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# The Rail Transit/Land Use Synergism--Case Study of the San Francisco Bay Area

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In the San Francisco Bay Area, there has been an increased focus upon the expansion of rail transit systems as a solution to the region's transportation ills. Due to the predominance of relatively low density land uses in the Bay Area, the following will be presented: a brief overview of the extent and history of the rail transit systems in the Bay Area ; a discussion of the increasing importance of rail transit in California and the Bay Area; an overview of the relationship between land use density and rail transit options; an identification of the possible rail options that can be supported by the existing and projected land use densities in the Bay Area; a discussion of strategies which may be followed to continue to successfully and efficiently implement rail transit options in the future in the Bay Area.

Future population forecasts indicate that the Bay Area as a whole will be de-densifying over the next fifteen years. Therefore, comprehensive strategies should be implemented to strengthen the existing urban core throughout the Bay Area and focus future zoning strategies on strengthening existing rail corridors. Because of the proven rail transit/land use synergism, it is imperative to gain a better understanding of these issues and implement appropriate policies. A continuing discussion of these broad issues is necessary and encouraged. In order to maintain an overall effective and affordable direction in the planning and implementation of rail transit infrastructure, this dialogue must be brought to the forefront.

## INTRODUCTION

The San Francisco Bay Area (Bay Area) is considered to be made up of nine Counties: San Francisco, San Mateo, Santa Clara, Alameda, Contra Costa, Solano, Sonoma, Napa, and Marin (see Figure 1). In the Bay Area, the combined effects of new congestion management requirements, tough air quality regulations and the imminent completion of probably the last of the major freeway expansion projects result in an increased focus upon the expansion of rail transit systems as a solution to the region's transportation ills. A large portion of the development in the Bay Area has occurred during a period when the automobile has functioned as the dominant mode of transportation. A variety of factors, including the dominance of the automobile, local density and height restrictions, and the public's appetite for suburban-style single family housing, has brought about low density development in the Bay Area. Low density land use is not particularly conducive to efficient and successful operation of transit systems.

The Bay Area currently is home to one rapid rail system, one commuter rail system, two light rail systems and one intercity rail system. The five rail transit systems include the Bay Area Rapid Transit system (BART), the CalTrain Peninsula Commute Service, the San Francisco Municipal Railway (MUNI) Light Rail system, the Santa Clara County Transportation Agency's Light Rail system and the recently inaugurated Amtrak *Capitols* between San Jose and Sacramento. The Bay Area and the locations of these systems are shown in Figure 1.

The purposes of this paper are to review existing material on the relationship between land use density and rail transit demand, and to evaluate the optimum rail transit alternatives which could potentially be supported in the Bay Area, based on present and forecasted land use density. This broad view of urban rail transit could serve to identify some of the possible directions that may be taken to ensure efficient and effective land development and investment in rail transit infrastructure.

Land use density is only one of a number of factors that impact the success and efficiency of rail transit. But, a review of which ranges of land use density are appropriate for various rail transit options provides a good perspective on windows of opportunity for implementing and expanding rail transit systems. In subsequent sections of the paper, the following will be presented:

- A brief overview of the extent and history of the rail transit systems in the Bay Area as well as planned extensions.

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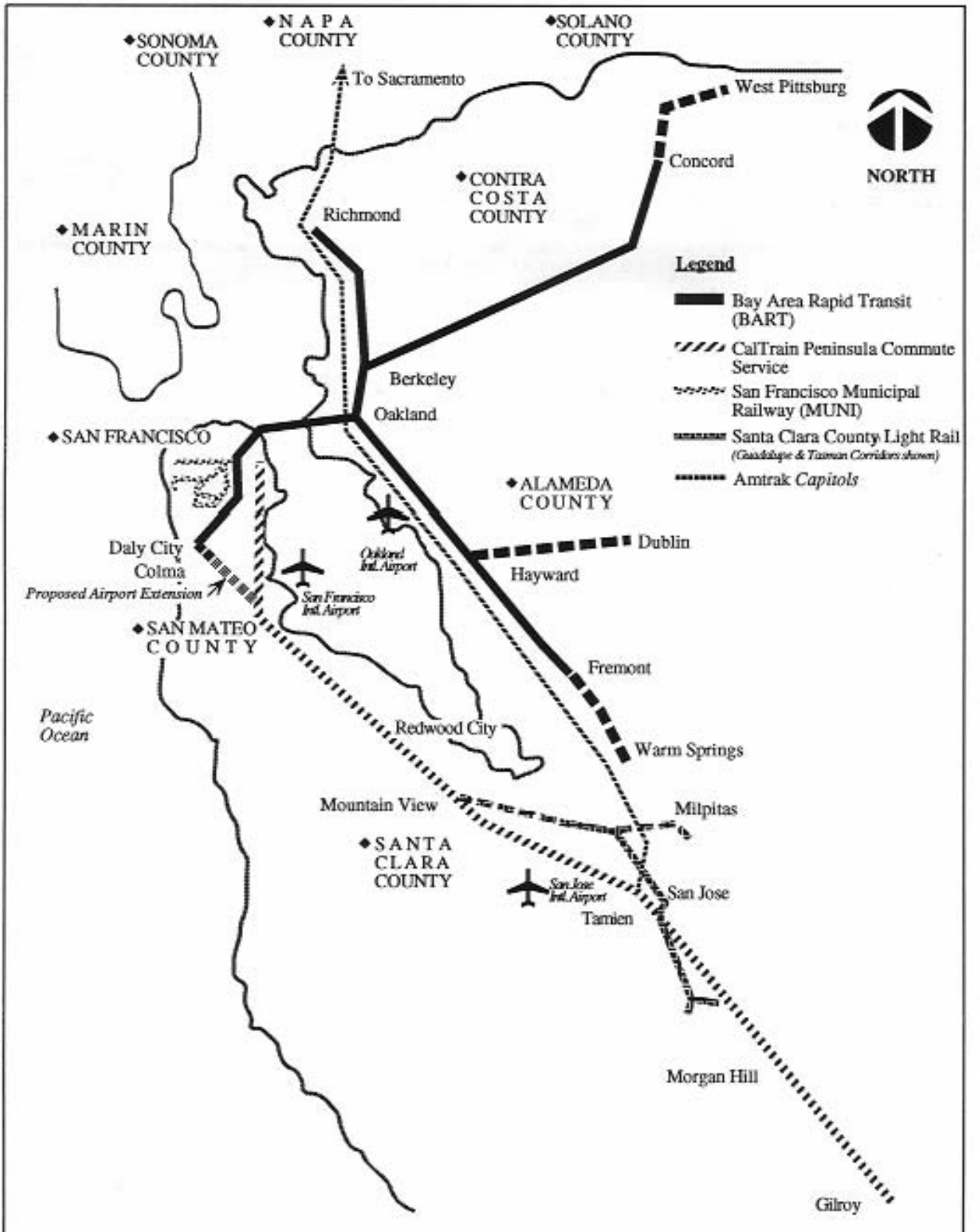
**FIGURE 1 • EXISTING BAY AREA RAIL TRANSIT SYSTEMS**




**BAY AREA RAIL TRANSIT SYSTEMS**

- A discussion of the increasing importance of rail transit in California and the Bay Area.
- An overview of the relationship between land use density and rail transit options.
- An identification of the possible rail options that can be supported by the existing and projected land use densities in the Bay Area.
- A brief discussion of strategies which may be followed to continue to successfully and efficiently implement rail transit options in the future in the Bay Area.

## BACKGROUND - RAIL TRANSIT IN THE BAY AREA

The discussion of the current generation of rail transit systems in the Bay Area will begin with a brief description of the development of the BART system.

Preliminary planning for the BART system essentially began as early as 1920 when George Goethals, the builder of the Panama Canal, proposed constructing an underwater tube connecting San Francisco to the East Bay. Then in 1947, a joint Army-Navy report was issued, again recommending an underwater tube to relieve traffic congestion on the San Francisco-Oakland Bay Bridge. In 1957, the BART District was formed, and plans included a vision for a 482.8-kilometer (300-mile) system encircling San Francisco Bay, providing a continuous rail link through the nine Bay Area counties. Funded by sales tax, property tax and bridge tolls, five Bay Area counties initially joined the BART system: San Francisco, Alameda, Contra Costa, San Mateo and Marin. San Mateo and Marin withdrew in 1962. The first BART service began in 1972, and by 1974 the 115.1-kilometer (71.5-mile) system was in place, extending from Daly City to Concord, Richmond and Fremont, and a 5.6-kilometer (3.5-mile) light rail tunnel (MUNI Metro) in San Francisco. In 1988, the voters of San Mateo County voted to contribute $200 million to the West Pittsburg and Dublin Extensions in the East Bay, in exchange for a 1.6-kilometer (1.0-mile) extension to Colma. Final environmental planning is near completion for a 10.3-kilometer (6.4-mile) continuation to the San Francisco International Airport. In the East Bay, construction of the 12.6-kilometer (7.8-mile) BART West Pittsburg Extension and the 20.9-kilometer (13-mile) Dublin Extension is beginning, and an 8.7-kilometer (5.4-mile) extension to Warm Springs near the Alameda County/Santa Clara County line is in final environmental study.

The CalTrain Peninsula Commute Service extends 75.5 kilometers (46.9 miles) from the terminal at Fourth and Townsend Streets in San Francisco to the Cahill Street station in San Jose, with limited service an additional 32.0 kilometers (19.9 miles) south to Gilroy, in southern Santa Clara County. The San Francisco terminal is located approximately 2.4 kilometers (1.5 miles) south of the heart of the city's financial district, which is the major destination of northbound commuters. This line, the oldest continuously operated passenger railroad in the west, began service in 1864. Southern Pacific owned and operated the system until December 27, 1991, when the San Francisco - San Jose - Gilroy Rail Corridor was purchased by the Peninsula Corridor Joint Powers Board (JPB), a public agency comprised of representatives from San Mateo, Santa Clara and San Francisco counties, now responsible for operation of the system. As of July 1, 1992, Amtrak operates sixty trains per day along the system. An improvement plan is under way, including provisions for grade separations and eventual extension of the San Francisco terminal approximately 2.0 kilometers (1.25 miles) to the Transbay Transit Terminal (TTT), to provide a closer link to BART, MUNI and the financial district.

In addition to the famed cable cars, with 12.9 kilometers (8 miles) of track, the San Francisco MUNI provides bus and LRT service throughout the City and County of San Francisco. Known as the Muni Metro, the 40.2-kilometer (25-mile) LRT system (87.2 kilometers or 54.2 milesof track) shares stations with BART in a subway along Market Street, and extends to the western residential areas. The present LRT system was upgraded from the original trolley system during the time of BART construction. Current plans call for a 4.0-kilometer (2.5-mile) F-Line Extension along the Embarcadero from the Ferry Building to Fishermans Wharf and a 2.4-kilometer (1.5-mile) Muni Turnback and 6th Street Extension along the Embarcadero and Townsend Street, past the CalTrain terminal.

The 33.8-kilometer (21-mile) Santa Clara County Guadalupe Corridor LRT system was completed in 1991, and includes park-and-ride facilities and a transit mall through downtown San Jose. There is a direct link to CalTrain at the newly completed Tamien multimodal station. Preliminary design is complete for the 22.5-kilometer (14-mile) Tasman Corridor LRT system which will expand the Guadalupe Corridor. Santa Clara County has recently adopted their *T2010* Transportation Plan which describes a 201.1-kilometer (125-mile) intra-county light rail master plan, including extensions of the LRT system from downtown San Jose south to Los Gatos along the Vasona Corridor (16.1 kilometers or 10 miles) and from the eastern terminus of the Tasman project south along the Capitol Avenue Corridor (20.9 kilometers or 13 miles). Santa Clara County is not a part of the BART system. There are preliminary studies in progress looking at the feasibility of extending BART from Warm Springs 17.7 kilometers (11 miles) south to downtown San Jose. In the

absence of BART in Santa Clara County, the light rail system is receiving the majority of attention.

Amtrak has recently inaugurated limited commuter rail service between San Jose and Sacramento. Dubbed the *Capitols*, with three passenger trains per day in each direction, this service has exceeded ridership forecasts and has the potential to provide connections to BART stations in Alameda and Contra Costa Counties.

The rail transit network in the Bay Area is dominated by BART and is augmented and fed by many bus services. In 1988, the Metropolitan Transportation Commission (MTC) enacted Resolution 1876 in order to integrate the rail systems of the Bay Area and "set forth the New Rail Transit Starts and Extensions Program." (4) The current grouping of five relatively independent rail transit systems is not yet fully integrated.

For many people, the concept of BART Around The Bay is very promising. Completing the Fremont - San Jose link and extending BART through Marin, Napa, Sonoma and Solano Counties would be crucial to achieving this milestone. Certainly, BART plays the leading role in the family of Bay Area rail transit systems. San Mateo County has made a strong commitment to BART with the Colma Extension currently under construction and the planned continuation through South San Francisco and San Bruno to the San Francisco International Airport. San Mateo County has also made a firm commitment to the CalTrain downtown extension. As of yet, San Francisco and Santa Clara Counties have not echoed this commitment to the downtown extension with funding assistance.

## INCREASING IMPORTANCE OF RAIL TRANSIT IN CALIFORNIA

The Loma Prieta Earthquake of October 1989 drew attention to the necessity of public transit systems. Earthquake damage caused the closure of certain freeway links, leading to increased BART ridership. Pre-earthquake daily average ridership stood at 224,000. Immediate post-earthquake ridership increased to an average of 314,000 for November 1989, with a highest day ridership of 357,000. Since then, the sustained post-earthquake ridership has been approximately 250,000. The earthquake also precipitated a temporary extension of CalTrain south to Salinas. Since 1989, portions of freeways have remained closed for repairs and short sections have been demolished. The momentum towards greater public transit service in the Bay Area seems to be increasing.

Several counties in the Bay Area are in the midst of ambitious self-help highway expansion programs, which some have dubbed as being the last of their breed. Beginning with Santa Clara County's *Measure A* one-half cent sales tax, passed by voters on November 6, 1984, San Mateo, Alameda and Contra Costa Counties have followed with similar programs. In Santa Clara County, the *Measure A* freeway expansions and completions may mark the end of major freeway capacity improvements in Silicon Valley. San Mateo County's sales tax program includes the addition of auxiliary lanes and improvement of interchanges, with no major freeway capacity additions. The ambitious programs in Alameda County and Contra Costa County include major freeway expansions, many of which are presently under construction or in planning and design stages.

Combined with the major freeway construction programs currently underway are the transportation planning and development measures included as parts of State Proposition 111, a gasoline tax measure for statewide highway projects, and Proposition 108, a rail bond measure, approved by California voters in June, 1990. With the propositions came the requirement that California's urban counties designate a congestion management agency (CMA) to prepare, implement and annually update a congestion management program (CMP). The function of a CMP is to develop a procedure to relieve or manage forecasted roadway congestion and to ensure that "federal, state, and local agencies join with transit districts, business, private and environmental interests to develop and implement comprehensive strategies needed to develop appropriate responses to transportation needs." (1)

The Bay Area is classified as a nonattainment area for ozone and carbon monoxide under the Federal 1990 Clean Air Act Amendments. In addition, the Bay Area is classified as a severe nonattainment area for ozone and carbon monoxide under the 1989 California Clean Air Act. Because motor vehicle use contributes a large share to Bay Area air pollution, MTC has enacted Resolution 2270. This states that a major transportation project must demonstrate that when completed, there will be fewer and less severe violations of the 8-hour National Ambient Air Quality Standards (NAAQS) for carbon monoxide than there would be if the project were not built. There will be a need to reduce automobile travel and to reduce the use of single-occupant vehicles if current air quality standards are to be met. (2)

It has been shown through recent voter behavior, public opinion polling and rider behavior that rail transit is experiencing a renaissance in the Bay Area and in California as a whole.

Passenger rail, "formerly viewed as a novelty, is emerging as California's new choice of transportation." (3) Environmental regulations have determined many transit decisions; and particularly in California, the high right-of-way and construction

costs for building additional lane miles of freeway have encouraged consideration of transit options.

The success of the San Diego Trolley South Line (1982) helped spawn the recent interest in rail transit in California. The creation of a successful system without Federal funding, using an existing rail right-of-way caught a lot of attention. Also, the Sacramento LRT, built at only $6.0 million per kilometer ($9.6 million per mile), has exceeded ridership projections. Ironically, Los Angeles is notorious for the dismantling of a substantial urban and interurban rail system. In what could be a rail revival, plans are underway for up to seven commuter rail services on existing rail rights-of-way in Southern California.

## RELATIONSHIP BETWEEN LAND USE DENSITY AND RAIL TRANSPORTATION

The development of the western United States has featured wide open spaces, resulting in comparatively low density urban areas. The general westward movement in the United States was in part inspired by an overall human desire for open space. There is an inherent paradox involved when on one hand, Californians value low density living and on the other hand become enthusiastic about the merits of rail transit as a transportation solution in urban areas. These values conflict with one another when a comparatively low density urban area attempts to apply a transportation solution that by definition relies on relatively high densities for ridership and revenue. Rail transit by nature requires a certain density adjacent to the rail corridor in order to ensure an acceptable ridership level which will in turn fuel revenue. In addition, rail transit requires a destination which is transit accessible, such as a dense concentration of employment and other activity centers. High density corridors traditionally do not exist in the newer American urban areas, especially in the west. This conflict presents an opportunity to examine what possible relationships may exist between land use density and transit alternative applications.

This section will explore previous data which have been compiled in the attempt to draw conclusions from relationships between existing land use density and the viability of public transit. These relationships will be compared to aggregate land use density on a countywide basis in the Bay Area. This comparison will only be made in the aggregate; no attempt is being made to analyze the residential densities present along specific existing or future rail corridors in the Bay Area. It is also recognized that there is a demand-supply interaction; i.e. if rail transit is provided, the adjacent land use densities will change.

In looking at land use density and rail transit options, there must be sufficient density within a rail station's primary service area (usually within a 1.6-kilometer or one-mile radius). There must also be sufficient massing of density in the vicinity of the rail station, primarily within a 0.4 kilometer (one-quarter mile) radius. In addition to high density, there must be groupings of other density levels. Finally, there must be a major destination, which would serve as the magnet for rail transit use. In the Bay Area, downtown San Francisco currently serves as the major destination, with other areas such as Silicon Valley in Santa Clara County, employment centers in Oakland, Berkeley, and eastern Contra Costa County functioning as other attractions.

### Existing Relationships Between Land Use Density and Public Transit Options

A reliable measure for analysis of development density is housing unit density, which is the number of housing units per acre of residential land.(6) Gross population density is also used, which is the total population of a political jurisdiction divided by the total land area within that jurisdiction's boundaries. However, the use of gross population density can be misleading, since each jurisdiction may be composed of varying amounts of vacant land.

There are three variables which affect the difference between housing unit density and gross population density. The first is the percentage of gross acreage devoted to exclusively residential use, which can be between 30 and 70 percent (6); second is the vacancy rate of housing units, particularly of multi-unit dwellings; and third is the number of persons per housing unit.

Pushkarev and Zupan developed a chart which converts gross population density per square mile to a range of housing units per residential acre, calibrated with 1963 and 1970 data from the New York Region. The authors show that these data are also applicable to other American urban areas such as Los Angeles and Dallas-Fort Worth. The authors then compiled population and density data from a number of urban areas in the United States and discovered some general relationships between housing unit density and transit mode use. (6) As urban development density increases, in general, auto use decreases and use of public transit is encouraged. Table 1 shows Transit Modes Related to Residential Density, and indicates that certain levels of residential density adjacent to a transit system/corridor will support implementation of different transit modes.

In general, average residential densities from a number of urban areas in the United States suggest that:

TABLE 1 TRANSIT MODES RELATED TO RESIDENTIAL DENSITY

| Mode | Service | Minimum Density (dwelling units/acre) | Remarks |
|---|---|---|---|
| Dial-a-Bus | Many origins to many destinations | 6 | Only if labor costs are not more than twice those of taxis |
| Dial--Bus | Fixed destination or subscription service | 3.5 to 5 | Lower figure if labor costs twice those of taxis; higher if thrice those of taxis |
| Local Bus | "Minimum," 0.8 km (1/2 mile) route spacing, 20 buses per day | 4 | Average, varies as a function of downtown size and distance from residential area to downtown |
| Local Bus | "Intermediate," 0.8 km (1/2 mile) route spacing, 40 buses per day | 7 | |
| Local Bus | "Frequent," 0.8 km (1/2 mile) spacing, 120 buses per day | 15 | |
| Express Bus--reached on foot | Five buses during two hour peak period | 15 Average density over two square mile tributary area | From 16.1 to 24.1 km (10 to 15 miles) away to largest downtowns only |
| Express Bus-- reached by auto | Five to ten buses during two hour peak period | 3 Average density over 20 square mile tributary area | From 16.1 to 32.2 km (10 to 20 miles) to downtowns larger than 20 million square feet of nonresi-dential floorspace |
| Light Rail | Five minute headways or better during peak hour | 9 Average density for a corridor of 25 to 100 square miles | To downtowns of 20 to 50 million square feet of nonresidential floor space |
| Rapid Transit | Five minute headway or better during peak hour | 12 Average density for a corridor of 100 to 150 square miles | To downtowns larger than 50 million square feet of nonresi-dential floorspace |
| Commuter Rail | Twenty trains a day | 1 to 2 | Only to largest downtowns, if rail line exists |

Source: B.S. Pushkarev and J.M. Zupan. *Transportation and Land Use Policy,* 1977.

- Transit usage is minimal at densities between 1 and 7 housing units per residential acre (units/acre).
- A density of 7 units/acre appears to be a threshold above which total public transit use increases sharply.
- More than half of the trips tend to be made using transit in areas with density above 60 units/acre.
- Reduction in auto trips, total trips per person and increase in transit trips with rising density are most pronounced among middle income households. Low income households only make the most essential trips, experience the least impact to total trips due to rising density and substitute transit trips for auto trips more than others. High income households buy more transportation at any density and experience the least pronounced impact to total trips with rising density. (6)

Auto ownership is reduced by an average of about 0.4 autos per household with a tenfold increase in residential density. In addition, in terms of auto ownership, a nearby rapid transit station can have an effect equivalent to more than a tenfold increase in residential density. This relates strongly to the point that transit demand is related to concentrations of residential uses along a specific corridor. (6)

**San Francisco Bay Area**

In order to arrive at land use densities in a form compatible with those of Pushkarev and Zupan (Table 1), an analysis of Bay Area land use densities was carried out. This analysis examined densities on a

TABLE 2 SAN FRANCISCO BAY AREA HOUSING UNIT DENSITY

| County | 1990 Population | 1990 Housing Unit Density | 2005 Population | 2005 Housing Unit Density |
|---|---|---|---|---|
| Alameda | 1,279,200 | 9.3 | 1,444,600 | 6.4 |
| Contra Costa | 803,700 | 5.3 | 946,900 | 3.9 |
| Marin | 230,100 | 4.4 | 258,400 | 2.6 |
| Napa | 110,800 | 4.5 | 127,400 | 3.2 |
| SanFrancisco | 724,000 | 33.2 | 774,300 | 34.1 |
| San Mateo | 649,600 | 6.9 | 681,900 | 5.1 |
| Santa Clara | 1,497,600 | 6.6 | 1,658,100 | 5.6 |
| Solano | 340,400 | 6.3 | 455,400 | 3.3 |
| Sonoma | 388,200 | 2.5 | 486,000 | 1.9 |

countywide basis, not along specific existing or projected future transit corridors. It therefore primarily examines the question of whether rail transit could be implemented on a much larger scale than is existing or currently planned.

Table 2 shows the Bay Area's Housing Unit Density for each county for 1990, using actual 1990 census population data and residential acreage from the Association of Bay Area Governments (ABAG) *Projections 90.* (10) Table 2 also shows the Housing Unit Density for 2005, based on population and projected residential acreage from *Projections 90.*

Using the 1990 census data for total housing units and the ABAG data for residential area, the 1990 housing unit density was calculated for the nine Bay Area counties. The greatest housing unit density is in San Francisco, with 33.2 housing units per residential acre. The lowest housing unit density is in Sonoma County, with 2.5 housing units per residential acre. The average housing unit density for the nine Bay Area counties for 1990 is 8.8 housing units per residential acre.

Using the 1990 census data, a ratio of population to housing units was calculated for each county. The average number of persons per housing unit is 2.5, assuming no vacancies. The actual ratio for each individual county, ranging from 2.2 in San Francisco to 2.9 in Solano County, is considered to remain constant for the year 2005.

Using the ABAG population projections for 2005, with the constant ratios of persons per housing unit, projections for the number of housing units for each county in 2005 were calculated. The additional increment of land predicted to be available for residential development in the year 2005 was added to the previous residential acreage in each county to obtain projections for total residential acreage in 2005.

To obtain the projected 2005 housing unit density, the 2005 housing unit projections were divided by the 2005 residential acreage. In 2005, the greatest value of housing unit density is projected to be 34.1 units/acre in San Francisco. Much of San Francisco's street pattern along with parcel sizes and density had developed prior to 1920, before the automobile began affecting land use decisions. In contrast, the lowest value of housing unit density would be 1.9 units/acre in Sonoma County. The average projected housing unit density for 2005 would be 6.9 units/acre.

The calculations described above follow the form suggested by Pushkarev and Zupan, and indicate a trend toward an overall reduction in housing unit density in the Bay Area by 2005 combined with an overall population increase. According to these calculations, the average housing unit density of the entire nine Bay Area counties is projected to decrease by 1.8 housing units per residential acre between 1990 and 2005. San Francisco displays the only increase in housing unit density during this period, largely because there is little or no new land available for future development.

As a check against what Pushkarev and Zupan have stated in regard to the relationship between gross population density and housing unit density, the 1990 and 2005 gross population density figures for each Bay Area county were plotted on the chart relating the two values for other urban areas in the United States. It was shown that the Bay Area counties do in fact display relationships between gross population density and housing unit density similar to those of other urban areas in the United States.

### Feasible Public Transportation Options Based On Land Use Density

Based on the housing unit density calculations, some general relationships can be discussed, with regard to the ability of a certain residential density to support a particular type of rail transit. This analysis was carried out in order to determine the overall ability of a residential area to support rail transit. It was not attempted to determine densities in the existing or future rail corridors themselves.

Looking at Table 1, it appears that in addition to dial-a-bus and local bus, Alameda County could potentially support express bus and/or commuter rail

technologies in 2005. Contra Costa County appears to be able to support dial-a-bus, local bus, express bus and/or commuter rail in 2005. The table also shows that Marin County could possibly support commuter rail in 2005. It also appears that Napa County and Solano County could support express bus and/or commuter rail in 2005. San Francisco can and does support rapid transit, local bus and/or express bus. According to the analysis, San Mateo County and Santa Clara County could support dial-a-bus, local bus, express bus and/or commuter rail in 2005. Finally, Sonoma County could apparently support commuter rail in 2005. These are merely observations from what Pushkarev and Zupan have developed, and the term *support* relates solely to how projected housing unit density compares with the general categories developed and does not relate to the appropriateness of existing and planned rail corridors.

## PERSPECTIVE ON POSSIBLE RAIL TRANSIT OPTIONS

This section explores possible land use strategies which could be implemented to optimize the viability and effectiveness of public transit in the Bay Area as well as the concept that rail transit corridors could be subjected to a directed evolution into the future. In view of the fact that the predominance of relatively low density residential areas will not be able to support intensive rail transit in a comprehensive fashion, it is important to look at developing higher densities in specific corridors over the long term. It is also important to look at a broad vision for the evolution of rail corridors and transit facilities into a truly integrated transit system for the Bay Area.

### Land Use Strategies

While the studies prepared by Pushkarev and Zupan are illustrative, and the data are supported by the characteristics of the nine Bay Area counties, it is not appropriate to infer that the relationship between a specific land use density and a specific rail transit option is the only characteristic which governs success of a rail transit system. The relatively low density development on the periphery of the Bay Area metropolitan area is projected to continue over the next fifteen years. Therefore, based on a comparison of Table 1 and Table 2, the relatively low residential densities found in the Bay Area in the future *would not be expected to support* sophisticated, extensive rail transit systems with sufficient ridership and revenue unless some drastic land use changes are implemented.

In view of the relatively low residential housing unit densities present, what should be done in the future to maintain, develop and continue the coordinated improvement of the regional rail transit network ? Certainly, concentration of future development, redevelopment and joint development around existing and planned rail corridors would have a significant impact. Pushkarev and Zupan stated that clustering 2,000 apartments within walking distance of a rapid transit station at a moderate distance from a moderate sized downtown and at a density of 15 dwellings per acre, instead of spreading them evenly across a square mile, could add nearly a carload of riders a day to the transit system.(5) A recent contest for the design of transit-based communities at three transit stations in the Bay Area resulted in concepts for focusing housing, childcare and retail within walking distance of the stations. "Urban planners say that if you put affordable housing complexes, parks, shops, cafes, perhaps even a cinema, within walking distance of a station, commuters and others will come." (8) Joint development schemes are beginning to receive greater attention and this should be encouraged.

Future land use strategies should consider densification around existing rail corridors and stations. Joint development at stations should be pursued further. The Bay Area may at some point see a greater role for regional government, with unified decision making related to transportation, land use, air quality and utilization of resources. There are merits to focusing future development in established transportation corridors with convenient access to the excellent rail transit systems. The Bay Area population is projected to increase by approximately one million residents by the year 2005. Although this is a significant increase (on the order of fifteen percent), it does not offer the opportunity to substantially change the overall land use patterns. If these additions are correctly planned for, they could, however, add to the successful implementation of future rail transit.

Full community and agency support will ensure that the goals of MTC Resolution 1876 are realized. More focus should be placed on integrating the existing rail and transit systems in terms of facilities and in terms of schedule, or coordination in the dimensions of time and space. Emphasis on intermodal transfer points and timed transfers should be heightened.

### Directed Evolution

A long term vision for an integrated transportation system in the Bay Area must be maintained, with facilities planned and designed around that vision. The ideal future rail transit components would be fully integrated with overall efficiency maintained at convenient intermodal facilities.

*Projected Future Plan*

The transit component of a future regional transportation system could consist of an expanded network of coordinated transit on different frequency and service levels, including intercity rail, rapid intraregional rail transit, intracity light rail, feeder bus and paratransit systems. This network could include numerous intermodal and intramodal nodes facilitating easy transfers, accessible to the mobility impaired, pedestrians, and bicycles. These nodes would be ideal sites around which to focus housing, office, retail and childcare facilities. The heavy rail and commuter rail systems would be supported by light rail systems such as the Muni Metro, and the Santa Clara County light rail lines. Possible variations of the recently proposed Bay-Link concept, including East Bay light rail lines and additional transbay rail capacity could also be applicable. Integrated bus feeder systems could effectively serve all rapid rail and light rail stations. The transfer nodes could also become intensive business, residential and cultural activity centers.

Due to the present political and funding realities, this Bay Area transit vision could be pursued by making incremental decisions working progressively towards the ultimate vision. In order to achieve this, existing corridors need to be preserved and new creative zoning and financing schemes need to be developed. Cities and counties should take strong leadership roles in encouraging redevelopment and enacting zoning policies which will strengthen the urban core present in the Bay Area and strengthen the existing and planned transit corridors. Cities and counties could explore mechanisms to encourage these policies through the Congestion Management Agencies or through air quality policies. At some point, perhaps counties would be able to require individual cities to develop citywide zoning plans, in order to develop comprehensive, phased strategies for strengthening development patterns along transit corridors over a reasonable period of time. Counties could then base distribution of funds to the various cities upon each city's compliance with the overall zoning strategy.

An example of a facility which was constructed for the long term is the Transbay Transit Terminal (TTT) in San Francisco, built in 1939 as a part of the San Francisco - Oakland Bay Bridge rail transit system. In 1959, the TTT was converted for bus use and it currently is used by Golden Gate Transit, Alameda and Contra Costa County Transit, San Mateo County Transit District and the San Francisco Muni. Situated within walking distance of two BART stations, the facility recently became home to Greyhound Lines' San Francisco depot and is the planned new CalTrain Downtown Terminal. "This will allow the structure to become a truly regional transit terminal" (9) This is a shining example of how a successful transit system can be optimized, not necessarily by creating new systems but creating systems that can handle transitions and intermodal relationships for the long term.

**Perspective on Existing and Prospective Bay Area Corridors**

Numerous rail transit corridor studies have been undertaken in the Bay Area over the last twenty years. The results of these studies have not always conformed with the pure application of the Pushkarev and Zupan approach. This is due to a complex combination of political, institutional, environmental and economic reasons. Two of these corridors are discussed below.

*San Francisco Peninsula Corridor*

Numerous studies have been performed concerning the San Francisco Peninsula, including BART extension studies, studies that recommended the local bus transit systems in San Mateo County and Santa Clara County, the Peninsula Transit Alternatives Project studies, the Peninsula Mass Transit Study and the Guadalupe Corridor studies. In addition, several recent developments have taken place in the corridor:

- Beginning of construction of the BART Colma Extension.
- Selection of the preferred alternative for the BART San Francisco International Airport Extension.
- Purchase of the former Southern Pacific right-of-way by the Peninsula Corridor Joint Powers Board and continuing CalTrain service with Amtrak as new operator.
- Extension of CalTrain service to Gilroy and increased service frequency.

Recent studies have also investigated the extension of CalTrain to downtown San Francisco, to enhance access to downtown and connections to BART and the MUNI Metro LRT. This project is not presently fully funded, and underground construction greatly impacts the high estimated construction cost. In addition, discussions have centered on improvements to the CalTrain system, including electrification, central train control, automatic ticket collection and implementation of an outside boarding policy. Other proposals over the years have included the possibility of extending BART or LRT from the San Francisco International Airport south to San Jose. The Pushkarev and Zupan methodology has indicated that San Mateo County could support a commuter rail system, but not necessarily implementation of such intensive and varied rail systems. When exploring the institutional, political and economic realities, it

becomes apparent that there are numerous factors which govern rail transit corridor decisions.

*Marin-Sonoma Corridor*

The Marin-Sonoma Corridor extends approximately 104.6 kilometers (65 miles) north of San Francisco along the U.S. 101 freeway, and includes the Golden Gate Bridge. The combined populations of Marin County and Sonoma County is approximately 650,000 people. There is a high concentration of Marin County residents commuting to San Francisco, particularly in the southern Marin portion of the corridor. Presently there is excellent peak period bus service. During the off-peak periods, headways are significantly less. Bus service is oriented directly to commuters, with many peak hour/peak direction services, ranging from standard buses to luxury coaches. Local bus services, while provided in both counties, is lightly utilized.

An analysis using the Pushkarev and Zupan technique has indicated that commuter rail may be warranted in the Marin County-Sonoma County corridor. Several site specific factors would make implementation of any rail mode problematic, primarily due to the high construction cost per mile which would be encountered:

- Mountainous terrain through much of Marin County would lead to high construction cost. There is an existing single track freight rail line running through both counties, which could potentially be rehabilitated at substantial cost.
- Crossing the Golden Gate, the mile-wide opening of the San Francisco Bay, would be costly. Although a lower deck addition to the Golden Gate Bridge has been discussed for many years, the weight of heavier commuter rail trains, as opposed to LRT or BART, may exacerbate the structural challenges of this crossing.
- Within San Francisco, high densities and public policy would likely necessitate extensive tunnel construction, to avoid complicated utility conditions and to provide interconnections with the BART and MUNI Metro LRT systems on Market Street.

In addition, new employment development in Sonoma County has been low density in nature. In Marin County, new employment development has been outside of walking distance of the existing rail corridor. The local preference currently appears to be LRT in the southern portion of the corridor, serving most of urban Marin County. The preference in Sonoma County, in the northern portion of the corridor, appears to be commuter rail, with potential joint use of track by both modes in the southern portion of the corridor. Another possibility is commuter rail service in the northern corridor, with connections at high speed ferries to downtown San Francisco and Oakland. Consideration of these constraints amplifies the fact that a complex variety of factors influence decisions regarding potential rail corridor implementation. The specific physical conditions present in a corridor may dictate the rail development which may be significantly different from what may be indicated by the Pushkarev and Zupan approach.

## DISCUSSION AND CONCLUSIONS

Future population forecasts indicate that the Bay Area seen as a whole will be de-densifying over the next fifteen years. Pushkarev and Zupan developed an overview of the relationship between land use density and transit, which attempts to quantify the correlation. Realizing that this is not the only factor governing the success of a rail system, this quantified correlation has been applied to land use densities in the Bay Area utilizing actual census data and population predictions. Using the relationship developed by Pushkarev and Zupan, the rail system which can be supported by the existing and projected land use densities were identified. The results indicated that the existing and projected land use density can, in general, only support the existing and already planned corridors, but will not support extensive additions to the rail system over a wide area.

It is therefore imperative that proactive measures be taken to create intensified densities where they will have the greatest impact. This would be best served through the implementation of comprehensive strategies to strengthen the existing urban core throughout the Bay Area and focus future zoning strategies on strengthening existing rail corridors. This will call for strengthening regional planning and zoning organization and may require tougher zoning laws as well as other congestion management and air quality mechanisms which may indirectly impact land use development. In short, an attempt should be made to add the majority of future development and population around existing and projected rail corridors, if the intent remains to promote urban rail transit systems.

Most transportation systems evolve from a series of individual corridors into more a complex integrated transit network. An efficient strategy would include the directed evolvement of rail systems. In following such a strategy, some of the facilities that are planned, designed and constructed must be created for not only the immediate or medium term but also for the long term.

It is recognized that the results and discussions presented heretofore only address a portion of the issues associated with the development of rail

systems and land use. In addition, the proposed solutions represent only a beginning. The institutional issues associated with stronger and directed zoning and land development need to be studied in greater depth, and further proposals need to be made. Because of the proven rail transit/land use synergism and the high initial and continuing cost of rail transit, it is imperative to gain a better understanding of these issues and implement appropriate policies. A continuing discussion of these broad issues is necessary and encouraged. In order to maintain an overall effective and affordable direction in the planning and implementation of rail transit infrastructure, this dialogue must brought to the forefront.

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