
| Pleasant Hill | 1,414 | 0-100 |
| Walnut Creek | 1,156 | 0-100 |
| Lafayette | 982 | 0-100 |
| Orinda | 939 | 0-100 |
| Hayward | 861 | 0-100 |
| South Hayward | 483 | 0-100 |

a Includes only BART stations with parking lots filled daily.

b As of November 1976; a few additions in capacity have been made since.

c As of May 1976, based on BART Passenger Profile Survey and site inspection to nearest 25 cars.

d Fewer than about 100; no indications of significant impact.

Survey results indicate that around the Daly City and Concord stations residents were more often unhappy with the parking overflow than with any other effect of BART. *(Q15; see page IV-11.)* In reaction to this problem some residents began parking on the street at night to reserve their driveways for guests, some put "no parking" signs in their driveways, and many petitioned their city police and councils for restrictions on all-day parking. This was a much higher level of action than that observed elsewhere or for other impacts. *(Q16A. "We're interested in anything you do or do differently now in your everyday life because of this change. Is there anything at all—even little things?")*

In addition it appears that the overflow parking creates an obstruction or "barrier" effect at the Daly City and Concord stations. A substantial number of respondents at these stations responded affirmatively to a question concerning whether BART has resulted in their being "blocked from getting to places in the neighborhood." *(Q15; see page IV-11.)* Thirty percent of the survey respondents at Daly City and over 50 percent of those at Concord perceived such barrier effects. These proportions were about the same throughout the area within four blocks from the stations, which coincides with the area affected by parking problems. Obstruction of pathways by the station structure itself is minimal at each of these stations; the Daly City station was built adjacent to an existing freeway, and the Concord station is beside an abandoned railway embankment. Therefore, the barrier concern shown by respondents at both stations seems clearly related to the inconveniences posed by the on-street parking and associated traffic congestion.

### Traffic Safety

BART has had no noticeable effect on traffic safety near most stations, although the increase in automobile traffic near a few heavily used suburban stations has caused some local congestion and an attendant small increase in the frequency of accidents. Police officials were consulted for all BART station-area jurisdictions, and traffic volume and accident data were reviewed where available. In most cases no BART-related problems were found, apparently due to careful traffic engineering by BART and the cities. Significant BART-related increases in accidents (from 1-2 to 8-10 in similar time periods before and after BART) involving parked cars were found only near the Daly City station, where there is heavy BART commuter traffic and parking along two-lane residential streets. Moving-vehicle conflicts have been attributed to BART near principal station exits or entrances where traffic controls are absent or fail to operate effectively under increased traffic volumes.

Almost half of the respondents at the Concord and Daly City stations felt that the danger of traffic accidents had increased. *(Q15; see page IV-11. "Safety from traffic accidents near your home" and "traffic congestion near your home.")* About two-thirds of the respondents at these sites also reported behavioral changes in reaction to the increased traffic, but most changes were relatively passive (e.g., "drove and walked more carefully"). *(Q16A; see page IV-16.)* This suggests that while traffic congestion causes dissatisfaction, it does not disrupt neighborhood life in a major way.

An observed lack of traffic safety problems at the El Cerrito Plaza station was confirmed by the residential survey response. The majority of respondents were indifferent to BART's traffic effects, and those with stronger reactions perceived good effects more often than bad. There are a number of reasons for this low level of impact and response. El Cerrito Plaza is a mid-line station with a relatively small parking lot (800 cars) and low volume of traffic. Moreover, it was built adjacent to an existing major shopping center with a large parking lot; thus, local adjustment to traffic and parking problems was previously accomplished. Finally, the location is well served by arterial streets, so very little station-oriented traffic makes use of the local residential streets.

Review of accident data and interviews with public and police spokesmen indicated that there were no traffic safety problems attributed to BART in downtown station areas. However, pedestrian travel patterns, particularly those of BART commuters from the East Bay to downtown San Francisco, were somewhat changed due to BART's downtown station locations relative to the bus terminals and automobile parking lots used prior to BART. BART station mezzanines, street improvements and minor BART-related changes to bus routing near downtown stations appear to have helped maintain the prior level of safety despite increased concentrations of pedestrians. In addition, since BART leaves patrons two or more blocks closer to most downtown San Francisco work places than possible by transbay buses, there is a slightly reduced exposure to traffic hazards.

**Social Environment**

BART stations were anticipated by some to have potentially disruptive effects on the local social environment. Of particular concern was the possibility of increased crime and changes in the socioeconomic character of the neighborhood. This study revealed little change, whether actual or perceived, to either of these neighborhood characteristics.

Crime

BART's effects on crime around its stations appear to be minimal. Theft and burglary of automobiles were found to occur on the streets around some stations with parking lots and overflow parking. However, BART patrons were the most frequent victims, and nearby residents do not perceive a threat to themselves. (*Q15; see page IV-11. "Safety from crime here at home" and "safety from crime in this neighborhood."*) Interestingly, no similar increases in automobile-related crimes have occurred on streets near the two San Francisco feeder stations without parking lots (Balboa Park and Glen Park), even though both are sites of substantial BART on-street parking.

Although some public officials expected crime around BART stations to increase with the addition of night service in early 1976, this has generally not occurred. Urban area officials in particular expressed concern about higher crime rates accompanying night service. However, there have been only slight increases in the numbers of arrests, with most of these related to intoxication. Violent crime has apparently remained at its original low levels, particularly around the stations away from downtowns and other traditional high-crime areas.

A large majority of respondents (66 percent to 82 percent) at the station sites surveyed felt that BART had no effects on home and neighborhood security or that its overall effect was neutral ("half and half"). Among those who felt that BART does affect their safety from crime, respondents at Daly City and El Cerrito more often felt BART actually increased home and neighborhood safety, while at Concord the preponderant feeling, especially among residents closest to BART, was that it decreased safety.

These reactions appear to have little relationship to actual crime in the areas. The perceived security effects are probably related to station context. In Daly City and El Cerrito, stations were located in areas where strangers consistently passed or entered the neighborhood before BART's construction because of nearby transportation arteries and shopping centers. BART staff and commuting patrons could be seen as legitimate "regulars" to these areas, and therefore deterrents to crime. In Concord, though, BART was the factor which introduced large numbers of "outsiders" to the neighborhood.

Few residents reported changes in behavior patterns because of BART-related crime, and the few changes reported were predominantly passive reactions such as using increased caution in driving and walking. (*Q16A; see page IV-16.*)

## Neighborhood Composition and Mobility

Nearness to a BART station seems to have had some effects on considered and actual changes of residence, although population characteristics of station areas do not appear to be changing as a result. Proximity to BART was a factor in choosing a home for relatively high proportions of survey respondents at the station sites (15 percent at Concord, 16 percent at Daly City, and 22 percent at El Cerrito). (*Q28A. "In choosing a place to live, did you try to find a home where you could easily get to a BART station by walking, bus or car?"*) In addition, 13 to 20 percent of the respondents reported knowing others for whom BART was a factor in choosing a home. (*Q30B. "Do you know of anyone [else] who has moved into this neighborhood because of BART?"*)

Forty percent of the Concord respondents and 26 percent of those at Daly City and El Cerrito have considered moving away in the last few years. BART was a contributing factor among 48 percent of the Concord residents who considered moving, but among only 8 percent of those in Daly City and El Cerrito. (*Q29A. "Have you seriously considered moving away from here in the last few years?" 29B [if yes]. "What were your reasons?" 29C [if BART not mentioned]. "Was BART part of the reason?" Q 30A. "Do you know of anyone else who has moved or considered moving away from this neighborhood because of BART?"*) Residents at Concord and Daly City were much more likely to know others for whom BART was a major factor in moving away than residents at El Cerrito (19 percent and 16 percent versus 4 percent); this probably reflects the adverse effects of overflow station parking and traffic in terminal station areas.

There were no indications of major changes in neighborhood population characteristics such as age structure, household type or economic status around any of the stations studied. Since comparative before-after census data were not available in most cases, this tentative finding is based on the opinions of the residents surveyed. However, it is significant that these residents, who might be expected to be particularly sensitive to such changes, gave no evidence of such concerns. Similarly, these respondents did not believe that any real changes in neighborhood upkeep or housing character had occurred since BART began service there. *(Q15; see page IV-11. "The kinds of people who live around here," "construction or removal of nearby houses," and "the general appearance of your neighborhood.")*

**Visual Quality**

BART's effects on three aspects of station-area visual quality were evaluated: effects on neighborhood appearance and view from home, shadows, and illumination. It was found that shadow effects of station structures were insignificant, since these large structures are usually within a parking lot and distant from residents. Neighborhood appearance, view, and nighttime lighting were the subjects of more detailed study as reported below.

Appearance and View

Although the study's technical evaluation judged BART stations and parking lots to be of incompatible scale where they occurred in low-density residential surroundings, most residents found the station architecture to be an asset. The contrast of BART's large above-ground station structures and parking lots with small-scale residential surroundings was thought to cause adverse visual impacts. This technical judgment was based on a systematic comparison of key visual factors of BART structures and their environment (e.g., mass, color, texture, and activity), emphasizing the visual compatibility of a station with its context.

Survey respondents residing in small-scale residential environments adjacent to three stations appear to disagree with the professional evaluation. *(Q15; see page IV-11. "The general appearance of your neighborhood.")* This was true even at Concord, where respondents were most critical. While 25 percent of the Concord respondents reported bad effects on neighborhood appearance and 11 percent stated that the effects were good, nearly two-thirds were indifferent.

BART stations built near existing large structures such as shopping centers or freeways were judged to complement the existing structures by being similar in scale and function. Two stations studied are near existing large structures (i.e., Daly City separating homes and a depressed freeway, and El Cerrito Plaza between homes and a shopping center). At these, BART's effects on overall neighborhood appearance were felt to be good by 36 to 40 percent of the respondents, with most of the rest indifferent. *(Q15; see page IV-11. "The general appearance of your neighborhood.")* Similarly, 13 to 20 percent of these respondents felt that BART enhanced the view from inside their homes, again with most other respondents indifferent to this factor. *(Q15, see page IV-11. "The view from inside your home.")* These findings suggest that to most residents the architectural quality of nearby above-ground BART stations is high enough to offset negative effects arising from their large size and contrast with the residential surroundings.

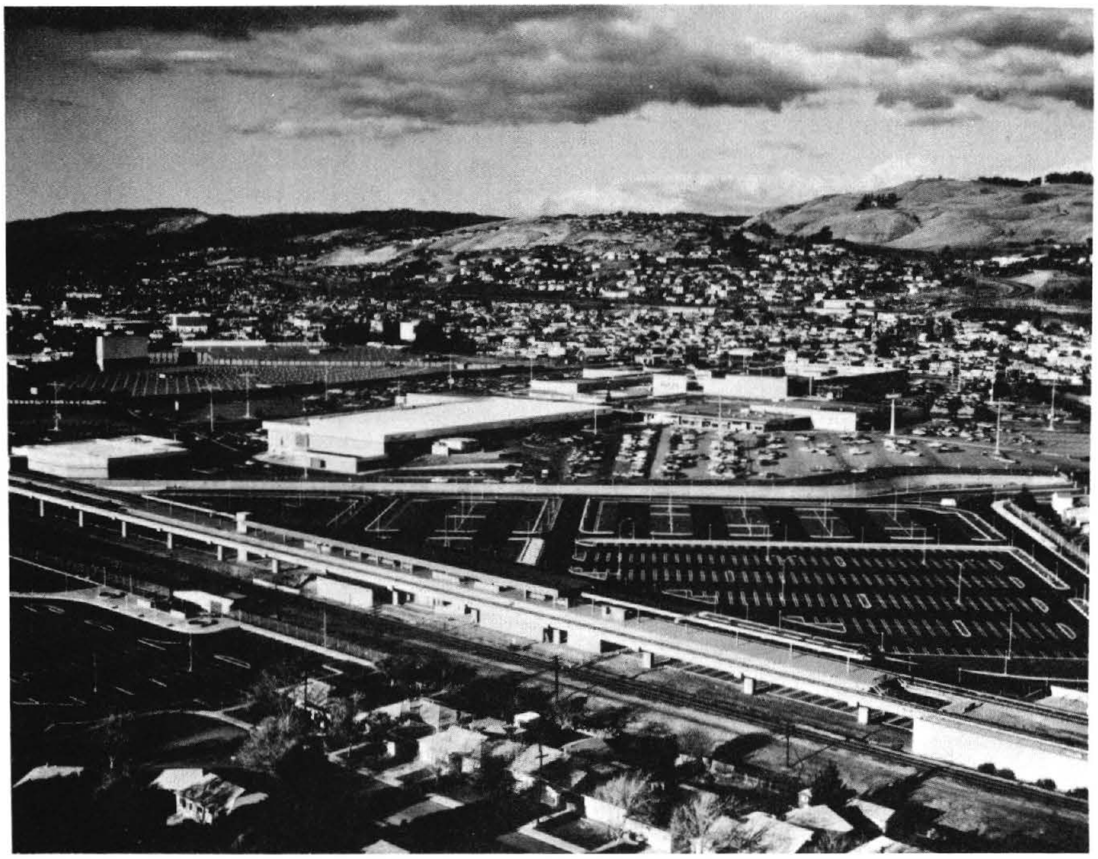


**PLATE IV-3**
**BAYFAIR SHOPPING CENTER ADJACENT TO BART STATION**

The use of trees, especially that of existing mature trees, was helpful in integrating large parking lots into residential areas. In some instances landscaping was used to visually integrate stations and related parking facilities into a developed area by extending neighborhood landscaping patterns into the station site areas. This judgment was supported by the opinions of nearby residents, most of whom reported BART station-area landscaping as a benefit. (*Q15; see page IV-11. "Trees and other natural features."*)

Lighting

Despite expectations of problems with nighttime glare, BART's extensive station and parking lot lighting was found to be either valued or of no importance to residents. The nighttime glare on houses and yards from station parking lot illumination was assessed to be a potential problem at some stations. Most stations have unshaded high-intensity lights throughout their parking lots. During the 1973 energy crisis about half the lights at most parking lots were removed from service. Because the level of illumination remained adequate there has been no attempt to resume using these lights.

Contrary to expectation, most nearby residents were indifferent to BART lighting, and substantial numbers viewed it as a benefit. (*Q15; see page IV-11. "The amount of lighting near your home at night."*) At the Daly City and El Cerrito Plaza station sites, a large majority of the respondents in the row of dwellings nearest BART felt that the lighting has a positive effect. Most Concord respondents were indifferent to BART lighting, and while they reported ill effects more often than did respondents in Daly City and El Cerrito, comments were still more positive than negative. Residents apparently relate the lighting to protection from crime and to safety from accidents while walking. Glare on surrounding homes and yards is evidently not perceived as a problem.

## LINE IMPACTS

**Environmental impacts along BART lines have been small except for the effects of BART train sound near some of the aerial line segments.**

The effects of BART associated with at-grade and aerial line segments are described in this section. No operational impacts are associated with BART subway lines.

### Acoustics

BART train sound was found to be the system's most severe environmental impact along its lines, although not a problem of overriding concern to most residents or others nearby. Vibration was found to be a lesser but significant problem.

#### Sound

Technical measurements indicated that BART train sound is noticeable and potentially troublesome to residents living near some segments of above-ground lines. Instantaneous sound levels of BART train pass-bys ranged from 75 to 88 dB(A), depending on factors such as train speed and track configuration. This is roughly equivalent to a passing delivery truck—a noticeable but not uncommonly intense sound. To permit assessment of the amount of sound actually added by BART to the existing background levels, these individual train pass-by sound levels were averaged over BART's operating hours for the frequency of trains in operation at each point. The commonly accepted $L_{eq}$ (equivalent sound level)[1] measure was used in this time-averaging. The resulting "average" BART sound levels were compared with estimated background $L_{eq}$ sound levels systemwide to identify locations where the BART sound was dominant.

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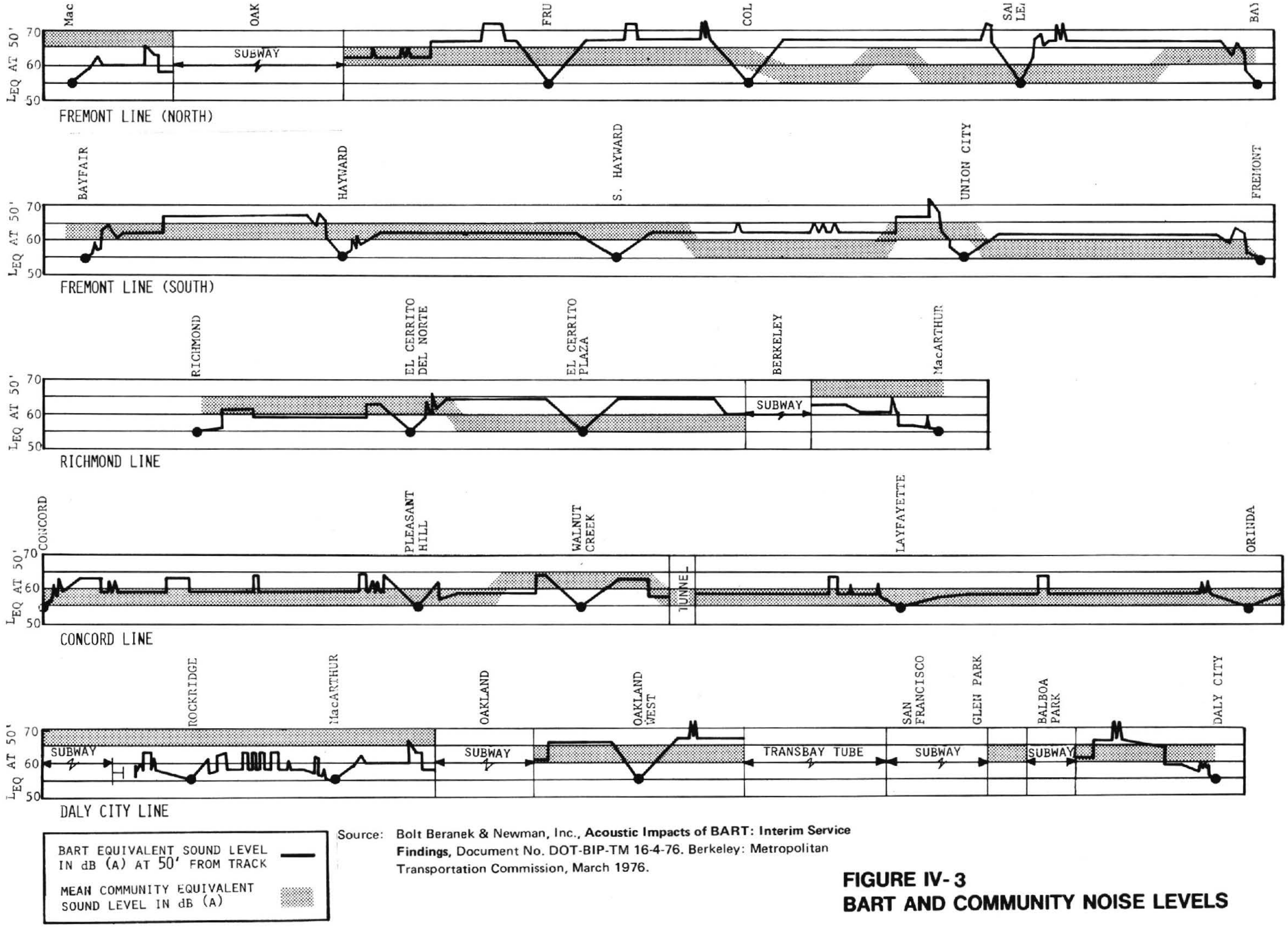
1 $L_{eq}$ is proportional to the logarithm of the average sound level in dB(A) recorded over a specific period of time, usually one hour.

As seen from Figure IV-3, along approximately 10 percent (seven miles) of BART's trackways the daytime time-averaged sound of BART was found to exceed background time-averaged sound levels ($L_{eq}$) by at least 5 dB (perceptible), but not by more than 12 dB (substantial). This effect diminishes with distance, falling mainly on dwellings that lie within 250 feet, or about one block, of the trackways. Because of lower community sound levels at night, BART's time-averaged sound level may exceed the community's in these same areas by up to 17 dB, extending the perceptible effect to about 500 feet.

**PLATE IV-4**
**HEAVY SOUND IMPACT CONDITIONS: AERIAL LINE, HAYWARD**

Train noise was the most common cause for complaint among residents in the aerial line survey sites. (*Q15; see page IV-11. "Noise inside your home" and "noise outside your home—in the yard, on the porch."*) A majority (51 percent to 71 percent) of the survey respondents at each aerial site except Oakland (where the ambient noise level was high prior to BART) reported that BART train noise has bad effects in or near their homes. As might be expected, residents nearest the aerial trackway reported adverse train sound effects even more often (55 percent to 85 percent of those respondents). Although some residents in study sites abutting BART at-grade lines cited train sound as an irritant, the frequency of concern was much lower than along aerial lines.

Orientation of the homes nearest BART lines was found to affect residents' perception of train sound. Residents whose homes faced BART had fewer complaints than those whose backyards abutted the right-of-way. Distance from lines was also a key factor; only the first row of homes along at-grade lines appeared to be significantly affected. Near aerial trackways the frequency of complaints was substantial as far away as two blocks, although much higher in the first block than in the second. Beyond this distance only small proportions (typically zero to 10 percent) of the surveyed residents reported adverse effects.



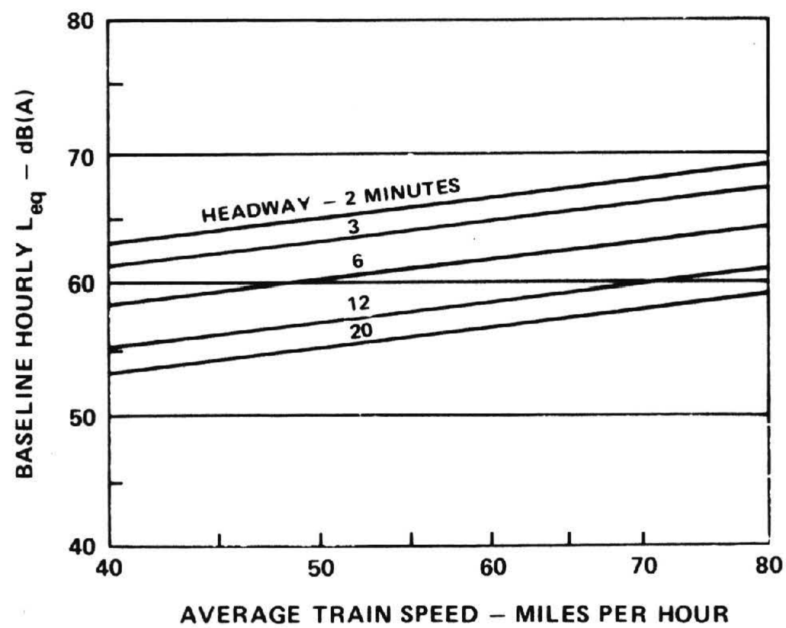

Source: Bolt Beranek & Newman, Inc., **Acoustic Impacts of BART: Interim Service Findings,** Document No. DOT-BIP-TM 16-4-76. Berkeley: Metropolitan Transportation Commission, March 1976.

**FIGURE IV-3**
**BART AND COMMUNITY NOISE LEVELS**

Few residents have taken any actions to counteract BART train sound. Residents were asked to identify actions taken in defense against train sound, with expected responses ranging from writing letters of complaint to soundproofing the home or changing the uses of rooms. (*Q16A; see page IV-16.*) However, very few residents reported having taken actions to complain formally, to avoid the sound, or to adapt to it through behavioral change. This seems to indicate that the problem is not of overriding importance to most of the people affected.

Factors important to the intensity of BART's train sound include train speed, track and wheel condition, train length and frequency, and the presence of point noise sources such as switches and curves. The data in Figure IV-4 indicate how the time-averaged ($L_{eq}$) sound levels vary as a function of different train speeds and headways. For instance, a six-car train traveling 65 mph on tie-and-ballast at six-minute headways would have an equivalent sound level ($L_{eq}$) of 62 dB(A).

**FIGURE IV-4**
**BART EQUIVALENT SOUND LEVEL ($L_{eq}$)**
**AS FUNCTION OF TRAIN SPEEDS AND HEADWAYS**




NOTE: These sound levels include the effects of BART trains traveling in both directions at the headways stated.

Source: Bolt Beranek & Newman, Inc., **Acoustic Impacts of BART: Interim Service Findings,** Document No. DOT-BIP-TM 16-4-76. Berkeley: Metropolitan Transportation Commission, March 1976.

Table IV-3 lists corrections that can be applied to Figure IV-4 to account for differences in configuration and train length. For example, the $L_{eq}$ for eight-car trains operating at 65 mph with six-minute headways over a switch on an aerial section would be 62 + 1 + 5 + 5 = 73 dB(A).

**TABLE IV-3**
**CORRECTIONS TO BASELINE $L_{eq}$***

| Trackway Condition and Train Length | dB(A) Effects |
|---|---|
| Tie and ballast (berm or grade) | +0 |
| Aerial structure | +5 |
| Switch on berm or grade | +3 |
| Switch on aerial | +5 |
| Curve (radius < 4,500') | +5 |
| Two-car train | -3 |
| Four-car train | -1 |
| Six-car train | +0 |
| Eight-car train | +1 |
| Ten-car train | +2 |

* Baseline condition is a six-car BART train on tie and ballast track with no switches or curves.

In addition, comparative measurements of train pass-bys on track segments most recently ground from a few months to several years ago showed that frequent rail grinding (at least once a year in comparison with the three- to five-year intervals found in some locations on BART) can reduce sound levels by as much as 5 dB.

Vibration

BART trains cause vibration which is perceptible, but probably not damaging, within about a block of its aerial lines. In structures near BART subways, the instrument-measured vibration level was not noticeably greater for BART train pass-bys than for vehicular traffic on the street above. In areas adjacent to aerial trackway, perceptible groundborne vibration (65 to 75 VdB[1]) may be encountered within 200 feet of the BART track, but damage to structures due to that vibration is highly unlikely. Beyond 200 feet, vibration levels are lower than 65 VdB, the generally accepted perception threshold.

1 Vibration intensity measure with frequency distribution weighted to reflect human perception.

The level of negative response to vibration was lower than that noted for sound, ranging from 14 percent (Oakland) to 51 percent (Albany West) of the respondents in the aerial sites surveyed and 4 percent (Hayward South) to 14 percent (Richmond) in the at-grade sites. (*Q15; see page IV-11. "Vibration inside your home" and "vibration just outside your home."*) Except for the Oakland site, negative responses were much more frequent at aerial line sites than in the sites near the at-grade tracks. Little behavioral change and no indication of overt protest in response to vibration were found. (*Q16A; see page IV-16.*) In addition, on-site observation suggests that vibration is typically minor, particularly in comparison to that experienced near the elevated lines of older systems in other cities (e.g., Boston, Chicago).

## Atmosphere

BART has had some effect on television reception in certain line areas. The addition of structures and passing of trains has had no significant effect on ground-level wind patterns or intensity. No other atmospheric effects were found relevant for study along the line segments.

### Television Interference

The passage of BART trains above ground appears to cause perceptible television interference in nearby homes. This problem has been regarded as relatively minor, since virtually no complaints to BART or other local groups were found. The problem surfaced only in the residential survey, where substantial incidence of TV reception interference was reported (*Q15; see page IV-11. "Television or radio reception."*) No precise cause of the interference has been established, but the passage of BART trains on aerial trackway structures seems clearly to be the source of the problem.

The effect was noted most often among surveyed residents living directly adjacent to aerial BART lines; 37 to 74 percent of the respondents there reported TV interference. While the effect was widely perceived, few persons have taken actions in response (e.g., complaining to BART or others, subscribing to cable TV, installing higher antennas). (*Q16A; see page IV-16.*)

## Earth and Water Systems

The only potential problem affecting land and water systems along BART lines is underground electrolysis from the BART rail distribution system. BART's construction and operation have not resulted in significant impacts on biota, soils, or drainage systems.

### Underground Electrolysis

Potential corrosion to nearby metallic structures due to stray electricity from the rail distribution system has been identified by BART as a significant problem.[1] BART has received several complaints about corrosion of underground facilities, but in each case, according to BART officials, the problem was traceable to causes other than BART system leakage. However, after evaluating the possibility of long-term effects, BART concluded that the exchange of current might ultimately result in corrosion to underground structures.

BART designers expected some electrical leakage, since, like other transit systems using direct current for power distribution, BART utilizes its running rails for negative current return. Consequently, the steel rails were initially mounted on insulated fasteners to minimize leakage. This was found to be insufficient, however. BART is presently working with utility companies to make substantial system modifications to reduce the amount of stray current to acceptable levels.

## Neighborhood Travel

BART has created virtually no change in traffic congestion or safety near its above-ground lines. Barrier effects have been minimal.

### Barrier Effects

BART has created few new physical barriers for pedestrians or vehicles, since much of the BART line is parallel to other transportation rights-of-way. Only 12 of the 300 streets which cross BART lines were closed. Even these closures tended to have positive effects by blocking through traffic from local streets.

The aerial trackway poses no barriers, and all major thoroughfares were made to cross over or under lines at grade. In general, the aerial configuration was used where many crossing points were required, while the lines were placed at grade in relatively undeveloped areas, or alongside or within freeway medians.

At-grade trackway was fenced for neighborhood and train safety, and, as a result, pedestrian cross traffic was blocked along 12 miles of the right-of-way. Problems resulted in a few locations; fences were cut apparently to provide shortcuts across the tracks. In cooperation with the cities involved, BART built pedestrian bridges at these locations. This appears to have stopped virtually all trespassing onto the right-of-way. No injuries to trespassers have been reported.

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1 H. E. Bomar et al., "Stray Current Aspects of BART." Paper No. 153 presented to the 1974 International Corrosion Forum of the National Association of Corrosion Engineers, March 4-8.

The study's survey, which was done several years after the pedestrian bridges were installed, found only a small incidence of complaint concerning BART's barrier effects and no actions against those effects. *(Q15; see page IV-11. "Helping or blocking you from getting to places in the neighborhood." Also Q16A; see page IV-16.)*

**Social Environment**

Aspects of the social environment studied were privacy, neighborhood composition and mobility, and security from crime. It was found that BART has had virtually no effect on security in areas adjacent to BART lines. Minor effects on privacy and neighborhood mobility were found.

Privacy

Where BART trackway is elevated and overlooks residential backyards, the loss of privacy is frequently of concern. Approximately 30 percent (21 miles) of the BART system is elevated and close enough to adjacent houses and yards to expose them to passing trains. A loss of privacy is most often felt by persons living adjacent to aerial trackway and to a lesser extent by residents along at-grade lines. *(Q15; see page IV-11. "Privacy in your backyard" and "privacy inside your home.")* However, there were few reports of actions in response to the exposure (e.g., fences, window covering), and loss of privacy was seldom rated among the "worst" of BART's impacts. *(Q16A; see page IV-16.)*

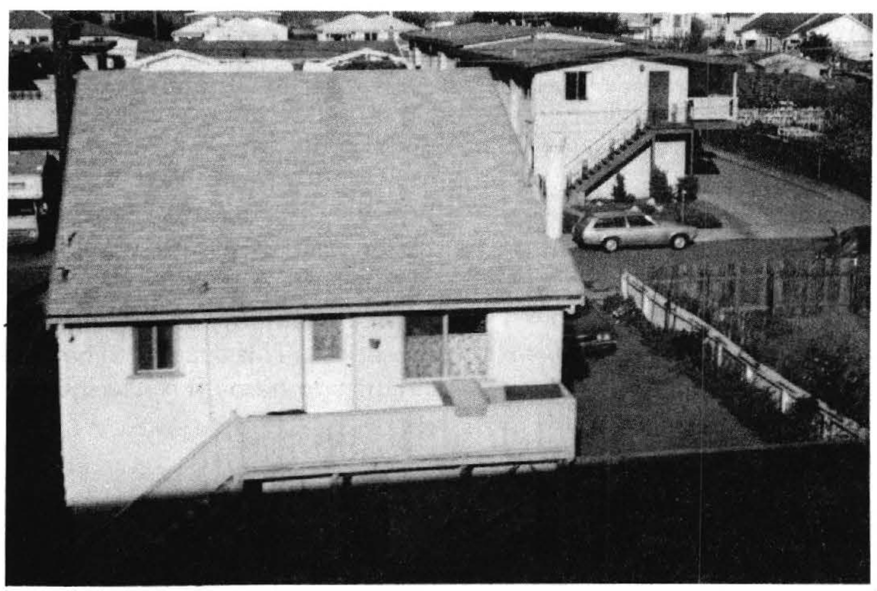

**PLATE IV-5**
**HOME AND BACKYARD VIEWED FROM BART TRAIN, EL CERRITO AREA**

A majority (53 to 55 percent) of the survey respondents whose backyards adjoin BART aerial trackway felt loss of privacy to be an adverse BART effect. Where aerial right-of-way is narrow, exposure of houses which directly face BART is often perceived as a problem by residents. This was the case at Hayward South, where 37 percent of the residents living nearest BART reported adverse effects on privacy. Twenty-one to 26 percent of the respondents whose backyards abutted at-grade lines reported similar bad effects. Disturbance of privacy inside the home was reported by fewer respondents, although their proportions were still substantial among BART-adjacent residents (11 to 12 percent along at-grade lines and 13 to 21 percent at aerial sites).

Neighborhood Composition and Mobility

BART appears to have had no effect on the kinds of people living along its lines. However, the aerial lines may be a factor in decisions to move away. This study's limited land use assessment and informal survey staff observations suggest that there has been very little housing removal or construction along the line since BART construction and that no change in neighborhood housing or upkeep has occurred.

Few residents reported that BART has had an impact on changes in neighborhood residents. (*Q15; see page IV-11. "The kinds of people who live around here."*) The few respondents perceiving BART effects on neighborhood composition felt they were good more often than bad.

Between 24 and 43 percent of the respondents at all sites surveyed considered moving away during the last ten years. (*Q29; see page IV-18.*) Among those considering a move at four of the five aerial line sites surveyed, BART was reported as a contributing negative factor by 42 percent to 64 percent (55 to 58 percent among those living nearest BART). It was less often a factor in considering moves from the Oakland aerial site and from the at-grade sites, Richmond and Hayward South.

At all line sites except Oakland, BART was rarely a positive factor in choosing a home nearby. (*Q28A; see page IV-18.*) Twelve percent of the Oakland residents indicated that BART was a factor in choosing their homes; this apparently referred to the site's unusually good bus access to nearby stations. Still, larger proportions (15 to 22 percent) of the station-site respondents saw BART as a positive factor.

## Visual Quality

Four different aspects of BART's effects on visual quality were studied. These were effects on neighborhood appearance, view from home and yard, lighting, and shadows.

### Appearance

While the study's technical assessment found that large BART structures cause visual conflict in residential areas, a majority of the wayside residents surveyed were indifferent to such effects. During the technical assessment portion of the study it was judged that the large BART structures, particularly aerial line structures, were well designed but tended to create visual conflicts with the smaller-scale single-family residential structures. However, in most line areas survey respondents were found to be indifferent to BART's effects on neighborhood appearance. (*Q15; see page IV-11. "The general appearance of your neighborhood."*)

Adverse effects on neighborhood appearance were most often perceived by residents near aerial line sites with little or no landscaping; almost one-fourth of the residents in Hayward North and San Leandro survey sites rated the appearance of BART as bad.

### View

In some residential areas view has been adversely affected by BART aerial and at-grade trackway. Although the majority of survey respondents living near BART lines were indifferent to BART's effects on view, those whose backyards adjoined the BART aerial line most often considered its effects adverse. (*Q15; see page IV-11. "The view from inside your home" and "the view from your backyard."*) All negative responses were confined to houses in the first row facing BART; up to half of these residents felt that BART harmed their view.

BART's linear park and the visual separation of incompatible land uses are sources of visual enhancement for adjacent neighborhoods. The visual benefits of linear park under aerial trackway are highly valued by nearby residents. (*Q17. "How do you think the landscaped strip and walkway has affected things—would you say it's had a very good effect, a fairly good effect, a fairly bad effect, or a very bad effect around here?"*) About 90 percent of the survey respondents near the 2.7-mile linear park in Albany and El Cerrito believe it to have a "good" or "very good" effect. However, the visual benefits do not seem to lessen or nullify perceptions of the adverse effects (e.g., train sound) which accompany an aerial trackway configuration.

Along some segments, BART line structures have provided a limited visual screen between residential land uses on one side and industrial uses on the other. An example of this occurs along BART trackway between Concord and Pleasant Hill.

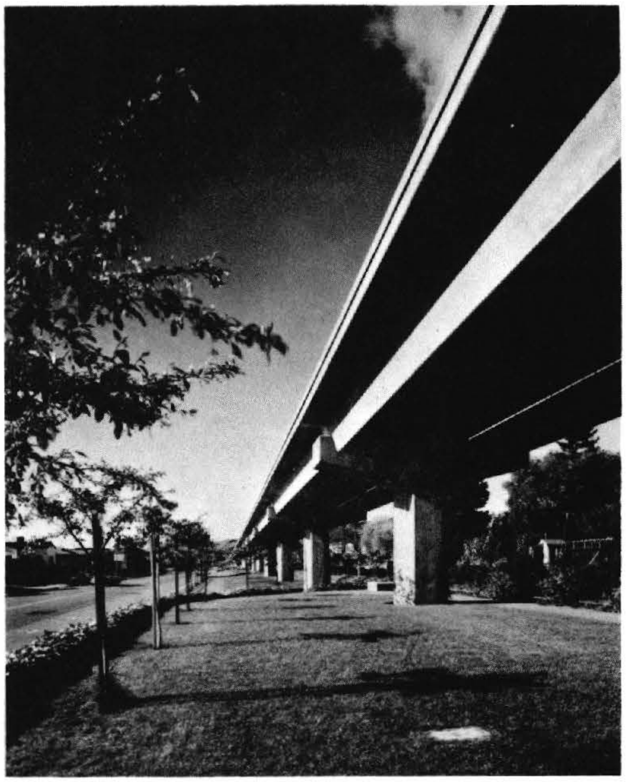

**PLATE IV-6**
**LINEAR PARK**
**IN EL CERRITO**

Lighting

Increased street illumination from linear parkway lights has been viewed as beneficial by many residents facing the park. There is some evidence that residents believe the lighting has improved security from crime. (*Q15; see page IV-11. "The amount of lighting near your home at night."*) The lights are more attractive than nearby streetlights and spaced at closer intervals.

Shadows

Shadows tend to create adverse effects in areas where the line is in an aerial configuration and very close to residential structures and yards. The primary determinants of shadow impacts in residential areas near aerial structures (seven percent of BART's 71 miles) include: height of BART trackway, orientation of trackway relative to the sun, and proximity of houses and yards. The design intention to minimize silhouettes dictated that elevated structures be placed in streets or areas with a width of 100 feet between building lines. However, the intention was not always achieved.

Between a quarter and a half of the residents nearest BART's aerial tracks judged the structure's shadow effects to be adverse. In four of the five aerial line sites, negative responses of respondents living nearest the trackway ranged from 24 percent to 50 percent, with the remainder indifferent. In the fifth aerial site, Albany West, the nearest homes are across a wide street and have no shadows from BART except briefly in the early morning. These findings suggest that shadows are a substantial problem where aerial structures are sited close to homes and yards.

## BART SERVICE FACILITIES

In addition to its stations and trackway, BART's facilities include an administration building, three train-vehicle maintenance and storage yards, and one shop for maintenance and repair of the trackway and structures.

The **BART administration building** is located in Oakland adjacent to the Lake Merritt station. Between 400 and 450 persons are employed there, mainly in administrative positions.[1] In addition, the automatic train control center and the systemwide communication network are housed in the eight-story building. Off-street visitor parking is provided across the street from the building, and employee parking is located about four blocks away beneath a freeway. The area in which the building is located is an active one with mixed land uses, including multiple-family residential units, Laney College, Oakland Art Museum, and nearby government buildings. No discernible environmental impacts were identified relative to the administration building.

**Inspection, service and storage** of BART trains occur in three locations: Richmond, Concord, and Hayward. These yards and shops occupy from 20 acres to nearly 50 acres, and up to several hundred persons are employed at each facility. Work is done on a 24-hour basis seven days a week. Major activities at each facility include preventive and unscheduled maintenance, car damage repairs (heavy repair work is done only at Hayward), car modification and parts replacement, cleaning, assembling and dispatching of trains, and storage of vehicles when not in operation. Each yard can store approximately 160 cars. At the Hayward yard a two-and-one-half-mile engineering test track is available (along the main line) for testing of new cars or repaired cars.

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1 Approximately 70 other BART administrative personnel work in space leased in a downtown Oakland office building.

**PLATE IV-7**
**HAYWARD BART YARDS AND SURROUNDING AREA**

Impacts from these yards fall largely onto non-residential areas. Where there are pockets of residences, complaints have been voiced relative to nighttime noise associated with the movement of BART cars within the yard area. In order to reduce noise levels, BART has muffled service vehicles and equipment and attempted to keep their nighttime activities away from yard areas near residential locations.

Personnel based at the **Oakland Shop,** located between the Lake Merritt and Fruitvale stations, are responsible for maintenance and repair of all trackway and structures, electrical supply and distribution systems, and repair and service vehicles. Approximately 300 to 400 people work out of this facility, which includes complete machine and fabrication shops. These facilities are located in an industrial area adjacent to a freeway and railroad. Consequently, no environmental impacts to residential neighborhoods are experienced.

## CAUSES OF IMPACT

**Many factors contribute to BART's environmental impacts.** These factors include BART attributes as well as characteristics of the physical and social environment. The most important of these determinants are shown in Table IV-4. For each determinant several conditions or options occur; for example, BART's line configuration can be either aerial, at-grade, or subway. Each such condition is shown in the table, along with a description of its effects on impact.

Typically, BART attributes and the environmental characteristics shown were found to occur in combinations which determined the location and intensity of impact. Table IV-5 shows combinations of determinants which led to the most adverse impacts around BART stations and lines. This combining of determinants illustrates why some, but not all, outlying BART stations and aerial lines generated adverse environmental impacts.

Some factors contributed to reduction of BART's adverse impacts or the creation of environmental benefits. These factors are equally as important as those which caused the adverse impacts. Table IV-6 lists some of the major determinants of these good effects. However, without them BART's adverse effects would have been much more widespread. Such location and design options deserve careful consideration in the development of future transit systems.

Along the BART lines the worst combination of factors was the high-speed operation of trains on aerial tracks along narrow rights-of-way in some residential areas. This has caused significant adverse effects. These include train noise and vibration, blocking of views by the prominent trackway structures close to existing homes, exposure of previously private yards to observation from BART trains, and creation of undesirable shadows. Avoidance of such combinations of factors substantially reduced most impacts. For example, nearly 85 percent of the BART line is located along existing freeways, railroads, and arterial streets. Where the existing route was heavily used and is reasonably distant from buildings, the environmental effects of adding BART tracks to the right-of-way were modest. Exceptions to these conditions do occur; where BART aerial trackway follows, for example, a railroad which is lightly used, BART's acoustic impact may be almost as great as if there had been no existing transportation route. Adverse visual effects sometimes occur where a highway through open space or through a suburban area was widened substantially to accommodate BART.

Some of the BART stations that include parking lots, and especially the end-of-the-line stations in residential areas, have led to adverse local effects. These include residential and commercial dislocation, some visual disharmony, traffic congestion, and especially the possibility of heavy overflow parking on nearby streets. BART is attempting to alleviate parking overflow problems by working with bus agencies to improve feeder transit service and by expanding parking facilities.

These locations of substantial adverse environmental impact are shown in Figure IV-5. Also shown are the locations of BART's beneficial impacts due to street beautification projects fostered along downtown subway line segments.

## TABLE IV-4
## MAJOR IMPACT DETERMINANTS AND EFFECTS

| Impact Determinants | Types and Magnitudes of Impact |
|---|---|
| *BART ATTRIBUTES: FACILITIES* | |
| Line Configuration | |
| Aerial | Sound, vibration and visual exposure. |
| At-grade | Barrier to cross traffic movement; some sound impact, but less than aerial. |
| Subway | Pedestrian and vehicular traffic disruption during construction. |
| Traffic Engineering | |
| Straight runs | Gradual sound changes all along track. |
| Switches, curves, tunnel portals | Sudden sound changes creating intense impact to small areas. |
| Station Access Provisions | |
| Downtown (buses, no parking) | No apparent impacts. |
| Other stations without parking | Probable traffic and on-street parking congestion. |
| Other stations with parking | Traffic and on-street parking congestion possible, particularly at most remote stations. |
| Station Location | |
| Suburban residential area | Most sensitive to impacts, especially those related to automobile access. |
| Other suburban areas | Less sensitive to impacts of all types. |
| *BART ATTRIBUTES: OPERATIONS* | |
| Hours of Operation | |
| Day | Variety of impacts perceived by nearby residents. |
| Night | Significant increase in sound impact due to lower ambient noise level at night. |
| Train Speed | |
| 70-80 mph | Train sound likely to be above residential ambient levels. |
| 30-50 mph | Train sound probably not above residential ambient levels. |
| Train Frequency | |
| Frequent (BART: 6 minutes) | Substantial train sound levels. |
| Less frequent (BART: 12 minutes) | Barely noticeable reduction in train sound levels. |
| Track/Wheel Maintenance | |
| Typical BART grinding (two to five years) | Significant contribution to train sound. |
| More frequent (at least yearly) | Reduction of 2-5 dB(A) in train sound. |
| Train Length | |
| Two cars | Baseline: least train sound on BART. |
| Ten cars (BART maximum) | Significantly higher (about 5 dB(A) ) train sound on hourly $L_{eq}$ basis. |
| *CHARACTERISTICS OF BART'S ENVIRONMENT* | |
| Adjacent Land Use | |
| Residential—single-family homes | Most susceptible to all impacts, especially sound and traffic. |
| Residential—multi-family homes | Better adapted to impact, but more persons affected. |
| Commercial/industrial | Potential encouragement for public and private renovation and development. |
| Undeveloped/open/recreational | No ecological damage due to BART, but elsewhere could be serious. |
| Distance to Nearest Homes | |
| Narrow right-of-way (adjoining homes) | Potentially serious train sound, vibration, visual exposure, and obstruction of view. |
| Wider right-of-way or across street from homes (50 to 100 feet) | Significantly smaller impacts of all types. |
| Adjoining Transportation (Lines) | |
| None | Most likely to experience adverse impacts, especially sound. |
| Low-use railroad, local street | Nearly as likely to have adverse impacts. |
| Busy railroad, arterial, freeway | Unlikely to have adverse impacts. |
| *SOCIAL AND SITUATIONAL CHARACTERISTICS* | |
| Age, sex, income, ethnicity | No apparent effect on perceptions of impact. |
| Use of BART | Regular BART users tend to be significantly less critical of BART's environmental impacts on their homes than occasional or non-users. |

## TABLE IV-5
## DETERMINANTS CONTRIBUTING TO ADVERSE ENVIRONMENTAL IMPACTS OF BART

| Impact Determinant Types | DETERMINANTS BY TYPICAL LOCATIONS | | |
|---|---|---|---|
| | Downtown Stations* | Outlying Stations | Surface Lines |
| *I. BART ATTRIBUTES* | | | |
| Facilities | | • Inadequate parking<br>• Aerial stations<br>• Trackway switches | • Aerial trackway<br>• Narrow right-of-way<br>• No landscaping |
| Operations | | • High patronage, most arriving by car<br>• Night service | • High train speed<br>• Frequent trains<br>• Long trains<br>• Night service |
| *II. ENVIRONMENTAL CHARACTERISTICS* | | • Residential area<br>• Inadequate street capacity or layout | • Residential area<br>• Backyards adjoining trackway<br>• Lightly used adjacent railroad or arterial, or no adjacent transportation right-of-way |
| *III. SOCIAL AND SITUATIONAL CHARACTERISTICS* | ............(no important determinants identified)............ | | |

* Subway lines and stations (downtown) were found to have no significant environmental impacts beyond construction.

## TABLE IV-6
## DETERMINANTS CONTRIBUTING TO REDUCTION OF BART'S ADVERSE ENVIRONMENTAL IMPACTS

| Impact Determinant Types | DETERMINANTS BY TYPICAL LOCATIONS | | |
|---|---|---|---|
| | Downtown Stations | Outlying Stations | Surface Lines |
| *I. BART ATTRIBUTES* | | | |
| Facilities | • Subway configuration (after construction)<br>• Street beautification programs<br>• Station plazas | • Siting near other large structures to blend visually<br>• Minimum use of street frontage (low visibility)<br>• Parking lot layout to minimize mixing of vehicles and pedestrians<br>• Landscaping to match neighborhood (especially preservation of large trees)<br>• Division of parking lot into smaller visual units | • Well-designed aerial structure, visually simple<br>• Frequent street and pedestrian crossings of at-grade tracks<br>• Linear parks<br>• Other landscaping |
| Operations | | • Bus feeder service emphasis | • Lower speed<br>• Less frequent trains |
| *II. ENVIRONMENTAL CHARACTERISTICS* | | • Shopping center or commercial area<br>• On edge of residential area rather than within | • Non-residential or busy multi-family area<br>• Nearest homes across street or farther from BART<br>• Beside or within heavily used railroad, arterial or freeway right-of-way |
| *III. SOCIAL AND SITUATIONAL CHARACTERISTICS* | ............(no important determinants identified)............ | | |

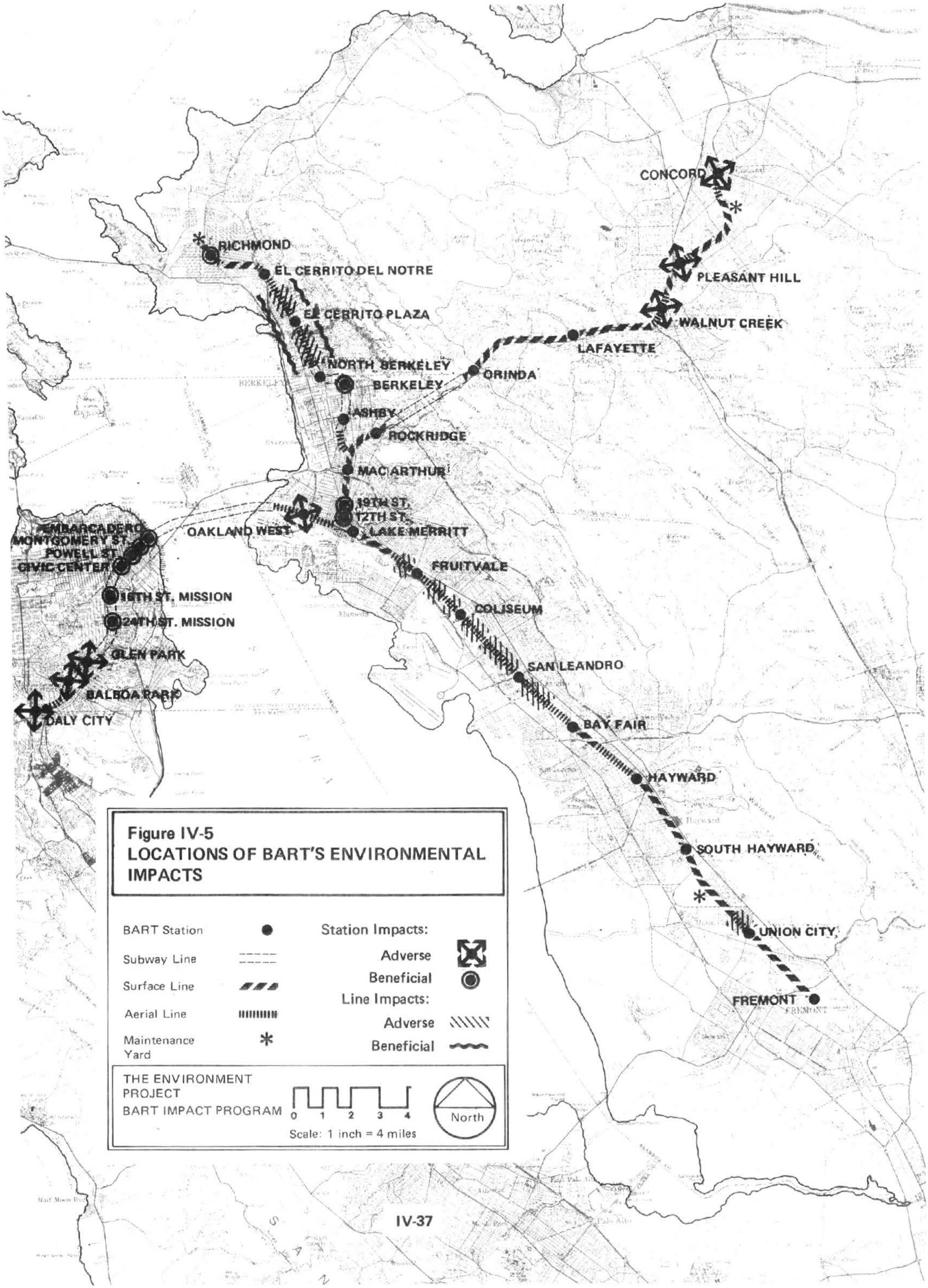


**Figure IV-5**
**LOCATIONS OF BART'S ENVIRONMENTAL IMPACTS**

## LOCATIONS OF IMPACTS

**BART has substantial adverse impacts around seven stations and along seven miles of trackway.**

The previous section listed BART's major causes of impact at stations as overflow parking and traffic congestion. At 12 BART stations the parking lots were found to be essentially filled to capacity all day in late 1976. At five of these there was evidence of a substantial overflow of parked cars onto the surrounding streets, resulting in an adverse impact. In addition, two stations in San Francisco (Balboa Park and Glen Park) which do not have BART parking lots have substantial overflow of parked cars. Thus, adverse impacts occurred at nine stations. BART-related traffic congestion or accident increases were found at one of these same stations (Daly City) and increased accident potential at others. The sizes of the areas affected vary but generally extend from one to three blocks from the station.

Sources of impact along lines were mainly increases in sound levels and disruption of views and privacy to nearby homes. BART train sound ($L_{eq}$) levels were found to be noticeably above ambient community sound levels along seven miles of aerial trackway in residential areas. Areas affected extended from one to two blocks on each side of the tracks. In about half of the same neighborhoods the extreme nearness of the aerial trackway to the backyards of residences creates significant adverse visual impacts and loss of privacy for those homes.

## POPULATION AFFECTED

**Impacts along BART's lines and at its stations could affect the homes of up to 13,000 persons, 35 percent of whom are ethnic minorities.**

In most instances BART's impacts extended less than four blocks (one-quarter mile, or 400 meters) from the station. In some of these cases many of the nearest residences avoided impact because of factors such as the nature of the street layout, traffic patterns, topography, and location of the station entrances. As a result, although approximately 12,500 persons live within four blocks of the BART stations with parking and traffic problems, a more realistic estimate of the number of persons whose homes were actually affected is about 8,000.

Along the trackway segments with adverse impacts, the abutting census blocks had populations totaling about 5,000 in 1970. Since these census blocks typically range from one to two conventional city blocks in size, this provides a reasonable estimate of the number of persons potentially affected. Added to those affected near BART stations this produces a total estimate of about 13,000 persons whose homes could be adversely affected.

Some 65,000 to 70,000 persons per day make trips by BART, and many more could use the system. About 50,000 persons live in census blocks which adjoin BART but have no major adverse environmental effects. The population of the three-county BART area is about 2,400,000; some 1,000,000 live within one mile of BART. Compared to such numbers the 13,000 that could be adversely affected by BART's environmental impacts is not a large population. However, in any absolute sense this is still many people.

This finding should be tempered by several other results of the study. First, the study's survey of residents exposed to BART's impacts included four sites affected by train sound along the aerial trackways. In these sites only about half (45 percent to 67 percent) of those within one block of BART actually reported that they found the sound objectionable. The same was true of persons living near stations who reported adverse effects of parking and traffic. Finally, even smaller minorities (from 22 percent to 32 percent) of those interviewed in these survey sites had negative reactions to BART's overall environmental impacts on their homes. This suggests that the number of persons who feel that they are adversely affected systemwide could be less than half the 13,000 estimate.

### Population Characteristics

Most indicators of this population's ethnicity, age structure and income are available only for census tracts. These are much larger in size than the areas actually affected by BART's environmental impacts and may not accurately reflect the characteristics of persons in the affected areas. However, by interpolating among the figures for adjacent tracts along the line and using census block-level figures where available, some general estimates are possible. These estimates, which are displayed in Table IV-7, indicate that BART's environmental impacts are borne primarily by non-minority persons.

### TABLE IV-7
### POPULATION AFFECTED BY BART'S ENVIRONMENTAL IMPACTS

| Location and Type of Impact | Total Population Affected | Percent Ethnic Minorities* |
|---|---|---|
| Stations (parking, traffic) | 8,000 | 45 percent |
| Aerial lines (sound, view, privacy) | 5,000 | 20 percent |
| TOTAL | 13,000 | 35 percent |

* Includes Black, Spanish, Filipino, Chinese and Japanese categories from 1970 census tract tapes, mapped by location within tracts by Jefferson Associates, Inc. Percentages are approximate.

# V. INDIRECT ENVIRONMENTAL IMPACTS

## INTRODUCTION

In this chapter, microscale changes in land use policy and land development within a quarter- to half-mile radius of BART stations are identified and their environmental impacts are discussed.[1] Building development (mostly private and commercial) is considered, as well as some of the city-sponsored street surface improvements done in conjunction with BART construction. The study does not address possible development changes on subregional (city and county) and regional (Bay Area) scales; these issues are now being studied by the Land Use and Urban Development Project as part of the BART Impact Program.

No attempt is made here to determine the degree to which land development changes are BART-induced. While the BART system clearly has contributed to changes in Bay Area activity patterns, it is only one factor among many which affect development. In short, development potential results from the timely interaction of certain regulatory, economic, market and political factors. It is generally agreed that most of the development near BART stations is a redistribution of development potential which probably would have occurred somewhere within the Bay Area had BART not existed.

The findings reported here must be viewed as interim findings because the full consequences of the system have not yet been experienced.[2] This is especially true of development changes resulting from complex public and private decisions made over a long period of time. In downtown San Francisco, forces beyond BART's influence are generating great change. In other areas, the development impetus has not yet materialized, and it remains to be seen if the right combination of factors will occur to cause change.

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1 For more complete discussions of these findings, see the following report: Gruen Associates, Inc., **Indirect Environmental Impacts**, Document No. DOT-BIP-TM 24-4-77, Berkeley: Metropolitan Transportation Commission, July 1977. Prepared as part of the documentation for the Environment Project.

2 Hypothetical extensive station-area development is discussed in Chapter VII, A Look Ahead: BART's Future Impacts.

## METHODOLOGY

Changes in land development near stations were identified by comparing 1965 and 1975 aerial photographs and through discussions with local planning officials. Public policy changes were identified through contact with local jurisdictions.

The 34 BART station areas were then screened for (1) the significance of development and/or policy changes, and (2) the degree to which a particular station represents a broader group of station areas. Other factors considered include: development scale and timing in relation to BART, direction of policy change (more or less restrictive), potential for environmental impact, and the possible attribution of changes to the presence of BART. The 12 stations selected for study after this screening were:

- **Downtown Berkeley, Downtown Oakland (Lake Merritt, 12th Street, 19th Street), Downtown San Francisco (Civic Center, Powell Street, Montgomery Street, Embarcadero), and Richmond:** fully developed areas which have experienced more intensive private or public (urban renewal) development before, during or after the development of BART.

- **Walnut Creek:** some development and/or significant policy change in an area which is not yet fully developed.

- **Fremont and Union City:** areas which were largely undeveloped prior to BART and which have experienced significant growth in the post-BART period.

In assessing the environmental impacts of the identified changes, the same categories were used as in the assessment of BART's direct impacts: acoustic, atmospheric, natural, social, and visual. Most of the information on impacts is from secondary data sources and interviews with locally knowledgeable persons. Where available, recent Environmental Impact Reports (EIRs) were used as sources of information.

The BART-related street improvement programs were chosen for study because:

(1) They are clearly examples of environmental enhancement stimulated by BART construction.

(2) They were financed with public funds.

(3) They represent differences in approach, functional concept, scope, expense, and degree of effectiveness.

Information about street improvement projects which enhance station site development quality was gathered primarily through site visits and interviews with city officials and project representatives. News clippings and project-related publications supplied additional information.

## DEVELOPMENT SETTING AND CHANGE

**Development changes around BART stations have occurred in only a limited number of areas (12 station sites). In most instances associated environmental impacts have been small in scale.**

The development status and land use patterns around station areas can be summarized as follows:[1]

- A large majority (27) of the 34 BART stations were located in fully developed areas, with the remaining seven in partially developed or largely undeveloped areas.

- A majority (19) of the stations were located in areas with a mixed land use pattern, generally combining residential and commercial-retail activities. A substantial minority (9) are in downtown commercial-retail areas, and the remaining sites are either predominantly residential (4) or vacant (2).

Since the decision to construct BART, changes in local land use and zoning policies have occurred at 26 of BART's stations (Table V-1). The number of sites with policy change which encourages increased density or a new type of development (e.g., a change from residential to commercial uses or a lifting of building height restrictions) is double those with new policies which discourage such change. Each of the policy change options—more restrictive, less restrictive, or none at all—is well represented among fully developed station areas. Partially developed and undeveloped areas most often adopted policy changes permitting more intense development.

### TABLE V-1
### BART STATION AREAS BY DEVELOPMENT STATUS AND POLICY CHANGE

| Development Status Adjacent to BART Stations | Number Of Stations By Type Of Policy Change | | | Total Number of Stations |
|---|---|---|---|---|
| | Less Restrictive | More Restrictive | No Change | |
| Fully developed | 13 | 8 | 6 | 27 |
| Partially developed | 5 | – | 2 | 7 |
| TOTAL NUMBER OF STATIONS | 18 | 8 | 8 | 34 |

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1 Development status and predominant land use patterns are essentially the same around all BART stations for both 1965 and 1975, the period for which development and policy change are evaluated.

As shown in Table V-2, instances of less restrictive policy change have affected BART station areas within each land use category. Areas with no policy change and those initiating more restrictive zoning are most often in commercial areas or in areas of mixed land uses.

### TABLE V-2
### BART STATION AREAS BY TYPE OF ADJACENT LAND USE PATTERNS AND POLICY CHANGE

| Land Use Type Adjacent to BART Stations | Number Of Stations By Type Of Policy Change | | | Total Number of Stations |
|---|---|---|---|---|
| | Less Restrictive | More Restrictive | No Change | |
| Residential | 2 | 1 | 1 | 4 |
| Commercial | 8 | 1 | — | 9 |
| Mixed | 6 | 6 | 7 | 19 |
| Vacant | 2 | — | — | 2 |
| TOTAL NUMBER OF STATIONS | 18 | 8 | 8 | 34 |

Actual development change has occurred at only 12 stations (Table V-3), most of which are in areas which were already fully developed. Consequently, most of the change has involved redevelopment as in the downtown areas of San Francisco, Oakland, Richmond, and Berkeley.

### TABLE V-3
### BART STATION AREAS BY DEVELOPMENT STATUS AND DEVELOPMENT CHANGE BETWEEN 1965 AND 1975

| Development Status Adjacent to BART Stations | Number Of Stations By Development Change | | Total Number of Stations |
|---|---|---|---|
| | Change | No Change | |
| Fully developed | 9 | 18 | 27 |
| Partially developed | 3 | 4 | 7 |
| TOTAL NUMBER OF STATIONS | 12 | 22 | 34 |

Not surprisingly, much of the development change occurs in commercial/retail land use areas (Table V-4) near downtown BART stations. There is some development change in areas of mixed land uses (Lake Merritt and Walnut Creek) and new development in areas which previously were largely vacant (Union City and Fremont).

**TABLE V-4**
**BART STATION AREAS BY TYPE OF ADJACENT LAND USE PATTERNS AND DEVELOPMENT CHANGE BETWEEN 1965 AND 1975**

| Land Use Type Adjacent to BART Stations | Number Of Stations By Development Change | | Total Number of Stations |
|---|---|---|---|
| | Change | No Change | |
| Residential | – | 4 | 4 |
| Commercial | 8 | 1 | 9 |
| Mixed | 2 | 17 | 19 |
| Vacant | 2 | – | 2 |
| TOTAL NUMBER OF STATIONS | 12 | 22 | 34 |

Actual development change has most often occurred where policies have been altered to induce development (Table V-5). No change in development occurred at a large majority of the sites with more restrictive zoning or no policy change.

**TABLE V-5**
**BART STATION AREAS BY TYPE OF POLICY CHANGE AND DEVELOPMENT CHANGE BETWEEN 1965 AND 1975**

| Type of Policy Change | Number Of Stations By Development Change | | Total Number of Stations |
|---|---|---|---|
| | Change | No Change | |
| Less restrictive | 9 | 7 | 16 |
| More restrictive | 1 | 7 | 8 |
| No change | 2 | 8 | 10 |
| TOTAL NUMBER OF STATIONS | 12 | 22 | 34 |

In summary, ten station areas have experienced both development change and policy change, two have had development change only, 14 have had policy change only, and eight have experienced neither. These changes, along with land use and development status, are shown in Table V-6.

Fully developed downtown commercial areas near BART stations have been sites of nearly all of the development change that has taken place around BART stations. These changes range from construction of two buildings near the downtown Berkeley station to intense high-rise development near the downtown San Francisco stations. In most instances this development was encouraged by new zoning and parking policies.

In urban areas fully developed for residential and mixed residential/commercial uses, no new development has occurred except near the Lake Merritt station (a mixed-use area near downtown Oakland), where development includes cultural and educational facilities as well as BART headquarters. In most of these areas, either no policy changes occurred, or more restrictive policies were adopted, although five of the 18 areas in this group did initiate less restrictive zoning policies.

Five of the seven suburban (i.e., partially developed or relatively undeveloped) station areas adopted less restrictive zoning, and the remaining two had no policy changes. All suburban BART sites are residential or mixed residential/commercial in land use character. Mixed-use development has occurred at three suburban sites; this includes one ten-story office building (Walnut Creek), shopping/cultural/community complexes (Union City and Fremont), and single-/multi-family housing. Each of these developing sites has designated areas near BART for intensive development.

The changes in policy and development around each BART station are shown in Figure V-1 and described briefly in Table V-7.

**TABLE V-6**
**STATION-AREA DEVELOPMENT STATUS AND CHANGE: 1965-1975**

| STATION | LAND USE* | | | | DEVEL-OPMENT STATUS* | | DEVEL-OPMENT CHANGE | POLICY CHANGE 1965-1975 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Resid. | Comm. | Mixed | Vacant | Full Devel. | Partial Devel. | 1965-1975 | Less Restrictive | More Restrictive | None |
| Concord | | | X | | X | | | X | | |
| Pleasant Hill | X | | | | | X | | X | | |
| Walnut Creek | | | X | | | X | X | X | | |
| Lafayette | | | X | | | X | | | | X |
| Orinda | | | X | | | X | | | | X |
| Rockridge | | | X | | X | | | | X | |
| Richmond | | X | | | X | | X | X | | |
| El Cerrito del Norte | | | X | | X | | | | | X |
| El Cerrito Plaza | | | X | | X | | | | X | |
| North Berkeley | X | | | | X | | | | X | |
| Berkeley | | X | | | X | | X | | X | |
| Ashby | | | X | | X | | | | | X |
| Fremont | | | | X | | X | X | X | | |
| Union City | | | | X | | X | X | X | | |
| South Hayward | X | | | | | X | | X | | |
| Hayward | | X | | | X | | | X | | |
| Bay Fair | | | X | | X | | | X | | |
| San Leandro | | | X | | X | | | X | | |
| Coliseum | | | X | | X | | | | X | |
| Fruitvale | | | X | | X | | | | | X |
| Lake Merritt | | | X | | X | | X | X | | |
| MacArthur | | | X | | X | | | | X | |
| 9th Street | | X | | | X | | X | X | | |
| 2th Street | | X | | | X | | X | X | | |
| Oakland West | | | X | | X | | | | X | |
| Daly City | X | | | | X | | | | | X |
| alboa | | | X | | X | | | | | X |
| Glen Park | | | X | | X | | | | | X |
| Mission-24th | | | X | | X | | | | X | |
| Mission-16th | | | X | | X | | | X | | |
| Civic Center | | X | | | X | | X | X | | |
| Powell | | X | | | X | | X | X | | |
| Montgomery | | X | | | X | | X | X | | |
| mbarcadero | | X | | | X | | X | X | | |

*Predominant land use patterns and development status are essentially the same for 1965 and 1975 around all of the BART stations.

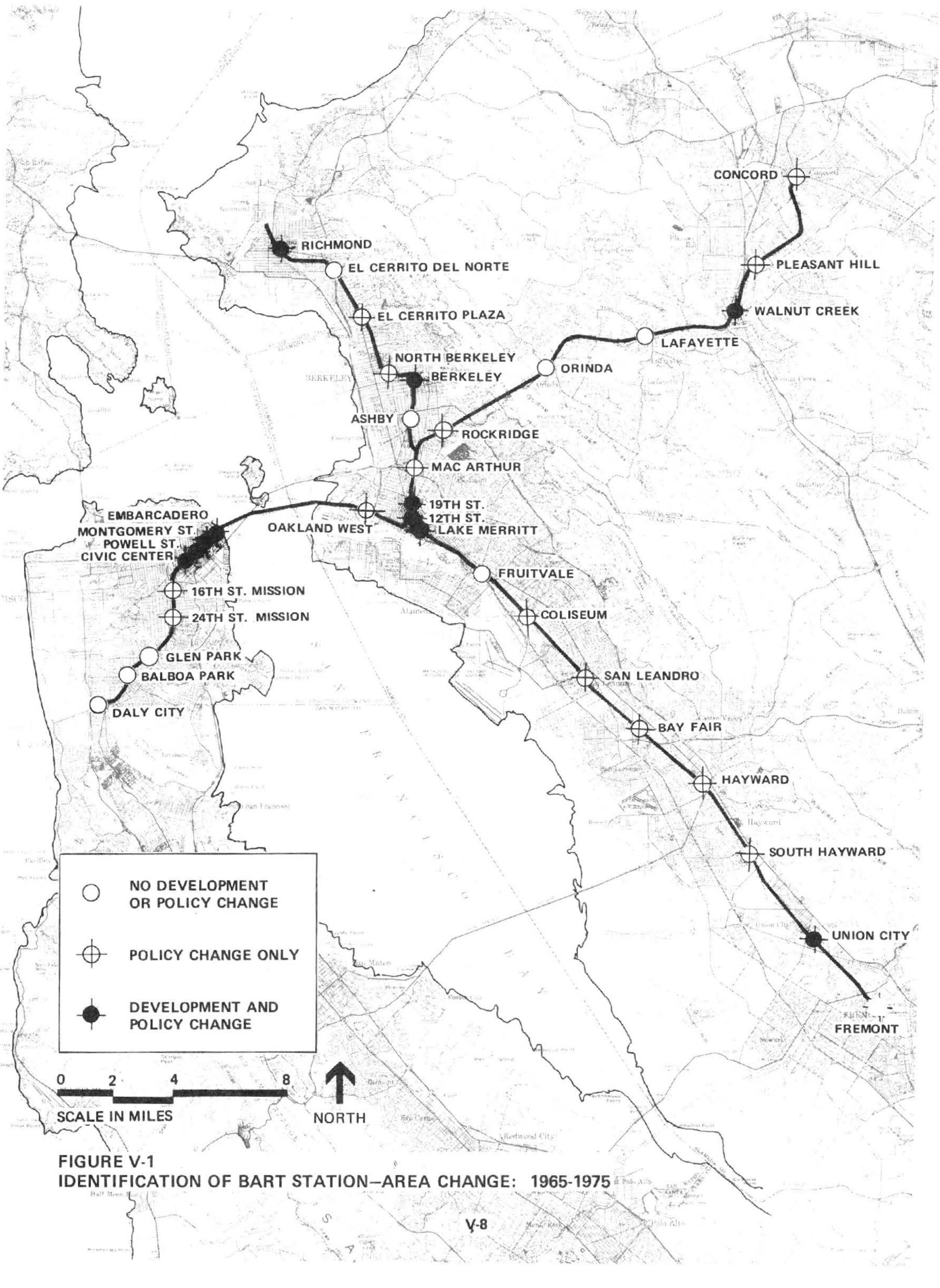


FIGURE V-1
IDENTIFICATION OF BART STATION–AREA CHANGE: 1965-1975

## TABLE V-7
## SUMMARY OF BART STATION-AREA POLICY CHANGE AND DEVELOPMENT CHANGE (1965-1975)

| Station | Policy Change | New Development |
|---|---|---|
| *RICHMOND LINE* | | |
| Richmond Station | Adjacent to 107-acre redevelopment project. | Government office (Social Security) and high-rise residential project built; proposed retail, medical center, transportation center, and additional housing. |
| El Cerrito del Norte | None. | None. |
| El Cerrito Plaza | Initial residential upzoning, but later downzoning. | Minimal. |
| North Berkeley | Zoning downgraded from apartments to duplex. | None. |
| Central Berkeley | More restrictive regulations (height, floor area ratio, parking). | One high-rise office building and a one-story bank. |
| South Berkeley (Ashby) | None. | None. |
| *CONCORD LINE* | | |
| Concord Station | 1972 Central Area Plan; area around station planned for high-density residential and office from single-family residential uses. | None. |
| Pleasant Hill | 1976 General Plan; area around station planned for office and multi-family from single-family residential uses. | None. |
| Walnut Creek | 1976 Core Area Plan; from single-family residential area around station to planned mixed office/retail/multi-density residential uses. | One ten-story office building across street from station. |
| Lafayette | None. | None. |
| Orinda | None. | None. |

## TABLE V-7 (continued)
## SUMMARY OF BART STATION-AREA POLICY CHANGE AND DEVELOPMENT CHANGE (1965-1975)

| Station | Policy Change | New Development |
|---|---|---|
| *FREMONT LINE* | | |
| Fremont | Late 1960s adopted Central Area Plan; CBD south of station; high-density residential north of station. | Regional shopping center, hospital, retail. |
| Union City | Area designated CBD. | Park and community center complex; community shopping center. |
| South Hayward | Zoned for commercial and high-density residential. | Minimal. |
| Hayward | 1973 zoned to Central City District; office, retail, residential. | None. |
| Bay Fair | 1966 Rapid Transit Zone created; residential density of 30-45 dwelling units per acre. | Minimal. |
| San Leandro | 1966 Rapid Transit Zone created around station; residential density of 30-45 dwelling units per acre. | None. |
| *OAKLAND* | | |
| Coliseum | Zoning changed from industrial to residential to conform with existing single-family use. | None. |
| Fruitvale | None. | None. |
| Lake Merritt | High-density residential zoning. | Laney College, City Museum, BART headquarters, park. |
| Rockridge | In 1974, College Avenue downzoned to less intensive commercial; residential area downzoned. | None. |
| MacArthur | Area immediately next to BART left as multi-residential; surrounding area downzoned to single-family to correspond with actual uses. | None. |

## TABLE V-7 (continued)
## SUMMARY OF BART STATION-AREA POLICY CHANGE AND DEVELOPMENT CHANGE (1965-1975)

| Station | Policy Change | New Development |
|---|---|---|
| *OAKLAND (continued)* | | |
| 19th Street | Part of 1966 Central District Plan for intensified commercial uses. | Several banks, telephone building, and Blue Cross office building. |
| 12th Street | Part of redevelopment area; part of 1966 Central District Plan. | City Center Project (office and retail); housing rehabilitation. |
| Oakland West | Rezoned to coincide with use, in some cases industrial to residential. | Regional U. S. Postal Service Center (planned before BART). |
| *DALY CITY LINE* | | |
| Daly City | None. | None. |
| Balboa Park | None. | None. |
| Glen Park | None. | None. |
| 24th Street | Zoning change from commercial to residential. | None (more vacancies). |
| 16th Street | Height limits increased and more restrictive parking structure policy. | None (more vacancies). |
| *DOWNTOWN SAN FRANCISCO (FOUR STATIONS)* | | |
| - Civic Center<br>- Powell<br>- Montgomery<br>- Embarcadero | More restrictive policies regarding provision of parking space and less restrictive policies regarding height limits. | Average growth rate of office space has been 1.3 million square feet annually since 1960. |

### Comparison with Other Transit Systems

Studies of land development impacts of recent transit improvements indicate that such impacts depend heavily on the presence of other factors in addition to transit system access.[1] In Toronto, for example, such factors included powerful zoning incentives, a major regional surge in demand for apartments and offices, and a tradition of in-town, transit-oriented living. Together these induced substantial high-rise development at some stations. On Philadelphia's Lindenwold Line, residential property values have been increased, but community preferences for a low-density environment have effectively limited development. Aside from some minor office development at one or two stations and one very large shopping and apartment complex, very little actual land use changes have occurred. In the case of the one large development, Echelon Mall, the key factor was the availability of a single large tract of land not near another regional shopping center; this was unique in the region.

Other new transit systems or extensions in Chicago, Cleveland and Boston have had effects smaller than those in Toronto and Philadelphia, all highly dependent on the existence or absence of powerful development-inducing forces in addition to the transit system. In many suburban areas, for example, stations have been located in other rail or freeway rights-of-way to ease land costs and direct environmental impacts, with the result that the station sites have not been attractive for development. In other cases strong counterforces in local policy, overall access of the site, difficult land assembly and lack of regional demand have been effective curbs on development. Many of these same constraints are found at BART stations outside the San Francisco central business district. Hence, the lack of new development around most of these BART stations is not surprising.

As in San Francisco, major new downtown development has occurred in Toronto and Montreal. In both cases most observers agree that the influence of the new transit system on such CBD growth was important, but other factors such as the availability of development capital, regional demand for new facilities, an already attractive and healthy downtown, and public policy encouragements were also powerful. These same factors have been visible in downtown San Francisco's recent surge of development.

The experiences of other cities thus support the results of this study's survey of land development around BART stations. With such generally small changes, it follows that environmental impacts are likely to be quite small. The next section considers the development to date around 12 BART case-study station sites in detail and estimates the present "indirect" environmental impacts of the transit system.

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1 R. L. Knight and L. L. Trygg, **Land Use Impacts of Rapid Transit: Implications of Recent Experience,** DOT-OS-60181, U. S. Department of Transportation, Washington, D. C., 1977.

## San Francisco

Downtown San Francisco has experienced the most dramatic change of any area along the BART system. From 1960 to 1975, major office space increased by nearly 21 million gross square feet through construction of 39 new buildings 10 to 52 stories in height. New buildings are generally taller and bulkier than those constructed before 1960 (Plate V-1). They are concentrated in an area of about one square mile near the Embarcadero and Montgomery BART stations.

There has been a corresponding increase in downtown office workers from 115,000 in 1960 to 192,000 in 1975. At current occupancy rates, additional buildings are expected to increase the total to 218,000 workers by 1980.

New CBD office workers since 1960 bring an estimated 12,000 additional automobiles to the area. Fifteen thousand off-street parking spaces were added to the downtown inventory between 1965 and 1975. San Francisco's municipal railway (Muni) service has not yet changed significantly, although major changes are being planned.[1]

Two direct links between BART and the new downtown development are the building bonus provisions in San Francisco's zoning ordinance and the policy of financial credits for redevelopment projects based on proximity to BART. Under the building bonus provisions, a developer can increase a project's floor area ratio (FAR) by having a direct entranceway to a BART station; a lesser bonus is offered for simply building near a BART station. Financial credit potential exists in downtown San Francisco at the Yerba Buena redevelopment project.[2] The prohibition of on-site parking has also acted as a development incentive in downtown San Francisco. The new development has most strongly affected the site-specific climate of the downtown area and the visual environment. Smaller effects on sound levels, air quality, energy demands, and safety/security have occurred. Each of these subjects, as well as natural geologic hazards, is considered below:

- **Meteorology (Climate).** An increase in street-level wind force results from a downward deflection of upper winds by the tall buildings. Winds are further intensified at building corners and within arcades. Besides being a hindrance to pedestrians, the winds cause a lower air temperature.

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1 As part of BART construction beneath Market Street, Muni's streetcar lines will be taken off the surface of Market Street and placed in the same subway using the same concourses and station entrances, but operating on separate tracks located above BART's tracks. Muni lines will serve the same areas as before. The changeover will not take place until 1979.

2 The City is eligible for crediting part of its local share of redevelopment monies against the cost of the building of the BART stations along Market Street.

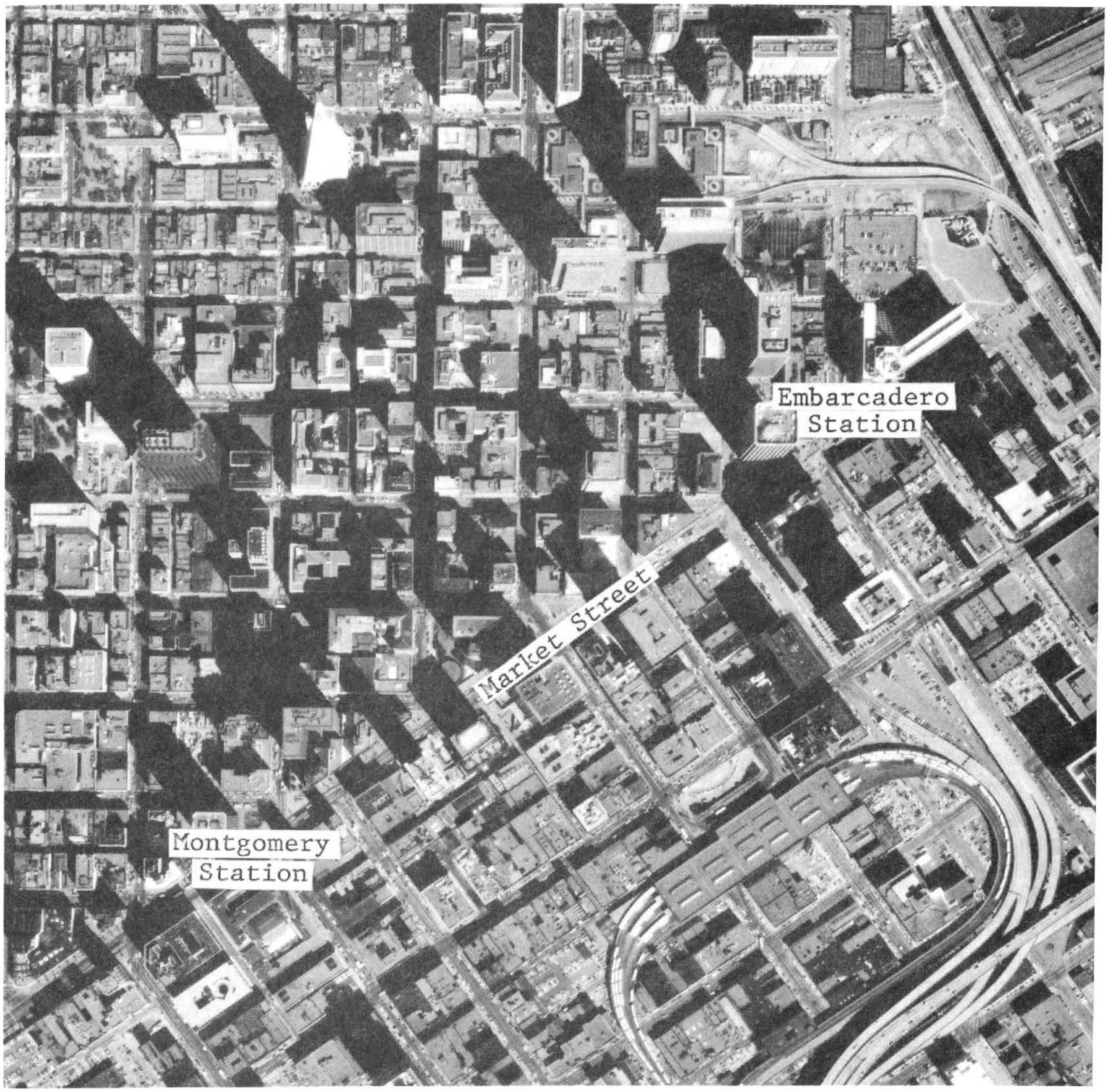


PLATE V-1
DOWNTOWN SAN FRANCISCO, 1975

- **Visual Effects.** The new buildings have both created and obstructed the views of occupants. The pedestrian's sense of spaciousness is constricted by the tall buildings, and the shadows cast by the buildings reduce the amount of sunlight reaching street level. The new buildings are concentrated in one area, and they are generally well designed and neutral in color. They do, however, overwhelm the small buildings in the area. The city's skyline as seen from a distance has been given a dramatic appearance by the new development.

- **Acoustics.** Downtown San Francisco experienced high levels of construction noise associated with demolition, excavation, heavy truck traffic, and riveting. Data for comparison of non-construction street noise levels over the period discussed are very limited. Any noise increase caused by added vehicular traffic is almost certainly offset by the recent production of quieter automobiles, although sound may be perceived to be louder near new buildings because of a "canyon effect" reverberation.

- **Air Quality.** Overall, carbon monoxide levels have steadily diminished in downtown San Francisco despite some increase in vehicular activity. The main reason for this trend, which is expected to continue through the mid-1980s, is implementation of stringent automotive exhaust controls. On a site-specific level, pollutants are sometimes trapped between buildings at ground level (due to the canyon effect) when the air is relatively still; when winds are blowing, however, this effect is countered by increased street-level winds.

- **Energy (Water, Gas, Electricity).** New development has substantially increased downtown demands for water, gas, and electricity. This is largely a transfer of demand rather than an absolute increase in Bay Area resource requirements. New downtown office buildings (1960-1975) account for 10 to 18 percent of San Francisco's total electricity consumption, 1 to 2 percent of its total water consumption, and less than 1 percent of its gas consumption.

- **Safety and Security.** Crime and security problems in the downtown area have increased over time, but not disproportionately in relation to increased crime levels throughout the city. Pedestrian and vehicular traffic safety has not changed noticeably in recent years.

- **Geologic Hazards.** The downtown development is largely built in an artificial fill area which is subject to strong earth movement in the event of an earthquake along the nearby San Andreas or Hayward faults. However, most new buildings have been designed to minimize potential damage from earthquakes. Some of the area is also subject to subsidence and liquefaction.

## Oakland

Within a few blocks of Oakland's 19th Street station, development since 1965 has included several office and bank buildings. Near the 12th Street station the primary development activity has been the City Center project, a 15-block, $150-million redevelopment project (now partially complete) combining public and private financing and providing office and shopping facilities. BART was instrumental in the City Center project, since the cost of the BART station at 12th Street was allowed in fulfillment of the City's required share of the project funding. HUD provided the remainder, with the result that the City accomplished the project without a major commitment of its own funds. Development since 1965 in the Lake Merritt station area includes the Oakland Art Museum, Laney College, and BART headquarters (Plate V-2). Laney College was built on land acquired partially with local funds and matching federal monies based on financial credit associated with the construction costs of the Lake Merritt station.


PLATE V-2
LAKE MERRITT STATION AREA

The environmental impacts of this new downtown Oakland development are small near the 19th Street and Lake Merritt stations. The City Center project near the 12th Street station, while providing significant economic benefits to the area, has had notable social and traffic-related impacts, and planned redevelopment projects (Chinatown, Victorian Row/Old Oakland and the Convention Center) will add to the area's impacts. Past and projected effects near BART's 12th Street station include the following:

- Displacement and relocation activities resulted in the displacement of 568 dwelling units.

- When complete, the project will attract 20,000 automobiles daily. If the proposed Grove-Shafter Freeway link to Highway 17 is completed, 58 percent of the automobile traffic would have direct access to the project's parking structures.

- The net effect of increased automobile traffic will be (1) potential for localized adverse air quality impacts along 14th Street and the plazas, and (2) a 5 dBA (perceptible) noise increase during evening hours.

**Berkeley**

New development near the downtown Berkeley BART station consists of one 14-story office building with an adjacent 400-car garage, a one-story bank building, and many new businesses in old buildings. Vehicular volumes near the station have increased slightly. Recent development regulations (in part a result of the recent development) restrict downtown parking provisions, building height (100 feet), and floor area ratio (FAR = 4). Associated impacts are at a low level.

**Richmond**

The Richmond BART station is adjacent to a 107-acre urban renewal project which encompasses downtown Richmond. New development projects in this area have received federal funding based on financial credits for proximity to the BART station. Recent development in the area includes a large Social Security Administration building (now employing approximately 2,000 persons), a high-rise residential project, and office/retail facilities. Planned projects include Kaiser medical facilities, an Amtrak cross-platform transfer station adjacent to BART (the beginning of a proposed multimode transportation center), and additional housing and commercial development. When complete, the urban renewal project will provide approximately 845 new dwelling units and 3,600 additional jobs.

It is estimated that an additional 700 automobiles daily enter and leave the area as a result of the new Social Security center. Parking problems are being encountered because more employees than anticipated are driving to work.

No significant adverse effects on the atmospheric, acoustic or natural environment are anticipated as a result of the urban renewal project. Significant positive impacts on the social environment are anticipated as a result of the new employment opportunities.

**PLATE V-3
SOCIAL SECURITY
BUILDING AND
PEDESTRIAN MALL
FROM RICHMOND
BART STATION**

**Walnut Creek**

Observed changes near the BART station in Walnut Creek since 1965 include a 10-story office building, commercial/manufacturing development, and multi-family housing. The development itself has caused no notable environmental impacts, but rapid growth in the city's population over the past 16 years and location near the interchange of a major freeway have resulted in traffic congestion near the BART station.

The Walnut Creek BART station is within the city's core area, an area which is not currently intensively developed despite its role as the central business district for nearly 80,000 people. A Core Area Plan was adopted which, if implemented, would add 2.5 million square feet of office and retail development and more than 1,000 apartment units.

The possible key impacts associated with the Core Area Plan are the following:

- Traffic congestion of certain intersections will worsen despite planned street improvements.

- Periodic violation of carbon monoxide standards can be expected within the core area due to traffic congestion on local streets and on freeways.

- Adverse noise impacts will result from increased traffic and from the location of residential uses in areas having excessive noise levels (unless new housing construction meets noise standards).

- Socioeconomic impacts include: (1) loss of 90 single-family homes, (2) gain of 1,035 apartment housing units, and (3) new employment totaling 7,500 office workers, 2,400 retail workers, and additional jobs related to hospitals and automobile sales.

- Although certain key view corridors are recommended for protection, other views will likely be lost as the downtown develops more intensively.

**Union City**

Union City is a fast-growing city whose population increased 90 percent to 27,800 between 1970 and 1975, but the area surrounding the BART station is still largely undeveloped. Development since 1965 includes a park and community center complex and a shopping center, as well as single-family housing. Environmental impacts of this sparse development are minimal. However, the area has been designated as the central business district and is slated for commercial and higher-density residential uses while retaining the current industrial uses. This will probably lead to impacts similar to those in Walnut Creek and Fremont.

**Fremont**

Development in the area surrounding the Fremont BART station includes a regional shopping center, a civic center complex, hospital expansion, and single-family housing. The major policy change in this area is the Central Area Plan, which was adopted in 1969.

The BART Area Plan covers a 600-acre area easterly of the Fremont BART station and is part of the Central Area Plan. Key environmental impacts likely to be associated with the BART Area Plan are the following:

- Population would increase from 15,600 to 20,000.

- High-density development could lead to traffic congestion on key streets.

- No significant impacts on air quality are anticipated; however, microclimate impacts in the form of changed wind velocities could occur with the proposed medium- and high-density development.

- Noise and vibration impacts are anticipated only during the construction phase.

- No disruption of natural areas or significant wildlife habitats is anticipated.

- Potential visual changes may occur related to the proposed high-density uses near the BART station.

## DEVELOPMENT QUALITY

**The public street improvements accomplished in conjunction with BART construction are varied in scope, cost, and degree of success.**

Publicly funded landscape and surface street improvements were made at several station sites to accommodate the new pedestrian and vehicular patterns engendered by BART and to renew deteriorating areas. While BART construction was the primary impetus for the improvements, their fruition was made possible by strong leadership and financial commitments from the local jurisdictions and business communities.

The BART-associated public improvements discussed here include projects along Market and Mission Streets in San Francisco, along Shattuck Avenue in Berkeley, and along Nevin Avenue in Richmond.

### Market Street

The Market Street project cost $34.5 million and involved extensive change along two miles of the street (between the Ferry Building and the Central Freeway Overpass). Sidewalks were widened and resurfaced with brick, a double row of sycamore trees was planted, and street furniture of bronze/granite/glass was installed. Major plazas were built at the Embarcadero, Powell Street, and the Civic Center stations; there are also smaller public and private plazas along the street. Funds for the project were obtained mainly by local bond issue ($24.5 million) and through the U. S. Department of Housing and Urban Development.

PLATE V-4
HALLIDIE PLAZA, BART STATION AT POWELL AND MARKET STREETS

Major streetwork and resulting disruption of Market Street lasted for ten years (including BART construction), causing business casualties and inconvenience to citizens. Delays in the project were caused by public controversy, funding delays, lawsuits, and long periods of negotiations with the Market Street business community.

In addition to the streetscape improvement programs, the city has attempted to curb urban blight and control the appearance and activities of Market Street. Actions taken have included license bans affecting pinball and peepshow operations, enforcement of noise ordinances, sign restrictions and health codes, arrests (and ultimate licensing) of street artists, and informal talks with special interest groups. Project follow-up continues to encourage further improvement and to promote solutions to the persisting problems of nuisance, litter control, and cleaning.

The Market Street design is effective and well executed. It integrates BART and Muni with the street, provides well for street activity, and creates a pleasant pedestrian-oriented environment. The improvements are generally well received and well used. Pedestrian traffic has increased greatly, and business along the street has improved.

**Mission Street**

The BART subway stations on Mission Street open into plazas at 16th and 24th Streets. Each plaza consists of two small areas located on diagonally opposite corners of the intersection. The central element of each area is a large BART station opening. While the plazas function well for BART purposes and provide some space for community functions, interface with the community could have been improved through design consideration of the community's ceremonial and open space needs.

Sidewalks for the first block on each side of the BART stations were widened, trees were planted, and furniture was installed. Funds for the project ($500,000) came from the Market Street beautification bond issue. Although initially attractive, the sidewalk improvements are not well maintained (litter accumulates and trees are not well cared for), street furnishings crowd the narrow sidewalk, and furniture has been broken without repair. Negotiations are underway between community representatives and the city for more effective maintenance and policing of the area. (The plazas in particular have reportedly attracted undesirable loiterers.) No new development or redevelopment has taken place along Mission Street.

**Shattuck Avenue, Berkeley**

Street improvements along Shattuck Avenue near the downtown Berkeley BART station include a block-long plaza and 12 blocks of widened sidewalks with landscaped pedestrian areas along a reengineered street. The funds for the project (estimated to have cost $100,000 per block) came from BART compensation funds (for city facilities displaced during station construction), and the rest of the funding came mainly from gax taxes.

The brick plaza is the site of the main BART station entrance, a circular structure enclosing escalators to the station concourse. The plaza is separated into circulation areas and a quieter central seating area; the circulation space is often crowded and inadequate for its activity level, while the seating area is little used when the weather is cool.

**PLATE V-5**
**BART STATION-AREA PLAZA, SHATTUCK AVENUE, BERKELEY**

Shattuck Avenue was reengineered to provide left-turn lanes for vehicular traffic and to separate head-on parking areas from traffic flow. The sidewalk area is enlarged at the ends of blocks, forming "bulbs" where landscaped bus stops and plantings are located. A parklike area facing the public library features a black granite fountain which replaces a fountain displaced during BART construction.

The accumulation of litter in the plaza and along Shattuck Avenue is an ongoing problem. Litter receptacles are inadequate in high-traffic areas, and their tops and liners are often broken. The improved area might benefit from extension of the pedestrian area along the BART station's east-west axis (Center Street) to join the city's Civic Center and the U. C. campus with the street improvements.

**Nevin Mall, Richmond**

Nevin Mall is a three-phase pedestrian thoroughfare which joins the BART station and the downtown redevelopment project in Richmond. The mall was created by closing off six blocks of Nevin Avenue in a designated redevelopment area; its cost of about $300,000 was paid by urban renewal funds. The mall intersects with the BART mezzanine below grade. Near the station it is a wide landscaped walkway; when it reaches grade it becomes a park; and in a third phase it is a citylike plaza.

Nevin Mall provides variety and pleasant surroundings for BART patrons and guides them to the developing downtown area in Richmond. Because development in the new downtown is not yet extensive, the new mall is not highly used. It remains clean, and there is no accumulation of litter. There have been no victim-oriented crimes and little vandalism.

**Development Quality: Conclusions**

Of the four projects studied, the improvements made on Market Street (San Francisco) and those on Nevin Avenue (Richmond) appear to be the most successful in enhancing the environment and attracting high-quality development. In each of these projects, focuses were established, realistic provision for area activity was made, and elements were designed for permanence. The improvements on Shattuck Avenue (Berkeley) and Mission Street (San Francisco) seem to lack focus, and they are not entirely responsive to community needs. All of the projects, however, bring visual emphasis to the BART stations encompassed and make the street settings into more pleasant pedestrian environments. The benefits and problems of each project will be seen more easily over time.

# VI. THE BART TRAVEL EXPERIENCE

## INTRODUCTION

The Environment Project's major concern has been with BART's effects on its external environment—the changes to settings of system facilities and their effects on residents and others who spend time in those settings. But from the standpoint of the BART traveler BART itself is an environment.

As travelers move through the BART environment, they meet with a variety of conditions and stimuli: heat, light, sound, movement, instructions, and other travelers. These variables affect the traveler's comfort, enjoyment, safety, orientation and satisfaction, and some are significant in the traveler's decision to use or avoid the system. This chapter considers these and other aspects of the BART patron's travel experience and discusses related lessons for designers of future transit systems.[1]

## GENERAL ASSESSMENT

**In most respects, BART is a pleasure for the traveler to use, although it continues to have reliability problems and is complicated for new or disabled riders to use.**

Within cost constraints, the highest possible levels of traveler protection and satisfaction are desirable goals in the design and operation of rapid transit facilities. BART was designed with these goals in mind, and the system is generally a pleasing and effective environment for patrons. Moreover, BART continues to improve its facilities and operations.

When compared to virtually every other transit system in the world, the BART environment stands out in many respects. In particular, the visual interest of the stations and trains, the systems's security and travel comfort are far superior to those of most other rapid transit or commuter rail systems. BART is also relatively fast and inexpensive, particularly for long commute trips. It is likely that these characteristics are major factors in attracting patrons. In addition, BART is accessible (although sometimes inconvenient) to handicapped persons and has facilities and programs to encourage bicycle access among patrons.

On the other hand, service and equipment reliability has been a problem. Equipment failures are more frequent than expected, although BART is working to improve the situation. Further, the limited station amenities and non-travel services (e.g., seating, restrooms) are sometimes inadequate, especially when crowds accumulate due to train delays.

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1 For more complete discussions of these findings see the following report: De Leuw, Cather & Company, **Environmental Impacts of BART: The User's Experience,** Document No. DOT-BIP-TM 23-4-77. Berkeley: Metropolitan Transportation Commission, July 1977. Prepared as part of the documentation for the Environment Project.

## STUDY APPROACH

After extensive review of related research literature and discussions with professionals experienced with BART or engaged in similar research, eight general qualities important to transit system users (e.g., convenience, comfort, reliability) were selected as a framework for the study. These categories were used as a convenient means to identify and group the many specific components of the BART environment (e.g., BART train noise) which affect the traveler.

Six methods were utilized in studying the BART environment. Given the qualitative nature of many factors studied, several methods and judgments were applied wherever possible to develop and verify evaluations of each factor. The major methods of study were as follows:

- Direct observation and technical evaluation of the system.
- Investigations of records, documents, and historical data.
- Informal interviews with BART personnel and other authorities.
- Review of the Environment Project's impact findings.
- Measurement using instruments.
- Interview surveys with patrons and station agents.

Instruments were used to measure sound levels. A series of sound level recordings was made in nine representative BART stations and on board seven BART cars during two complete end-to-end traverses of the system. Estimates of sound levels were then made for the entire system. Air quality was evaluated with respect to potential violation of accepted standards using regional air quality monitoring data already available.

A survey was conducted to verify professional evaluations and to gain perspective on the importance of each factor to the BART user. In-depth interviews were administered to some 60 BART riders and 15 station agents throughout the system. This group included a cross section of views; respondents were randomly selected at different stations but screened to insure inclusion of peak-period and midday users, young and old, male and female, ethnic minorities, and physically handicapped persons. Its purpose was to gain the perspective of a variety of user types, and it was not used as a basis for detailed statistical tests.

## ORGANIZATION

This chapter describes the factors influencing the traveler's experience in sequential order the way a typical BART traveler would encounter them. The first section explains how a traveler locates and arrives at a station. The next sections consider the traveler's experience in the station concourse, on the platform, aboard the train, and after the train trip. The last sections reflect the experience of special users: handicapped patrons and bicyclists.

## GETTING TO BART

**BART has inadequate parking at many of its stations and also lacks adequate feeder bus service in suburban areas.**

Finding a BART station and planning a trip are relatively easy because many information aids are available to potential users. The ease of getting to the station varies by location and with the mode of access used. Currently, 47 percent of BART's patrons arrive by automobile, 20 percent by bus, and 31 percent by walking.

### Information Aids

Foldout brochures entitled "All About BART" and "BART and Buses" are readily available and frequently used in determining BART station location, parking lot availability, and feeder bus routing. Telephone answering services are provided by BART and the feeder bus systems to transmit route, schedule and fare information to the potential user.[1]

Other sources of general BART access information include local AAA or gas station maps, telephone books, tourist guidebooks, hotel/department store displays, station attendants, and word of mouth. BART routes and station locations are shown on most common street maps of the Bay Area.

### Access to BART

As shown in Table VI-1, most suburban station patrons arrive by automobile during the rush period. In downtown areas, buses are the dominant mode of access. During afternoon and evening hours in suburban areas, automobile access drops while the percentage of walkers rises significantly.

Ease of automobile access to BART varies with station locality and type. Freeway exit signs direct automobile drivers toward the nearest BART station, but the absence of directional signs on arterial streets is troublesome to some BART users. Once in sight, the structure of the above-ground BART station contrasts markedly with surrounding architecture, making it easy for patrons to identify. Because subway station signing is not prominent and entrance design varies, it may be more difficult for first-time users to locate subway stations in high-density central urban locations.

Commuters driving to BART sometimes encounter traffic congestion at peak hours on streets near suburban BART stations. Some confusion and traffic congestion may also be encountered at automobile entrances and with parking lots due to unclear signing and circulation patterns.

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1 The Bay Area is served by several independent public transit authorities, making information coordination an important concern. The major transit authorities connecting with BART include the Muni (San Francisco), AC Transit (East Bay), SAMTRANS (San Mateo County), and the Santa Clara County Transit District (SCCTD).

## TABLE VI-1
## ACCESS TO BART STATIONS BY LOCATION AND TIME OF DAY

| Mode of Access to BART Stations | Full System | Downtown Stations* | | All Other Stations | |
|---|---|---|---|---|---|
| | All Times | AM Peak | Other | AM Peak | Other |
| Automobile | 47 | 16 | 14 | 67 | 50 |
| Bus | 20 | 50 | 25 | 15 | 20 |
| Walk | 31 | 33 | 60 | 17 | 27 |
| Other | 2 | 1 | 1 | 1 | 2 |
| | 100% | 100% | 100% | 100% | 100% |

* San Francisco Civic Center (Powell, Montgomery, Embarcadero), Oakland (12th Street and 19th Street), Berkeley (downtown).

Source: **1976 BART Passenger Profile,** BART District and Metropolitan Transportation Commission.

At 12 of the 23 BART stations with parking lots, the lots are completely filled all day. At five of these, the demand for automobile parking exceeds available spaces by at least 100 automobiles. The parking overflow ranges from about 100 to 625 automobiles per day and tends to be most severe at terminal stations which draw patrons from largely outlying areas. At two other stations (Glen Park and Balboa Park in San Francisco), no lots were provided because of the City's policy of encouraging use of buses. However, estimates of on-street parking at each of these stations range as high as 700 cars.

**PLATE VI-1**
**PARKING LOT CONGESTION, PLEASANT HILL**


PLATE VI-2
SUBURBAN STATION
ENTRANCE, SOUTH HAYWARD

PLATE VI-3
DOWNTOWN STATION
ENTRANCE, OAKLAND

When it is available, access to BART stations by bus is generally easier than access by automobile. There is feeder bus service to every BART station, although it varies widely in frequency and coverage. In the East Bay, AC Transit's bus stop signs and panel lights on the fronts of buses indicate routes passing BART stations with the words "To BART." This appears to increase rider confidence in the feeder bus services and reduce the need to ask bus drivers for directions. Similar aids are not available in San Francisco, which is served by the City's Muni system and in the areas served by SAMTRANS and SCCTD. In most station areas buses unload patrons directly outside station entrances, in many cases where overhangs provide weather protection.

With the exception of Market Street in San Francisco,[1] signs at street intersections near most stations direct persons walking to BART.

### Plaza and Parking Lot Crime

Security is usually not a concern to patrons as they leave their cars or buses at the stations. Crime rates in BART parking lots and plaza areas continue to be very low, even though BART now operates late into the evening (Table VI-2). During early 1976, crimes and other police-related incidents were reported to occur in BART parking lots and plaza areas at the rate of six per day, or about once for every 10,700 patrons. Here, as elsewhere on BART, most such incidents were either victimless crimes (e.g., fare evasion) or not crimes at all. Crimes against individuals in BART parking lots, plazas, stations and trains were found to be very rare—only about three percent of the reported police incidents. At this rate, the typical daily patron would be a crime victim only once in 340 years!

Automobile-related crimes, including car break-ins and thefts, are much more frequent and have been increasing since BART operations began. As of spring 1976, about 14,700 automobiles per day were parked in lots, with an average of about 4.4 incidents per day systemwide. This is one incident per 3,300 cars each day, or one per week, in the typical BART parking lot.

Several factors may be helping to hold crime rates down. Most parking lots are flat and visible from adjacent streets; landscaping usually does not interfere with visibility, and lots are well lighted in the evening. On the other hand, most lots cannot be seen by the station agent, and police patrols are infrequent, about once a day.

## INSIDE THE STATION

**BART station interiors are visually striking, safe, and function well, with minor problems only in orientation and use of the automated ticketing procedure by new patrons and a shortage of concessions and other non-travel conveniences.**

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1 Joint BART/Muni Metro signs will be placed at these station entrances when the Muni streetcar subway line paralleling BART is opened in 1979.

**TABLE VI-2**
**TYPE, LOCATION AND NUMBER OF BART POLICE REPORTS**
**(DURING THREE MONTHS FROM FEBRUARY THROUGH APRIL 1976)[a]**

| Type of Police Report | Number of Incidents by Location | | | | |
|---|---|---|---|---|---|
| | Train | Station | Parking Lot[b] | Other[d] | TOTAL |
| *PERSON CRIMES* | | | | | |
| Assault/battery | 1 | 6 | 3 | 3 | 13 |
| Strong-arm robbery | 0 | 3 | 5 | 1 | 9 |
| Purse snatching/pocket picking | 1 | 3 | 2 | 0 | 6 |
| Other grand theft | 0 | 0 | 4 | 4 | 8 |
| Indecent exposure | 2 | 4 | 4 | 3 | 13 |
| *PROPERTY CRIMES* | | | | | |
| Petty theft | 1 | 15 | 73 | 21 | 110 |
| Vandalism | 10 | 10 | 30 | 15 | 65 |
| Auto theft and burglary | 0 | 1 | 160 | 11 | 172 |
| *MISCELLANEOUS OFFENSES* | | | | | |
| Arson/weapons carrying | 0 | 8 | 22 | 50 | 80 |
| Fare evasion | 0 | 103 | 0 | 44 | 147 |
| Drunkenness | 19 | 44 | 2 | 12 | 77 |
| Narcotics | 1 | 2 | 1 | 4 | 8 |
| Disorderly conduct | 1 | 1 | 1 | 3 | 6 |
| Suspicious persons | 45 | 74 | 12 | 57 | 188 |
| *NON-OFFENSE INCIDENTS*[c] | 31 | 67 | 48 | 524 | 670 |
| *INCIDENTS NOT SPECIFIED* | 3 | 11 | 24 | 16 | 54 |
| *INCIDENTS NOT CODED* | — | — | — | 42 | 42 |
| TOTAL NUMBER OF INCIDENTS | 116 | 352 | 394 | 788 | 1,668 |

a Source: Metropolitan Transportation Commission coded crime and miscellaneous reports from BART Police Services; group summary categories by De Leuw, Cather & Company.

b Includes outside station and plaza incidents.

c Includes reports of ill or deranged persons.

d Locations not specified.

Having arrived at the station, the patron enters and traverses the station concourse. Depending on the station, entrance into the station concourse is accomplished in one or more of four ways: level entry, elevators, escalators, and stairs. The concourse areas are below ground in 11 stations, at ground level in 22, and elevated in one case (Rockridge). The concourse provides space for the entire ticketing/fare collection operation, a station agent's booth, directional and informational signs, and various passenger amenities.

The highlight of the travelers's experience at this point is the visual quality of the station interior. Orientation and fare payment for first-time users may be confusing, although the automated system is fairly simple to use after the first encounter. Non-travel services are limited, since BART design was oriented to people spending very little time in station areas.

### Entry

At present patronage levels, capacities of escalators and stairs are ample. These are usually centrally located except in the large subway stations which have multiple entrances. Some elevators are poorly located because they were incorporated into the system after designs for many stations were complete or construction was well advanced.

### Orientation

The functional layout of the concourse is similar in all stations. Orientation to the space is provided by several highly visible and uniform features, including ticket machines, fare gates, and the information booth. There are several sources of information about the system, including displayed brochures, graphics, and station agents—the latter being particularly important for new patrons. Directional signing was deliberately minimized, since the original intent was to lay out the space so as to minimize the need for signs. However, this was not always successful; signing improvements are now being made to correct deficiencies in some stations.

### Fare Collection

BART's fare collection system includes machines for change, tickets, entering and exiting (fare gates), and adding value to an existing ticket. Initial users are often confused by the fare process. The major difficulties are in following the multiple-step ticket-purchasing procedure. Additional inconvenience may be caused by the fact that change machines cannot handle bills other than $1 or $5. The ticketing and change machines are also subject to frequent jamming and breakdown. Space for patrons is ample for rush-hour volumes, and the number of fare gates is generally adequate. Where fare gates are not near station agents' booths, fare evasion is easy and occurs because of the ineffectiveness of the low gates as a barrier.


PLATE VI-4
ABOVE-GROUND CONCOURSE
DALY CITY


PLATE VI-5
SUBWAY CONCOURSE,
EMBARCADERO

### Safety and Security

Accidents in station concourses are rare, and those that occur are apparently not due to design faults. Most are falls, usually happening on ramps, steps, stairs, and escalators.

As shown earlier (see Table VI-2), crime in BART stations is rare compared to the total number of persons who use the system each day. Virtually none of the incidents reported are crimes against persons. Fare evasion is the most common offense inside the stations.


**PLATE VI-6**
**LOW BARRIERS FACILITATING FARE EVASION, POWELL STREET STATION**

Emergency help in stations is provided first by station agents. Further help is available via an easily accessible intercom with a typical response time of about four or five minutes for the arrival of BART police or local patrolmen.

### Visual Interest

The visual quality of BART stations is one of the system's most impressive features. The stations were designed by many different architects and with a minimum of BART-imposed constraints. As a result, the concourse interiors vary widely in appearance. The spaces themselves differ in size and shape, and various materials, colors, works of art and advertising displays were used to enhance station individuality. Lighting and the level of station maintenance vary somewhat, but in general they are good. There are virtually no graffiti on the concourse, the platform, or the trains. This is in part due to the heavy use of tile and other impervious surfaces, but is largely unexplainable unless simple respect for the system's beauty is involved.

### Non-Travel Services

Services are sparse in BART stations. This is primarily because of the original design assumption that trains would run at intervals as short as 90 seconds, with patrons therefore spending very little time in the stations. Restrooms can be unlocked only by station agents and are therefore somewhat inconvenient. However, this insures security and privacy for patrons using them. In most stations there are no concession stands and no concourse seating. Telephones are provided in all station concourses, as are vending machines for candy and cigarettes.

There are a few direct entrances into adjoining stores from stations in downtown San Francisco and Oakland. Like most rapid transit systems in the United States (but unlike that in Montreal and on some systems abroad), integration of stations and commercial land uses was not a major objective of BART station design.

## ON THE PLATFORM

**BART platforms look and function well, are quiet enough, and lack only sufficient seating and adequate information on train delays.**

Passengers board BART trains directly from the station platform, which is accessible from the concourse by stairways, escalators and elevators in all stations. Fourteen of BART's stations have subway platforms below the concourse. In the remaining 20 stations, the platforms are above an at-grade or elevated concourse. There are both center- and side-loading platforms.

Platforms are visually interesting, generally comfortable, safe and secure environments. However, the lack of information about train delays, which are frequent, is a major source of complaint among patrons. Seating and other amenities such as telephones are in short supply as well.

In downtown San Francisco BART stations there is a separate platform level for a sub-surface municipal light rail transit service serving the neighborhoods of San Francisco. Service on the Muni Metro, which is presently running as a surface streetcar system above BART, is scheduled to begin in 1979.

PLATE VI-7
ABOVE-GROUND PLATFORM,
FRUITVALE


PLATE VI-8
SUBWAY PLATFORM,
LAKE MERRITT

## Visual Quality

Like the concourses, platforms are usually striking in appearance. They vary widely in image from station to station, mainly because of the different materials and colors used on platform walls.

## Comfort and Health

### Sound Levels

To a person familiar with platform noise as a train arrives in older subway systems, BART is phenomenally quiet. Survey results confirm this observation; patrons indicated that on the platforms noise (particularly that from BART trains entering and leaving the stations) is not a source of perceived discomfort.

Measured BART noise levels generally fall within the strict goals set by the Institute of Rapid Transit (IRT).[1] Measured BART train sound equivalent levels ($L_{eq}$) were also found to be relatively consistent for stations of the same type. A comparison of the IRT standards and observed BART sound levels is shown in Table VI-3.

### TABLE VI-3
### COMPARISON OF OBSERVED BART PLATFORM SOUND LEVELS AND INSTITUTE OF RAPID TRANSIT (IRT) DESIGN NOISE GOALS

| Station Platform Sound Source | IRT Design Goal Maximum – dB(A) | Observed BART Range – dB(A) |
|---|---|---|
| Subway – trains entering and leaving | 80 | 75-86 |
| Subway – trains stationary | 67 | 62-68 |
| Subway – station ventilation system only | 55 | 52-57 |
| Above-ground – trains entering and leaving | 70-75 | 70-94* |

* 70-86 dB(A) excluding end-of-line stations.

Source: **The User's Experience** (see Documentation).

In BART subway stations, noise levels are reduced by acoustical treatment of platform ceilings. In the Embarcadero station (the last station constructed), the sound absorptive treatment is most extensive, but since the platforms elsewhere have no noise problems, the additional treatment has no apparent effect.

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1 Institute for Rapid Transit, **Guidelines and Principles for Design of Rapid Transit Facilities,** Washington, D. C., May 1973.

Other Aspects

Glass-enclosed shelters for wind protection were recently installed in above-ground stations, and partial roofs offer shelter from sun and rain. These appear to provide satisfactory weather protection in the mild Bay Area climate.

Ventilation in subway stations is primarily from the "piston" action of the trains in tunnels forcing air through the stations, with a secondary mechanical system for emergency conditions. Resulting wind effects are noticeable on platforms and in stair and escalator wells. These winds may be annoying, but otherwise present no real problems.

Localized air pollution levels in and around BART stations are affected primarily by meteorological factors and nearby motor vehicle activity, which vary considerably. The prospect of BART users being exposed to harmful levels of air pollution is very remote, even in the "worst" cases (freeway median), primarily because of the brevity of exposure.

Seating and other amenities such as telephones are scarce on platforms because of the original premise that patrons would spend only a few minutes there. When trains are delayed, however, waiting periods can be extensive. Seating is now being increased on some platforms, but more is needed to provide an adequate level of comfort. At one station, electronic games have been installed for waiting patrons.

### Safety and Security

Platforms are generally safe and accident-free. There is very little crime in platform areas (see Table VI-2), and most features of platform design do not seem to contribute significantly to accident potential. There is, however, a drop from platform to trackway, with no separating structure to prevent falling. Patrons (particularly handicapped patrons) have voiced concern about the danger of falling onto the track. Fortunately, accident reports show that few such accidents have occurred, and none with serious injury.

Platform edges are marked in all stations. The design of edge markings varies widely among stations, however, and some are more effective than others. This is a feature which should be more uniform in future systems. Markings which contrast texturally as well as visually are more helpful than those which provide only visual contrast. Textural contrast is particularly important in warning the sight handicapped of proximity to the edge. Train door stop locations are indicated as well along platform edges in some stations; these markings encourage commuters to form orderly queues for train entry.

### Information and Orientation

Since a station platform typically serves trains destined for different locations, electronic Train Destination Signs (TDS) were installed on each platform to display destinations of approaching trains. The trains themselves have no built-in signs and can be identified only by a card sometimes taped to the operator's windshield.[1] In the event of TDS failure, which

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1 These cards are to be replaced by bus-type roller signs which show terminal destinations.

is infrequent, this can present a problem to patrons. The length of trains is sometimes indicated on the TDS (trains are often short in off-peak periods) so that patrons can queue up in the proper area for boarding.

Train delays are fairly frequent and sometimes long. These delays, compounded by the lack of timely and accurate announcement of their cause and likely duration, bring the most frequent complaints from patrons. BART is currently taking steps to improve the quality of such information for patrons on platforms as well as on trains.

## ON THE BART TRAIN

**From the passenger's viewpoint, the train itself and the travel experience are excellent in all respects except for travel time unreliability due to frequent system malfunctions.**

The BART car is one of the most luxuriously appointed rail commuter vehicles in the world. It was designed to attract commuters from their automobiles by offering a very high level of comfort while still making the interior durable, simple, and easy to maintain. Survey results indicate that persons who ride BART are pleased with its comfort. In addition, BART's travel time ratings are good in spite of delays caused by low equipment reliability.

### Design and Layout

Train seating is comfortable and readily available except during rush periods. The cantilevered seats make maintenance of the carpeted floors easy and also provide ample package space beneath. Each car seats 72 patrons, but during peak periods at least twice that number may ride standing up. No stanchions are provided; instead, handholds were built into the seat backs adjoining the center aisle. Because of problems with falls when trains are crowded, ceiling-mounted handrails have now been installed for standees except in the vestibules. In future systems, either stanchions or handrails which are not obstacles to wheelchairs should be placed in vestibules as well as aisles, since standees congregate nearest the exits.

The doors between cars are difficult to open, but passage from one end of the train to the other is possible.

### Travel Time

When asked about overall impressions of BART, panel survey respondents gave BART's travel time more positive mention than any other feature. BART was built with wide station spacing to be a fast intra-urban system. Even though it has not attained initial estimates of speed, most persons are apparently satisfied with BART's current travel time.

### Comfort

BART's ride quality is generally excellent and probably equal or superior to any other rapid transit system in North America. When asked to mention particularly good features of BART trains, panel survey respondents most often cited ride comfort.

PLATE VI-9
BART CAR INTERIOR


PLATE VI-10
TRAIN OPERATOR'S C

One of the sources of comfort is a generally low level of vibration with little sway. BART cars are supported on eight air-cushion bellows which absorb more vibration than mechanical springs. With the continuously welded track, this creates a very smooth ride.

Other factors contributing to a comfortable ride are the air-conditioning system and the interior lighting. The air-conditioning equipment is adequate for all but extreme conditions. An excellent combination of daylight and artificial lighting produces a minimum of glare and very little contrast as the trains enter and exit from subway sections.

Maximum measured sound levels in the trains are generally higher than those measured on platforms, and the strict IRT design goals are not achieved inside the trains (Table VI-4). However, survey results indicate that few patrons seem to notice train sound levels. Moreover, in comparison with other transit systems the noise levels on BART trains seem extremely low.

### TABLE VI-4
### COMPARISON OF OBSERVED BART TRAIN INTERIOR SOUND LEVELS AND INSTITUTE OF RAPID TRANSIT (IRT) DESIGN NOISE GOALS

| Sound Variables | IRT Design Goal Maximum dB(A) | Observed BART Range Maximum dB(A) |
|---|---|---|
| Tie-and-ballast track bed – maximum speed | 68 | 76-79 |
| Open concrete track bed – maximum speed | 72 | 81-84 |
| Subways – maximum speed | 78 | 89-92 |

Source: **The User's Experience** (see Documentation).

The sound levels on board the BART vehicle vary with train speed and track configuration. Sound level recordings were conducted on board BART vehicles during two complete end-to-end traverses of the BART system, and the mean $L_{eq}$ for all the trips was 76-77 dB(A). Tie-and-ballast track configuration was found to create the lowest level of sound on board the vehicle, followed by track on aerial structures and in subways. In general, the differences in the maximum sound levels observed on aerial structures are some 4-5 dB higher than on tie-and-ballast track. The maximum sound level in subways is 0-13 dB higher than on open tie-and-ballast track. A few short subway segments contain tight turns or other track configurations which lead to a noticeable, but not severe amount of wheel squeal. Most of this is effectively masked by the car's insulation, fixed windows, and tight door seals.

No attempt was made to quantify differences in sound levels for various positions within a car. However, previously recorded data[1] indicate that a 4-5 dB difference is found between the loudest locations (over train wheels) and the quietest locations (near the center of the car). This amounts to a just-noticeable difference.

Ear discomfort is often experienced as trains enter the Transbay Tube and the Berkeley Hills tunnel. This discomfort is probably due to the sudden air pressure changes which occur as the train passes the tube's vent shafts. Occasional rapid acceleration to 70 mph from a stopped position also makes some persons uncomfortable. Neither of these is serious, but similar effects could probably be reduced in future systems.

### Orientation

Getting off the train at the appropriate station is usually not a problem. System display maps on the trains enable riders to check their location in relation to other stations, and upcoming stations are identified by easily visible signs along the platforms. In addition, train operators usually announce the name of each station on the public address system just before arrival.

### Enjoyment

BART cars are clean and well maintained. Graffiti and signs of vandalism are rare; the few occurring are, by policy, removed as quickly as possible. A small number of advertising displays usually add interest to car interiors. A major enjoyment of riding of BART is the view of the Bay Area as the patron traverses the 48 miles of above-ground trackway. Patrons and personnel were observed to be friendly; seating arrangements allow for a choice of privacy or social contact.

### Safety and Security

Accidents reported on trains are less frequent than those reported in stations and mainly occur when passengers are boarding or leaving the vehicle. Only once has a train itself been involved in an accident resulting in injury to patrons. Crimes are even less likely to occur on trains than in stations or parking lots (see Table VI-2). Emergency help can be summoned using a train intercom located in each car. However, this system (the same as on the platforms) is not always reliable, and its existence, as well as that of other emergency equipment, is not well publicized.

### Reliability

BART trains run on computer-controlled headways (intervals between trains) rather than on time schedules. Service is often unreliable, however, and train delay is one of the major complaints patrons have about the system. During a recent month (December 1976) on 10 percent (573) of the scheduled round trips there were equipment failures, and trains were unable to complete scheduled runs. When equipment failures occur, trains are moved to side tracks or to nearby maintenance yards.

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1 D. Dieckmann, "A Study of the Influence of Vibration on Man," **Ergonomics 1** (1975).

In a recent review of transit patron attitude studies, it was concluded that travel time reliability is even more important to patrons than the total elapsed travel time.[1] This study's limited interviews with BART patrons also found reliability to be a major concern. BART's biggest problem since the inception of service has been low equipment reliability, which affects both the level and quality of service. Most problems occur in transit vehicles, in which high rates of component failure cause reductions in speed, thereby slowing system operations. In addition, the California Public Utilities Commission (CPUC) has placed restrictions on BART's operation, requiring trains to be separated by a distance of at least one station until the automated Train Control System meets PUC safety requirements.[2] Progress is being made in improving the control system.

The original plan called for two- to five-minute intervals between trains. The combined result of CPUC restrictions and limited car availability has been that train frequencies have been low even during peak periods. Trains are currently scheduled to run every 12 minutes[3] during the day and every 20 minutes at night. These frequencies are often further reduced by equipment failures, although equipment performance is improving. Equipment failures tend to affect the entire system's operation, even when a single train is involved, because of the headway tolerances required and because the automatic train control system treats the entire BART operation as a single unit.

## LEAVING THE SYSTEM

**The exit procedure is simple, although new or infrequent users may have difficulty in finding the right street exit and information on connecting bus service.**

A traveler's main concern after the BART train trip is exiting from the station expeditiously. This involves passing through the fare gates, finding the correct station exit, and in some cases connecting with another transit mode.

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1 M. Wachs, "Consumer Attitudes Towards Transit Service: An Interpretative Review," **AIP Journal 42,** January 1976, p. 103.

2 Some of the technical problems of equipment reliability are mentioned only briefly here as background information, since this study is concerned primarily with what the traveler experiences. Readers wanting more detailed technical information regarding equipment reliability and maintenance should refer to **Transportation and Travel Impacts of BART: Interim Service Findings,** Document No. DOT-BIP-FR 6-3-75. Berkeley: Metropolitan Transportation Commission, 1976.

3 Six minutes in San Francisco and downtown Oakland stations, where the Concord and Fremont lines merge onto a single track, and also from Fremont to Lake Merritt, where the Fremont-Richmond and Fremont-Daly City lines merge.

## Leaving the Train

Two sets of double doors on each side of the car accommodate relatively quick movement out of the vehicle. Train doors usually remain open for 15 to 30 seconds, depending on the degree of crowding. The operator controls the closing of the doors, which normally allow for orderly entry and exit. If a patron misses a desired stop, additional travel time is likely to be less than 15 minutes.

## Station Exit Procedure

While exit signs on platforms indicate locations of escalators and stairs, they do not always specify where exits lead in relation to surrounding streets. Elevator locations are not marked. The fare gates can obstruct passenger flow (especially during rush periods) if there are not enough exit gates in operation. Also, infrequent users tend to become confused by the procedure at the gate, thereby delaying others. In such cases, lines may form at the "Addfare" and change machines near fare gates, causing traffic congestion. Ease of station exit and entrance during commute hours is aided by changes made in escalator flow. Escalator direction is controlled to accommodate major commuter travel flows.


**PLATE VI-11
EXIT-GATE TRAFFIC
CONGESTION, POWEL
STREET STATION**

### Leaving the Station

In smaller suburban stations the street destinations of exits are usually obvious. Such is not the case, however, in larger downtown stations, which may have eight exits or more. Where subway exits are not keyed to surrounding streets, this may be a source of confusion to patrons.

### Connections to Other Transit Modes

Finding a connecting bus can be difficult for infrequent BART users due to the lack of effective signing in some stations and at nearby bus stops; a more effective signing system is being planned for installation. BART station agents can explain bus connections and sometimes provide bus schedules to patrons. This is not publicized, however, and bus schedules are rarely displayed in stations.

Well-designed bus shelters exist outside most stations to provide weather protection for patrons waiting for buses, and very few accidents or crimes occur in these areas.

## BART AND THE HANDICAPPED

**Although BART is fully accessible to physically handicapped persons, including those in wheelchairs, some of these encounter a number of difficulties in their use of the system.**

Handicapped patrons encounter special problems associated with accessibility, orientation, and barriers to movement within the BART system. Most problems occur because provisions for handicapped patrons (most notably elevators) were added late in the design process. Currently, a task force of handicapped persons advises BART about desired improvements to facilities and allocation of resources to that end.

### Arrival and Entry

Most semi-ambulatory patrons can and do use public buses to connect with the BART transit system. However, persons in wheelchairs must use private transportation to and from a BART station because public buses do not have wheelchair lifts.

Design features such as special automobile stalls in parking lots and gradual ramps over curbs facilitate the handicapped patron's approach to a BART station. Elevator interiors have been carefully designed for the handicapped. At many stations, however, the elevators needed for station entry are inconveniently located with no directional signing to assist patrons in finding them.

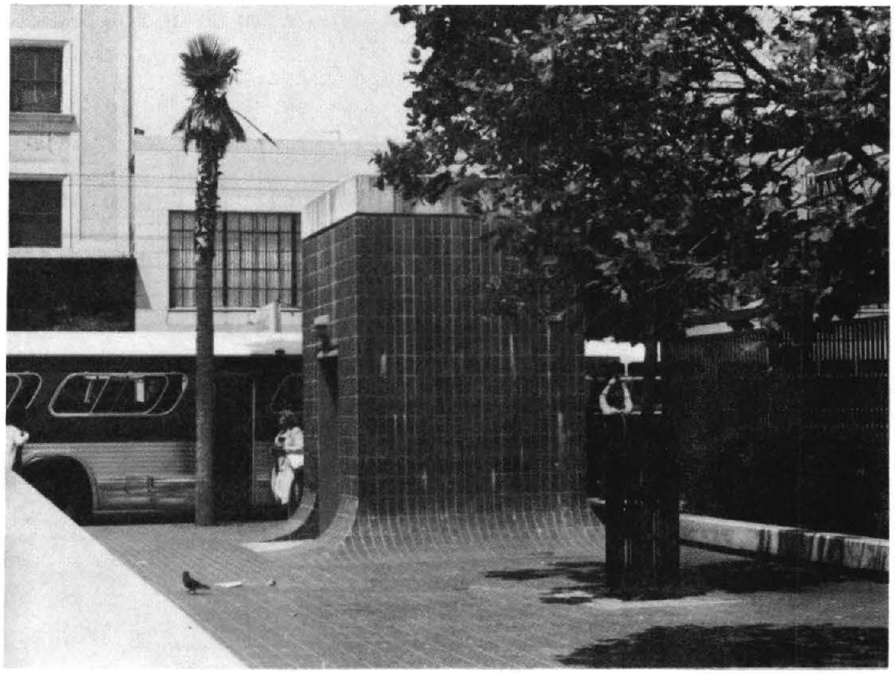

**PLATE VI-12**
**ELEVATOR, MISSION STREET STATION**

**Movement Within the Station**

Entrance gates, fare-vending equipment, telephones, restrooms and other station facilities have been designed with the problems of the mobility-handicapped patron in mind. For the blind patron, however, orientation is problematic, and movement is often hazardous due to a lack of non-visual guides in BART stations. Stair entrances and platform edges often have no textural differentiation; upright angled structures, such as the underside of escalators, can be dangerous, since they are often undetectable even with the use of a tapping cane. BART is now working to eliminate these hazards.

Patrons who must rely on elevators have found getting to the train time-consuming, complicated, and sometimes exhausting. They are subjected to long travel distances, unreliable intercom phones, and complicated fare-collection procedures. These inconveniences should be eliminated in future systems by providing for mobility-limited patrons in the original designs.

### On the Train

Handicapped patrons have additional difficulty in boarding trains and frequently need individual assistance and additional accessories for balance and support. There are no provisions for wheelchairs on the trains. As a result, it can be difficult to stabilize them during train acceleration/deceleration. However, apparently no accidents have resulted. The blind or near-blind patron must often rely on other riders for assistance in boarding and leaving the train.

### After the Trip

Handicapped persons, as well as other patrons, rely heavily on station agents for directions to proper exits and connecting bus lines.

## BART AND BICYCLES

**BART's efforts to encourage use of bicycles are extensive and successful.**

BART has installed bicycle storage facilities at some stations and implemented a limited program allowing patrons to bring bicycles on trains. Over 500 persons ride their bicycles to BART on an average summer weekday.

### Arrival

Within the BART parking lots, cyclists can reach the main station entrance safely before dismounting. Use of bicycles as a connecting mode of transport is most prevalent in suburban station areas.

### Storage

Bicycle theft was originally a problem because of the inadequacy of storage racks. The recent installation at all suburban stations of improved bicycle racks provides improved protection from theft, but not necessarily from weather. Bicycle lockers are soon to be installed at some stations; these should provide more complete protection at a five-dollar-per-month rental fee.

### Bicycles on BART Program

Standard bicycles are allowed on BART by permit during non-rush hours and in certain locations on trains. Currently, about 2,000 persons have BART bicycle permits, and about 200 persons per week take bicycles on BART. Folding bicycles are allowed in the system without permit or restriction.

**Stations.** The passage of a patron with a bicycle through stations, including the processing of tickets, can be accomplished easily without any obstruction or nuisance to other patrons. However, bicycles are not allowed on the escalators, and cyclists must instead use the stairs.

**Trains.** Cyclists who travel during non-rush periods generally cause no problems on trains. Folding bicycles, however, present the same obstruction as strollers, carriages, or wheelchairs. This is apparently not a significant problem, since few patrons use the privilege.

# VII. A LOOK AHEAD: BART'S FUTURE IMPACTS

## INTRODUCTION

The Environment Project's primary responsibility has been to observe and assess the environmental impacts which BART has generated **to date**. This emphasis on the past and present is in keeping with the BART Impact Program's main purpose, which is to assemble and evaluate the Bay Area's actual experience with BART.

However, BART is still new, and its ultimate level of impact has not yet been reached. Major increases in the level of service and patronage are expected within a few years, and certain effects of the system on the region's development pattern have not yet occurred. Both of these could have substantial environmental effects.

The purpose of this chapter is to forecast possible future changes in BART's environmental impacts. In contrast to the detailed evaluation of the system's current impacts, this chapter relies on hypothetical situations and order-of-magnitude impact estimation. Certainly its statements are much more uncertain and less definitive than those for current impacts. It does, however, help to complete the picture of BART's impacts by providing a reasonable judgment of how important BART's future environmental impacts may prove to be.

## SCENARIOS

Several events relevant to BART's environmental impact may occur in future years. For the purposes of this study's look into the future, three complementary scenarios are defined:

(1) Programmed changes in BART service characteristics and expected patronage increases over the next five years.

(2) A long-term increase in ridership beyond current expectations (either as a result of land use impacts or because of unforeseen events such as a major and continuing gasoline shortage).

(3) A possible long-term major BART impact on urban form through concentrated development around the system's stations.

**Short-term changes in BART service characteristics** are fairly reliably forecast from BART's Five-Year Capital Improvement Program.[1] These include use of longer, more frequent trains and an increase in patronage (from the current 137,000 to approximately 180,000 trips per day). These changes may produce increases in some environmental impacts around the stations and lines as well as to the BART patron.

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1 Draft in-house BART District document, early 1977.

**An unanticipated major increase in BART patronage** may occur in several ways. It could be evolutionary due to increasing concentration of development around the stations. It could also be encouraged by either a severe long-term energy shortage, affecting conventional automobile travel, or a stringent governmental restraint on the use of private cars in anticipation of such energy problems. If such a major increase in patronage were to occur, it could cause substantial impacts around the stations as well as within the BART facilities.

**Long-term BART impacts on urban form** may or may not prove to be substantial. If they are, however, the resulting "indirect" environmental impacts may be very large and different in kind from the system's direct environmental effects. These environmental effects might well overshadow the environmental impacts of the system itself. It is therefore appropriate to estimate the possible scale of such land use impacts, their environmental effects, and the potential significance relative to BART's direct environmental impacts.

In the remainder of this chapter, each of these scenarios and their environmental implications are discussed in more detail.

## SHORT-TERM CHANGES IN BART SERVICE CHARACTERISTICS

**Planned and expected changes will substantially expand areas subject to train noise impacts along aerial lines and worsen parking and traffic problems around stations, but will improve the quality of service for the BART user.**

According to BART's current Capital Improvement Program, over the next five years several key changes may be expected in BART service and patronage. These events are as follows:

- **Train lengths** are to be increased slightly to **ten cars** during peak periods and four to six cars during off-peak periods.
- **Frequency of service** is to be increased to result in the following **one-way** average day-time train intervals:

| | **Projected** | **Present** |
|---|---|---|
| Daly City Line | 3 minutes | 6 minutes |
| Richmond | 6 minutes | 12 minutes |
| Concord | 6-12 minutes | 12 minutes |
| Fremont | 6 minutes | 6 minutes |
| 12th Street-MacArthur | 3 minutes | 6 minutes |

- **Weekend service** is to be added at 15- to 20-minute frequencies.
- **Direct service** is to be added from Richmond to Daly City, eliminating the present transfer and shortening this line's travel time to San Francisco. This is expected to increase ridership on this line substantially.

- **Train speed** is to be kept at the present 70 mph maximum for normal operations, with continued restrictions on the use of the 80 mph "catch-up" speed.

- **Maintenance** will continue as a high priority so that train noise and facility attractiveness levels are kept at current levels.

- **Planned spur tracks** (at Oakland-downtown and Daly City) are to be put in operation, reducing system delay time.

- **Patronage will increase** steadily to approximately 180,000 (as compared to today's 137,000) within five years as above improvements are implemented.

- **Current parking shortage** will increase at most suburban stations as a result of the above; only small further increases are to be made in lot capacities because of lack of space, funds for expansion, and community acceptance.

- **Feeder bus service** is to be expanded to varying degrees at most suburban stations; bus access patronage will roughly double.

- **Fuel shortages** and increasing prices will result in slightly higher automobile occupancy and bicycle, walking and bus use to BART stations, but the main short-term result will probably be more long-distance carpooling rather than greater BART use.

- **Non-attended stations** may increase gradually in number to no more than ten, and only for weekends and with improved communications and policing.

- **Escalators** in some downtown San Francisco stations will be increased in number to accommodate increases in BART and Muni Metro patronage.

### Resulting Impacts Along Lines

The projected increases in service frequency will cause a small increase in the system's acoustic impacts. According to the Project's study of BART train sound levels and their causes, train frequency is a major factor. This study estimated the effect of a reduction in headways from 12 to 4½ minutes (as originally forecast for the Richmond Line) to be about 5 dB(A) at a distance of 50 feet on an hourly ($L_{eq}$) basis.[1] For the smaller increases in frequency forecast for the other lines, hourly $L_{eq}$ increases are about 2-3 dB(A). The increases in train length will add between 1 and 2 dB(A) more.

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1 The $L_{eq}$ sound measure reflects both the typical train sound level and the number of trains passing per hour. The sound generated by each train will of course remain unchanged, so peak sound levels will stay as they are now.

Such an increase in $L_{eq}$ is roughly equivalent to the 5 dB(A) amount by which train sound generated on an aerial structure exceeds that on at-grade tracks. This difference was shown to extend the width of the area affected from one to two blocks on each side of the line. Thus, it could be expected that the number of residences affected by noticeable levels of BART train sound will rise by up to an additional third to a half.

In addition, the homes already affected by BART train sound will be further exposed due to the planned weekend service. These effects will be similar to or less than those now experienced under quiet evening conditions, which are apparently moderate.

Vibration along the system's aerial lines will also increase. About half the surveyed residents in the row of homes nearest BART aerial trackways felt that its vibration under present train frequencies was at least a minor irritant. Such complaints are likely to increase somewhat, although the resulting vibration is unlikely to cause major complaints or structural damage.

### Impacts Around BART Stations

The major effect of the projected service and patronage changes is likely to be a substantial increase in station-area overflow parking and traffic. At current rates of automobile arrival by BART patrons, the projected 180,000 daily trip level suggests a 30 percent increase in the number of cars arriving at the stations unless carpooling and kiss-and-ride increases dramatically. This is an average of 60 to 600 additional cars per station, depending on current use. Since overflow parking and traffic are already viewed by local residents as the system's most serious problems at several stations, this is cause for some concern. Parking lots now near capacity at several other stations will probably overflow into surrounding residential areas. In addition, present problems with on-street BART patron parking in the residential and retail areas around the Glen Park and Balboa Park stations in San Francisco which have no parking lots are likely to intensify.

Unless action is taken to reduce or accommodate this additional demand, traffic density will also increase around the stations. Since traffic problems already exist at some stations, this is also likely to be an increasingly significant concern as patronage rises. However, most BART stations are adjacent to major arterial streets and freeways so that the increase caused by BART patrons will in most cases be small in comparison with total volumes. BART-related traffic problems then are likely to be limited to congestion at parking lot entrances and overflow parking on residential streets.

BART personnel are now undertaking a major study of station access. Out of that study is expected to emerge a proposal for a coordinated set of improvements in bus service, parking, kiss-and-ride, and other access facilities. Current BART plans include spot improvements at some parking lot entrances; more may be needed. In addition, feeder bus service is to be expanded, but no major increases in this service are now anticipated. Ultimately, cooperation among local jurisdictions, bus authorities and BART will be required to develop transportation system management strategies to resolve this increasing problem.

### Impacts on BART Users

Apart from the gradually increasing difficulty of getting to the station, effects of projected changes in BART characteristics and patronage on the users of the system should be very beneficial. The problems of station access have already been discussed; it is necessary here only to note that in addition to the effects this will have on the local environment and its residents, the BART patron will also be inconvenienced.

No new or increased problems are anticipated in the use of the trains and stations. These components were designed for user volumes in excess of 200,000 trips per day and give no indication of approaching capacity except at the Montgomery Street station in downtown San Francisco's financial district at the peak of the rush period. With the opening of the Muni streetcar subway (expected in 1979), which shares BART's concourse and street access systems in downtown San Francisco, a capacity problem may occur. Even here, however, the addition of more fare gates and escalators, both of which are planned, will substantially solve the problem.

Some significant benefits can be expected for patrons. Most important, the increased frequency of the trains will significantly reduce waiting time and make BART a much more attractive travel option. With the expansion of feeder bus service, station access options will expand for some patrons. On-time reliability of the system will increase, particularly due to the programmed construction of several spur tracks for storage of malfunctioning trains without need for long systemwide slowdowns. Improvements in the platform announcement of system delays are also to be made. In addition, a continuing series of improvements in patron comfort are being made, such as wind and rain shelters on outdoor platforms and more platform seating.

## LONG-TERM LARGE INCREASES IN BART PATRONAGE

**Major increases in BART ridership would overtax the capacity of escalators and stairs in some stations and produce very serious problems in parking and traffic at suburban stations unless bus access services and use were to be greatly expanded.**

BART's current five-year forecast of no more than 180,000 one-way passenger trips per day is as far as planning now extends. However, a longer-range view might indicate a much higher demand for travel by BART some years later. Should there be another energy crisis or a major shift in behavior brought about by increased costs of owning and operating automobiles, possibly coupled with regional disincentives to automobile use (e.g., restricted auto zones, higher parking taxes, or bridge tolls), a higher demand level for BART is quite conceivable. In order to assist other cities in assessing the importance of such a concern in their own system design, a brief review of the environmental problems which BART can expect to encounter under such conditions should be useful.

Since BART now carries only a small proportion of the trips made within its service area, even a small additional proportion could result in a very large absolute increase in patronage. Daily volumes in excess of double or triple the current level (137,000 one-way trips per day) might be encountered. If the overall utilization factor (ratio of passenger miles to seat miles) were to increase from its current 26 percent to say 45 percent, all else equal, the system patronage could be 380,000.[1] Such an increase would probably require additional trains, better equipment reliability, and modification to the train control system to safely operate trains at closer headways. Of concern here is whether such increases would lead to unacceptable impacts on users and the surrounding environment, and what aspects of BART would be most affected.

**Environmental and User Impacts**

Capacities of vertical movement systems in some stations and the station access and parking facilities will have to be expanded if BART is to serve a large increase in travel demand.

Most environmental effects would be felt by BART users themselves, through station access problems and crowding in the stations and trains, and by residents around stations who would be exposed to very heavy station access traffic and parking. No additional environmental impacts are likely along the BART lines due to such a major patronage increase, since increases in the number or length of trains running would be only marginal.

BART trains running at projected frequencies, with a longer peak arrival time (e.g., staggered work hours) and a high proportion of standees, could deliver several times the current number of persons to downtown San Francisco within a two-hour rush period. This suggests that the system's capacity is more likely to be limited by its access systems and stations than by its trains.

Within the stations spaces are quite large, but stairs and escalators, as well as the fare-collection facilities, are susceptible to overloading at the very high patronage volumes which might be reached under some conditions. Both the street-to-concourse and concourse-to-platform escalators are affected. This is particularly true at the three major downtown stations in San Francisco (Powell, Montgomery, and Embarcadero), where some peak-period congestion is already found. Even a doubling of current patronage would cause substantial congestion and delays in movement between the street and the platform.

Fare collection could probably be handled by increases in the number of fare gates or a shift to a faster method of fare collection. However, the shortage of vertical movement capacity would be much more difficult to overcome. The current BART Capital Improvement Program draft includes the addition of more escalators at several downtown San Francisco stations because even projected gradual increases in patronage (and the opening of the Muni streetcar subway) are expected to cause some problems in vertical movement. Clearly then, vertical movement would be a serious constraint under a substantially higher level of patronage than now projected.

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1 Keith Bernard, "Toward Higher Utilization of BART," paper presented at the National West Coast Meeting of the Society of Automotive Engineers, San Francisco, August 12, 1976.

Access to stations might well be an even greater constraint on BART's capacity than the shortage of escalators. This is especially true in outlying areas with already-overflowing parking lots. Feeder bus service would be expanded, but the high cost and other demands for bus service elsewhere would probably limit such expansions. Carpooling and possibly jitney service along station access routes would ease the problem somewhat, but automobile traffic and parking needs would almost inevitably increase substantially.

Effects would include delays for users and a general increase in the extent and intensity of the current problems of traffic and on-street parking by BART patrons in residential neighborhoods surrounding stations. At several stations (notably Daly City and Concord), these problems are already not only serious, but widespread, extending as far as four blocks from the parking lot. Even a doubling of the demand for parking in such areas would strain not only the capacity of the streets, but also the car-to-station hiking abilities of the patrons and the charity of the local residents.

## LONG-TERM LAND USE CHANGE

**Land use impacts of BART are unlikely to be so great as to have either good or bad environmental effects of much greater consequence than the direct environmental impacts already caused by BART itself.**

The new development surrounding the most highly developed of the Toronto rapid transit stations is often cited as an "ideal" in land use-transportation system coordinated planning. In addition to CBD intensification similar to that already observed in San Francisco, approximately 10 to 15 of Toronto's 49 stations are surrounded by several blocks of high-rise residential and office development. This intense development occurs largely in areas which were previously in lower-density uses and is considered to have been influenced by the presence of the rapid transit system. The Toronto example provides a demonstrable basis for definition of the maximum level of development which might be predicted around BART stations. This allows a conservative test of the hypothesis that BART's ultimate indirect environmental impacts (those caused by BART-induced development) will be larger than the direct environmental effects which have been this study's major concern.

### Future Development

If the Toronto scale of development were to occur around a similar proportion of BART's stations, the result could be an average of as many as 1,500 high-rise residential units around each of about ten stations, for a total of 15,000 units.

As in Toronto, the shapes and sizes of the areas involved would vary but would extend an average of about 1,000 feet from the station. Because of site-specific constraints to development, little is likely to happen around many of BART's stations. At several others a very high degree of development could occur; some cities served by BART, such as San Leandro, are already planning for intensive development on a scale as great as or even greater than that observed in Toronto. At still others, development pressures may arise, but social and physical constraints are likely to restrict the scale of development allowed. The average figures suggested above consider both the scale of Toronto development and those factors unique to the Bay Area.

The difficulty of achieving such a level of development should not be underestimated. It would require very substantial land assembly, household displacement, and local ordinance change. No other modern transit system except Toronto has been shown to have such major land use impacts.

### Environmental Impacts

In Toronto, the station-area environmental effects of the intensive high-rise development were found to be moderate and amenable to mitigation primarily through roadway and traffic control improvements.[1] BART's stations, like Toronto's, are generally located along major arterial streets and freeways and are surrounded by various types of land uses, including stable low-density residential neighborhoods. Therefore, if Toronto-like development were to occur around BART stations, it is probable that local indirect environmental impacts (e.g., traffic congestion) resulting from the concentration of activity around stations would be manageable.

If such development around about ten BART stations were to substitute for the increased low-density development of vacant land which is now forecast to occur at the urban fringe, could significant savings in the consumption of vacant land result? Based on ABAG forecasts,[2] approximately 100,000 acres of vacant land in the three counties in which BART operates and in areas near BART will be developed by the year 2000. Assuming that the density of development of this vacant land would be about three dwelling units per acre (the current density in the three counties), then about 300,000 additional dwelling units are forecast to be built. Using Toronto as a model, it was estimated that maximum station-area development would total about 15,000 units. This would reduce vacant land development by about five percent, or some 5,000 acres (eight square miles). Allowing for errors in the assumptions used, the correct figure is probably between two and ten percent, a significant but small proportional savings.

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1 Knight and Trygg, op. cit.

2 Association of Bay Area Governments (ABAG), **Series 3 Projections—Population, Housing, Employment and Land Uses, San Francisco Bay Region,** Berkeley, 1977. ABAG is the council of local governments in the nine-county San Francisco Bay region. It is the principal land use planning agency in the region. The Series 3 Projections are the latest in a series that is updated periodically. They comprise two sets of projections using varying assumptions about both national and regional trends and local development policies.

This brief analysis indicates that BART's possible long-term indirect environmental impacts are not trivial, but also are not overwhelming in comparison with the system's direct effects on the environment. A savings of several square miles in the amount of land now forecast to be developed within the three-county BART area is substantial, even if not large in comparison to the total. In addition, the continuing benefits which could arise from possible reductions in automobile miles driven by the 15,000 households who might locate near and use BART are also not inconsequential, nor are the potential intangible benefits of increased density, such as access to jobs and other services, in addition to rapid transit. However, this level of benefit on any reasonable scale of relative values does not overshadow the system's adverse environmental effects. It was noted earlier in this report, for example, that the construction process adversely affected some 38,000 residents. During operations to date, BART's train noise has adverse effects on the homes of about 5,000 persons. Approximately another 8,000 live near BART stations with overflow parking. Both impacts will affect more persons in the future.

This is not to say that these long-range benefits are less important than the direct environmental impacts assessed in this study; such a comparison between effects so different is neither reliable nor necessary. Certainly no conclusion of net long-term environmental benefit over detriment or the reverse is intended because the results suggest that neither positive nor negative effects clearly dominate. What can be concluded, however, is that direct environmental impacts must be dealt with as a significant part of a transit system's long-term effects on the environment. Long-term indirect environmental benefits arising from land use change may also be significant, but are unlikely to be overpowering.

# VIII. CONCLUSIONS AND IMPLICATIONS

## INTRODUCTION

The specific findings presented in the preceding chapters are numerous and diverse. In this chapter the findings are sifted and combined to identify key conclusions and implications for public transit development in the San Francisco Bay Area, as well as in other metropolitan areas. This chapter's interpretations should be of immediate value to others engaged in transit policy-making and planning. They will also serve as input to the BART Impact Program's final report (to be published in 1978), which will integrate the findings of each of its major sub-studies.

**Conclusions** are presented first, along with summaries of the supporting findings described in earlier chapters. These conclusions respond to the key issues the Environment Project was designed to explore:

- What is BART's **general level of impact?**
- What are its **principal environmental impacts?**
- What are the **determinants of the impacts?**
- What is their **distribution by location?**
- Who are the **populations affected?**

Decision-making **implications** of these major findings and conclusions are presented in a separate section. These are organized according to major transit development decisions (and their environmental aspects) faced by public policy makers across the country:

- Should a rail rapid transit system be considered? (What environmental impacts are likely to be associated with a new rapid transit system?)

- Where and how should such a system's lines be built? (What environmental considerations are important in line location and construction?)

- Where should the stations be placed, and how? (What environmental considerations are important in station location and design?)

- What kind of service should be provided? (What environmental considerations are important in design of the system's operations?)

## CONCLUSIONS

### General Level of Impact

**BART's environmental impacts are generally small, although more often adverse than beneficial.**

The study's main finding is that the level of BART's environmental impacts is generally low. Exceptions and variations occur in time and location of impacts, and some impacts were found to be more widespread and intense than others. More specific conclusions on these variations and their causes will follow.

The system's small environmental impacts have been primarily adverse rather than beneficial. More negative than positive effects arising from the facilities and operations of so large an undertaking were to be expected, but the overall small magnitudes could not have been presumed. The program's "no-BART alternative," which was based on a careful study of the economic and political decision history of the Bay Area, incorporated a conclusion that if BART had not been built, neither (in the same time frame) would a new transbay bridge and significant freeway capacity have been added. Had the alternative scenario included major freeway construction or chronic severe traffic problems, as it might elsewhere, the environmental benefits of BART compared to its most likely alternative would have been much greater. In the absence of such an alternative the localized, predominantly adverse effects of BART facilities and operations were its only environmental impacts.

### Principal Environmental Impacts

**BART's dominant impacts have been its disruption of traffic and related activities during construction, the noise of its trains in quiet residential areas, and traffic and parking problems around suburban stations.**

In Chapter III it was shown that during construction, environmental impacts were most severe around the downtown subway stations and other cut-and-cover portions of the subway line. These impacts included the shifting and restriction of both vehicular and pedestrian travel. Such inconveniences lasted for over five years in some locations and may have contributed to the loss of business by merchants dependent on pedestrian shoppers. At suburban stations, residential dislocation and land clearance for the parking lots were disruptive, as was the truck traffic in and out of these locations. Construction impacts along above-ground lines were minor.

As described in Chapter IV, the main environmental impact along BART's lines since the start of service operations is train sound along aerial trackways in quiet residential areas. Smaller impacts were also found along aerial trackways, such as blockage of view, creation of shadows, and intrusion on privacy, but residents were mainly concerned with train sound. At-grade trackways have quieter, acceptable sound levels and present no other significant problems. No adverse environmental effects of subways, once completed, were found.

The "linear park" built by BART beneath several miles of aerial trackway is appreciated; but at the same location, many people are disturbed by the noise of passing trains. Another major environmental benefit of BART is the provision of plazas for public use at several downtown station entrances. Additional street and sidewalk improvements (decorative paving, tree planting, street furniture, and improved lighting) resulted from the cooperation of BART with local jurisdictions during system construction.

At suburban stations most residents interviewed rated the appearance of BART facilities as good, even though the large structures and parking lots contrast in scale with their residential surroundings. Irritation with BART station traffic and overflow parking, however, was widespread wherever such problems occurred; the findings indicate that this is perhaps the system's worst environmental impact.

Environmental impacts to date arising from nearby land use changes possibly related to BART (Chapter V) were generally found to be quite small. Except in downtown San Francisco, little change has taken place. In San Francisco existing environmental impacts due to the area's dense development were extensive; hence, additional impacts of BART-associated development changes had little significance.

BART's environmental impacts extend inward to its users, as well as outward to nearby residents and others. Effects on BART users, as described in Chapter VI, are largely positive. The facilities are well designed and generally simple to use, and the travel experience is pleasant and safe. The system's continuing mechanical problems affect its reliability (though to a lessening degree as system maintenance procedures improve); this results in some confusion and discomfort, as well as inconvenience to waiting patrons. Some deficiencies are also evident in provisions for new or disabled users.

In the future, as analyzed in Chapter VII, BART's direct environmental impacts will continue at about the current level, except that parking and traffic problems will probably spread to several additional stations now nearing their parking capacity. This will affect both BART users and nearby businesses and residents. Corrective actions now planned or foreseen may somewhat ease these problems. BART equipment reliability will improve, making the travel experience more positive; no other major improvements (aside from additional parking) to mitigate environmental impact are planned. Land use changes due to BART will probably occur but are likely to be small. Their environmental impacts may be largely beneficial but will not be dominant in comparison with the system's direct environmental impacts.

## Determinants of Impact

**Subway station construction, the use of aerial trackways and high-speed trains in quiet neighborhoods, and unexpectedly high proportions of arrivals at stations by automobile have been the main causes of BART's environmental impacts.**

In general, BART's environmental impacts were not found to be caused by any single factor such as the use of aerial trackways. Most impacts resulted from combinations of factors involving not only BART, but also the nature of the specific environment at any point. Because of differences in the sensitivity of environments traversed, a particular BART attribute (such as aerial trackway) did not always lead to the same impact.

During construction the most disruptive impacts occurred where BART's lengthy cut-and-cover subway construction operations occurred on streets which had large vehicular and pedestrian traffic volumes. Although other considerations dictated BART's subway locations, if the downtown lines and stations had followed less busy streets these impacts could have been much less severe. Faster construction methods could also have mitigated impacts.

Construction impacts at suburban stations with parking lots were substantial in quiet residential neighborhoods. These impacts included noise, dirt, and dangers to children and others.

Since BART operations began, the only environmental problems at stations (overflow parking and related traffic) have been caused by a combination of inadequate feeder bus service and other station access alternatives to the automobile, a shortage of parking at several stations, and location of stations in residential neighborhoods and other areas not able to absorb the additional parking and traffic demand without disruption. This problem has occurred despite the fact that BART patronage is still much lower than that for which the system was originally designed. For patronage to expand significantly, improvements must be made in all modes of station access. BART is now undertaking a major study to define such improvements for implementation.

Noise impacts along the aerial lines occur only where trains travel at high speeds in quiet neighborhoods. At slower speeds or in non-residential areas noise is not a problem. If BART trains were noisier this would be a problem along more of the aerial line and along the at-grade trackways in residential areas.

Other adverse impacts of BART facilities have been relatively small because of factors such as high-quality architectural design; landscaping and linear parks; and extensive use (or paralleling) of existing streets, freeways and railroad rights-of-way by the BART lines. The generally excellent effect on the traveler is also due to the high quality of facility design, although some improvements in user-oriented details, such as provisions for disabled persons, fare processing and traveler orientation, are warranted.

## Distribution By Location

**During BART construction the most serious environmental impacts occurred within a few hundred feet of most of the stations. Since operations began, two kinds of locales have been affected—where an aerial line runs through a quiet residential neighborhood, a 500-foot band on either side of the track is affected; where parking capacity at a station is inadequate, areas up to four blocks from the station are affected.**

As shown in Chapter III, the heaviest adverse impacts during construction occurred around the nine subway stations in busy downtown areas. Smaller but significant impacts occurred at the remaining five subway stations, along the four miles of cut-and-cover subway line, and at the 15 above-ground stations which adjoin residential areas. Areas adjacent to above-ground lines were only slightly affected. In general, effects were limited to residences in the blocks adjoining the construction sites, although many of the travelers who passed through the affected areas (and who were likely to be inconvenienced by the construction activity) had origins and destinations elsewhere.

During BART's operations to date, significant adverse impacts appear to be limited to seven stations and about seven miles of the aerial line. The seven stations affected are those with overflow parking. The aerial line segments involved are those in quiet residential areas with noise impacts. Along these line segments the affected area extends no more than 500 feet from the trackway. At the stations the size of the area affected depends on the amount of parking overflow and available on-street parking; the radius of the area affected varies from one to about four blocks.

The subway station areas which sustained the worst construction impacts now enjoy the benefits of BART's public plazas and related downtown street improvements and have no continuing adverse effects. Conversely, the aerial line segments which now have the worst noise impacts had only minor disruption during construction. In contrast, most of the suburban station areas which now have parking overflow problems were also among those which had some problems with noise, dirt and truck traffic dangers during construction.

The proportion of the system's line mileage and station areas which were temporarily affected by BART constructjon is greater than that adversely affected by operations. However, the importance of BART's continuing operational impacts is evident in the size of the areas affected by parking overflow at stations (up to four blocks away from each of seven stations) and by aerial trackway noise (seven miles long by 1,000 feet wide).

## Population Affected

**While the residential population exposed to BART's environmental impacts is large, fewer than about 10 percent of the persons living within the potential impact zones around the lines and stations continue to be adversely affected. About one-third of those affected are ethnic minority members.**

In the earlier chapters on BART's impacts during construction and operations, estimates of the residential populations affected were presented. For various construction impacts these totaled about 38,000 persons. For substantial adverse impacts of the system's operations, the homes of as many as 13,000 persons may be affected; about 5,000 of these were also subjected to construction impacts and are included in the 38,000. This yields a total of some 46,000 persons whose homes may have been adversely affected to some significant degree.

The zone of potential environmental impact around BART was determined to be approximately 500 feet from all the lines and subway stations and up to one-quarter mile from the stations with parking. In 1970 the total population in this zone was approximately 180,000. A comparison of this population with that adversely affected indicates that about one-fourth of the population "within range" of BART's possible impacts may have been actually affected.

Most of this population experienced the adverse effects of construction. For operational impacts a much smaller proportion of the population may be affected. The 1970 population within 500 feet of BART's above-ground lines and stations with parking (i.e., excluding subway lines and stations) was about 150,000. The estimated 13,000 persons who may have been exposed to the impacts of BART operations are less than ten percent of the population within range of such impacts. Even this estimate should be tempered based on the results of the study's survey of residents exposed to BART's impacts. Only about half of the respondents who were exposed to noise or parking impacts actually reported them to be objectionable. Thus, although BART's impacts fall on considerable numbers of people, the numbers are small in comparison to the 150,000 persons who could have been affected if BART had been less carefully designed and located.

It is also apparent from the findings reported earlier that although minority and low-income groups do not bear a large share of BART's current environmental impacts, such groups were adversely affected by the system's construction in disproportion to their numbers. While most of the system is in middle-income, low-to-medium-density, non-minority areas, the high density of minority and low-income populations in the relatively small BART subway areas has resulted in large numbers of these people being exposed to impacts.

A tradeoff between construction and operational impacts is evident from these results. In contrast to the larger suburban middle-class populations now experiencing impacts along BART's aerial lines and around outlying stations, subway-area residents now remain free from undesirable environmental impacts and enjoy the benefits of BART-associated public plazas and street improvements.

## IMPLICATIONS

This section seeks to combine and interpret the key findings and conclusions in light of major strategic decisions to be made where rapid transit is considered as a possible solution to urban transportation problems. These include issues such as:

- What are rapid transit's likely costs and benefits?
- Where should lines be located and what is their best configuration?
- Where are stations best located and what is their best configuration?
- What kind of service should the system offer?

These are complex issues, and environmental impact is only one factor in each of them. **The implications which follow deal only with environmental impact** and may themselves affect other important factors such as cost, level of transit service, and patronage. Tradeoffs among these must be made in the local planning process. These implications, along with the more detailed findings and conclusions already presented, are not recommended rules, but rather provide an environmental perspective for decision-makers to consider. Together with other perspectives, these environmental implications should help in making informed trade-offs among the many factors in transit development.

### Likely Environmental Impacts

In early assessments of costs and benefits an indication of the likely degree and nature of environmental impact to be expected should be useful in reducing uncertainty. It is apparent from the BART experience that the environmental impacts of a new rapid transit system can be kept to a relatively low level. There appears to be little likelihood of impact on the natural environment if only because significant natural areas are unlikely to be found in dense urban areas where rail transit systems are most likely to be located. Consequently, most impacts to be expected are those affecting the area's people, particularly the disruptive effects of construction, the noise of trains, and danger and inconvenience to residents due to overflow parking. In contrast, impacts on neighborhood and regional air quality appear to be insignificant.

The environmental impacts of the construction process must be given particularly close attention, for they can affect many people and last several years at any one place. This is especially true for subway construction. Many low-income and minority persons, because of their location in densely populated central city areas, may be especially inconvenienced by subway construction.

The extent of impact occurring after construction is completed can be expected to vary widely by location, although with careful siting and design such impacts can be kept to a low level. Train noise and visual intrusion of guideways may be problems in residential neighborhoods, although they can be avoided as described in the conclusions. It is crucial that station access by all modes be provided; if provisions are inadequate, both transit patrons and nearby homes and activities will be adversely affected.

An even more important determinant of the overall level of impact is the set of transportation options available. If by building a rapid transit system other major environmental disruptions are avoided (such as building a major freeway addition), the result may be environmentally favorable, even though the system itself has some adverse effects. The hypothetical alternative to BART used in this study led to the conclusion that BART effects were to a small degree adverse. Elsewhere the balance may be much different. What the BART experience shows, however, is that even without such "benefits by avoidance," environmental impact need not be a major obstacle to the development of a rail transit system.

The time stream of environmental impact seems to be reasonably predictable. Construction impacts may affect the most people and last long enough to cause hardship. Impacts of service operations apparently develop quite rapidly upon the start or major expansion of operations. A period of adjustment to initial problems then follows, perhaps lasting several years. BART, for example, has made continual improvements in its station parking, as well as overall service reliability, and feeder bus service has been progressively increased. Impacts will continue to change, but at a slow rate and with only marginal effects.

Environmental benefits may also increase over time. In particular, some concentration of new land development may occur near the stations with associated reductions in the conversion of rural land resources, the cost of public services, and the problems of transportation. However, if the BART experience is a guide, such benefits are likely to be small and slow in appearing unless new ways of encouraging such development are found.

**Line Location and Design**

In the location and design of trackways, decision-makers can anticipate and minimize environmental problems through knowledge of a few factors. Among the most influential factors in determining impact are adjacent land uses, right-of-way width, and trackway configuration.

Low-density residential areas are highly susceptible to adverse environmental impact, particularly if they are not already accustomed to the sounds and visual effects of a major arterial street, railroad or freeway adjoining the proposed track alignment. If the right-of-way is narrow, people living in homes very close to the trackway are likely to be unhappy about the system's impacts. Subway construction can be expected to be disruptive to those living or working within a couple of blocks, but subway lines have no continuing adverse effects; in contrast, above-ground lines—particularly aerial trackways—have little construction impact but can cause substantial and perpetual problems with sound and visual intrusion in residential areas.

Clearly, these factors interact. From an environmental perspective, traversing of a quiet residential neighborhood with an aerial trackway on a narrow right-of-way without other major parallel transportation facilities should be avoided. There are several options for impact reduction in such cases. The line might be moved a short distance out of the residential area or into an existing transportation corridor, a wider right-of-way might be purchased, or a different line configuration might be used. Wherever possible, compensatory benefits such as BART's linear parks should be considered for use in residential areas. One configuration option worth consideration is the open-top subway used extensively in Toronto. This option avoids the sound and visual problems of aerial trackway and the barrier effects of at-grade lines, encourages joint development of the right-of-way, and is cheaper and faster to build than a full subway.

Since subways are likely to be necessary in heavily built-up areas, the relatively heavy construction impacts should be anticipated by careful planning and coordination with local officials. Where feasible, tunneling and the most rapid open-cut construction methods should be used. Periods of construction could be reduced through 24-hour, seven-day-week operations. Mid-block or full-block offsets of the route from heavily traveled or commercial streets could also be considered. There should be planning jointly with local merchants to seek ways for minimizing or compensating for economic damage to their businesses.

## Station Location and Design

Decision-makers should be aware of the environmental consequences of the station design and location options open to them. Changes in these factors could mean the difference between highly adverse impacts and none at all.

Adequate provisions for access to stations by car, bus and other modes are essential; at the same time, the surrounding neighborhood must be protected from the undesirable effects of increased traffic. The BART experience shows that this is possible, although results are varied among BART stations. In general, stations in bus-oriented downtown areas have few problems. Impacts at stations are most severe when the location is a low-density residential area poorly served by arterial streets from its potential tributary areas or already congested with parking and traffic.

Stations at the ends of lines, which typically attract automobile traffic from large feeder areas, are particularly critical potential problem areas requiring specially careful attention to access, circulation, and parking. These problems can be so severe, as they were initially at Daly City, that their impact is propagated to adjacent stations, which in turn experience overflow parking pressures.

Locations outside or at the edges of residential neighborhoods are environmentally preferable to sites surrounded by homes. In busy retail centers as well as quiet residential locations, however, adequate parking and bus access are paramount. This places a heavy responsibility on the planners, whose forecasts of station patronage must be backed by a commitment to provide and encourage the use of the buses, parking, and other access facilities they stipulate. If automobile access is to be discouraged by policy in favor of feeder buses, then the buses must provide a reasonable level of service to the expected users.

Several design-related factors are also important at stations. BART's excellent architecture was appreciated by nearby residents and others, and may have contributed to their lack of concern with the large size of BART structures in small-scale residential areas. Still, if the above-ground structures could be smaller the effect on neighborhoods could be even better. BART's architectural design also shows that there need be no significant adverse effects on the system's users.

The layout and location of parking lots are also important. Their entrances and internal circulation patterns can be planned to eliminate most problems. Landscaping can help significantly in softening the impact of these large open spaces. Nearby residential streets can often be protected from transit-related traffic and parking by combinations of traffic diversion barriers and parking regulations, in addition to provision of proper arterial access routes, lot entrances, and adequate lot capacities.

### System Operations

Environmental impacts vary with different intensities of transit operations as measured by train speed, headways, and hours of service. Decisions to provide very fast, frequent or late-night services such as BART's must be made with full awareness of their environmental implications. Along lines the main concern is with train sound. BART's acoustic impacts would be virtually eliminated with slower train speeds, even at the three- to five-minute frequencies planned for the future. The effects of night service tend to be slightly more adverse because of lower nighttime ambient sound levels; these should be evaluated separately in environmental assessments for planned systems. Although sound barriers or other sound attenuation devices were not evaluated in this study, they represent an additional alternative for reducing sound levels.

At stations, increases in patronage which may come with faster or more frequent service can be expected to affect the level of environmental impacts. As noted, these impacts are primarily due to overflow parking and traffic. In patronage forecasting particular care should be given to identifying the likely sensitivity of station patronage levels to changes in service. Where this sensitivity is high, consideration should be given to design provisions which offer future flexibility (e.g., early purchase of land for additional parking spaces) in meeting potential system service changes.

## A FINAL WORD: THE ROLE OF ENVIRONMENTAL CONSIDERATIONS IN TRANSIT DEVELOPMENT

This BART Impact Program study confirms the importance of environmental considerations in the selection, planning and design of public transit systems. The BART experience has demonstrated that the adverse environmental impacts of a rapid transit system can be kept small; the large residential population living within the area of potentially adverse impacts has illustrated the importance of efforts to minimize these impacts.

Some environmental impacts were avoided by BART or could be avoided in future systems, often at little cost and with no other adverse effects. Reductions of some other impacts were shown to involve substantial tradeoffs requiring increased cost, impaired travel service, or heightened levels of other adverse effects. Here local priorities must rule.

In addition to such tradeoffs, variations in local circumstances were found to be instrumental in determining the nature and extent of rapid transit-generated environmental impacts. Most notable are the offsetting environmental effects of alternative transportation strategies, including the "do-nothing" option. Also important is the degree to which the rapid transit system affects development and land use, with corresponding indirect environmental effects. In the BART case both of these factors were judged to be of only small environmental consequence, but elsewhere either could be pivotal in the selection of a regional transportation strategy.

The final report of the BART Impact Program will draw from the conclusions of all its component studies, including this one, to make tradeoffs among the various impacts more explicit. Even without this synthesis, however, the Environment Project's results and interpretations as presented in this report help to illuminate and simplify the consideration of environmental impacts in planning for new transit systems. In addition, the study provides new technical guidance for future impact assessments. Most important, through its evidence of what has actually happened with one pioneering rapid transit system it promotes informed and constructive participation of the public and its various representatives in the negotiation of effective and equitable solutions to regional transit problems.

# ENVIRONMENT PROJECT DOCUMENTATION

The reports produced by the BART Impact Program's Environment Project are listed below, each with a brief content description. Unless otherwise noted, these reports are available to the public through the National Technical Information Service, Springfield, Virginia 22151. Report numbers for ordering are shown in parentheses.*

### ENVIRONMENTAL IMPACTS OF BART: FINAL REPORT (DOT-BIP-FR 7-4-77)

Presents the results and accomplishments of the Environment Project, summarizing the assessment of BART's current environmental impacts (including direct wayside impacts as well as indirect impacts and effects on the system's patrons). Describes and evaluates BART's construction impacts and possible future impacts associated with the system's full-service level of operations.

### ENVIRONMENTAL IMPACTS OF BART: INTERPRETIVE SUMMARY**

Summarizes the findings of the Environment Project: BART's direct environmental impacts and the responses of those affected, the effects of construction, the indirect effects of land use changes and development near BART stations, and BART as an environment for its patrons.

### RESPONSES OF NEARBY RESIDENTS TO BART'S ENVIRONMENT IMPACTS (DOT-BIP-TM 25-4-77)

Documents residents' perceptions of and responses to BART impacts through analysis of data from a home interview survey of 700 persons living in ten case study sites within about four blocks of BART facilities (lines and stations).

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* DOT = Department of Transportation; BIP = BART Impact Program; FR = Final Report; TM = Technical Memorandum; WP = Working Paper; WN = Working Note; PD = Planning Document.

** Available through the Metropolitan Transportation Commission, Hotel Claremont, Berkeley, California 94705.

## INDIRECT ENVIRONMENTAL IMPACTS (DOT-BIP-TM 24-4-77)

Documents recent development and land use changes caused or contributed to by the BART system and assesses the associated impacts through station-area case studies. Also describes four street improvement projects associated with BART construction.

## THE USER'S EXPERIENCE (DOT-BIP-TM 23-4-77)

Presents the findings of the Environment Project's study of the BART travel experience—the effects of BART as an "environment" for its patrons.

## METHODOLOGICAL REPORT—RESPONSES OF NEARBY RESIDENTS TO BART'S ENVIRONMENTAL IMPACTS (WN 4-4-77)*

Describes the procedural details of the home interview survey which was the basis for the technical memorandum entitled "Responses of Nearby Residents to BART's Environmental Impacts," including descriptions of the survey sample and its selection procedure, the development of the survey instrument and its pretesting, and the editing, coding and data processing of the survey data.

## PHASE II COMMUNITY MONITORING (WN 3-4-77)*

Presents information on community responses to BART impacts. Data sources include BART comment files and interviews with BART riders and key informants (media and real estate personnel).

## PHASE II ADDENDA TO DIRECT IMPACTS (WN 2-4-77)*

Supplements assessments made in Phase I of BART's direct environmental impacts, considering changes in BART's operations and service, changes due to the passage of time and the availability of new data, and from new impact categories discovered since the original studies. Includes findings on BART-related acoustics, air quality, safety and security, television interference, and electrical current leakage.

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* MTC internal working paper available at the offices of the Metropolitan Transportation Commission.

## PHASE II PROJECT IMPLEMENTATION PLAN (PD 20-4-75)*

Presents a management-oriented framework for the Environment Project's Phase II work scope, including descriptions of work elements, work flow diagrams, required resources and their utilization, major milestones, proposed documents, project schedule, and plans to coordinate with other BART Impact Program projects and activities.

## INTERPRETIVE SUMMARY: THE ENVIRONMENTAL IMPACTS OF BART, INTERIM SERVICE FINDINGS (JULY 1976)**

Summarizes the interim findings of the Phase I work of the Environment Project; intended for public officials and others who have a general interest in transportation systems and their effects.

## ENVIRONMENTAL IMPACTS OF BART: INTERIM SERVICE FINDINGS (DOT-BIP-FR 2-4-75)

Documents the interim results of the Environment Project's initial study phase (April 1974-January 1976). Includes technical findings on BART's immediate effects on the physical environment: what aspects of the environment are affected, causes of impacts, where impacts occur, who is affected, and implications for other urban areas considering fixed-rail transit systems.

## IMPACTS OF BART ON THE SOCIAL ENVIRONMENT: INTERIM SERVICE FINDINGS (DOT-BIP-TM 19-4-76)

Discusses the social impacts of interest to the Environment Project, those which affect personal interactions in the vicinity of BART's physical facilities, including BART's effects on privacy, barrier effects, impacts on safety (against bodily harm) and security (against threats to persons or property).

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* MTC internal working paper available at the offices of the Metropolitan Transportation Commission.

** Available through the Metropolitan Transportation Commission, Hotel Claremont, Berkeley, California 94705.

**IMPACTS OF BART ON VISUAL QUALITY: INTERIM SERVICE FINDINGS (DOT-BIP-TM 18-4-77)**

Presents Phase I visual quality assessment findings on the effects of BART on the adjacent visual environment in terms of appearance, illumination, and shadows. Includes discussions of regional and local visual impacts.

**IMPACTS OF BART ON THE NATURAL ENVIRONMENT: INTERIM SERVICE FINDINGS (DOT-BIP-TM 17-4-76)**

Documents the study of BART impacts on the natural environment, including biota (wildlife and vegetation), soils and geology, and drainage and water systems.

**ACOUSTIC IMPACTS OF BART: INTERIM SERVICE FINDINGS (DOT-BIP-TM 16-4-76)**

Presents the findings and methodologies of the study of BART sound and vibration, focusing on the delineation of impacted regions, major factors affecting BART-generated sound, prototype versus operational sound levels, BART versus other transportation sound sources and BART-generated vibration levels.

**IMPACTS OF BART ON AIR QUALITY: INTERIM SERVICE FINDINGS (DOT-BIP-WP 20-4-76)**

Documents the findings and methodologies of the study of BART's atmospheric impacts (local and regional air quality and microclimate) in terms of regional air pollutant emissions CO, RHC, $NO_x$), station-area carbon monoxide emissions, and changes in wind direction and velocity.

**ANALYSIS OF PRE-BART URBAN RESIDENTIAL ENVIRONMENT SURVEY (DOT-BIP-WP 24-4-76)**

Presents an analysis of a 1972 home interview survey of 2,451 persons living near BART after most of the system's construction but before its operation. Emphasizes tests of the significance of relationships between perceived (or anticipated) environmental impacts of BART and hypothesized determinants of actual impacts (including BART characteristics, physical setting, and respondent characteristics).

## THEORY BACKGROUND FOR STUDY OF BART'S IMPACTS ON HUMAN PERCEPTION AND RESPONSE (DOT-BIP-WP 23-4-76)

Reviews behavioral science literature relevant to human perception and response and outlines a conceptual model of the impact process which includes the element of human response and its determinants.

## ENVIRONMENT PROJECT COMMUNITY MONITORING (DOT-BIP-WP 22-4-76)

Presents information on the general nature of community concerns for and responses to BART.

## BART AND ITS ENVIRONMENT: DESCRIPTIVE DATA (WN 1-4-76)*

Describes the characteristics of BART and the surrounding environment hypothesized to be the major determinants of impact.

## ENVIRONMENT PROJECT RESEARCH PLAN (PD 9-4-75)*

Presents the technical approach used in the assessment of BART's environmental impacts, complementing the Phase I and Phase II management-oriented work plans. Discusses Project objectives, issues to be addressed, conceptual structure of the study, strategy and methods of study, impact measurement techniques, approaches to impact assessment, and applicability of the study's findings to other locations.

## PHASE I WORK PLAN (PD 4-1-74)*

Presents the management framework for Phase I of the Environment Project, including work flow, milestones, deliverables, utilization of funding and resources.

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* MTC internal working paper available at the offices of the Metropolitan Transportation Commission.

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