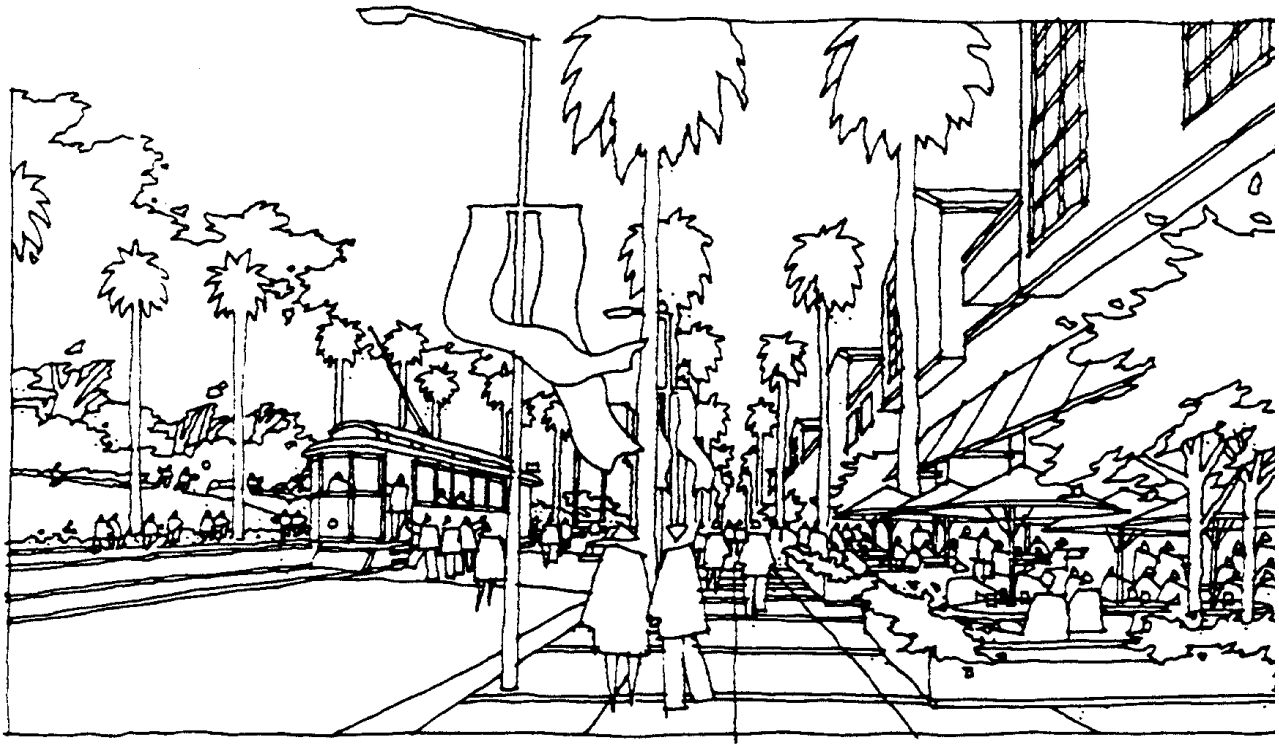
California Environmental Protection Agency

AIR RESOURCES BOARD



THE LAND USE - AIR QUALITY

L I N K A G E

How Land Use and Transportation Affect Air Quality

1997 Edition

Acknowledgments

This report was prepared by the staff of the Air Resources Board's Office of Air Quality and Transportation Planning under the direction and review of Lynn Terry, Assistant Executive Officer, and Anne Geraghty, Manager of the Transportation Strategies Group.

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1997 EDITION

This update of the ARB's *Land Use/Air Quality Linkage Report* presents a summary of information on linkages between transportation, land use and air quality. It incorporates new data that has become available since this report was first published in 1994, including results from three major ARB-funded research projects. It also provides several new California examples.

THE LAND USE-AIR QUALITY LINKAGE

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INTRODUCTION

The form and shape that growing cities take in the next several decades will have an important impact on the future air quality of California's major metropolitan areas. A growing body of literature and research indicates that land use and transportation strategies can reduce vehicle trips and vehicle miles traveled, and thus help reduce the air pollution produced by automobiles. By creating environments that are more conducive to alternative transportation modes such as walking, biking and transit, we can create more "livable" communities -- communities with reduced congestion, increased personal mobility, and cleaner, healthier air.

This report summarizes data currently available on the relationships between land use, transportation and air quality. It also highlights strategies that can help to reduce the use of the private automobile. And, it briefly summarizes several research projects funded by the California Air Resources Board (ARB). As new data becomes available, it will be added to updated versions of this report.

THE LINKAGES

Vehicle Use and Air Quality

While dramatic improvement has been made, most of California's metropolitan areas still exceed state and federal air quality standards. This is true despite the reduction of air pollution from both mobile sources (cars, trucks and buses) and stationary sources (utilities and other industries).

Mobile sources produce more than one-half of all smog precursors and over 90 percent of the carbon monoxide in the State's major urban areas. Today's new cars pollute about 90 percent less than models produced 25 years ago due to California's strict vehicle emissions standards. By 2003, the average new car in California will pollute 75 percent less than 1994 models.[1] But, although these standards will continue to greatly improve air quality, large increases in population and driving partially offset the benefits of cleaner motor vehicles.

During the past twenty years, the total number of "vehicle miles traveled" (VMT) in the state has increased at a much faster rate than population growth. We are driving more often and longer distances.

Between 1970 and 1995, total annual VMT in California more than doubled, increasing from 103 billion to over 270 billion miles of travel per year (although the growth rate in VMT tapered off somewhat between 1990 and 1995). Between 1970 and 1995, the state's population grew by 60 percent, increasing from 20 to 32 million people.[2]

Total Annual Vehicle Miles Traveled and Population in California, 1970-1995

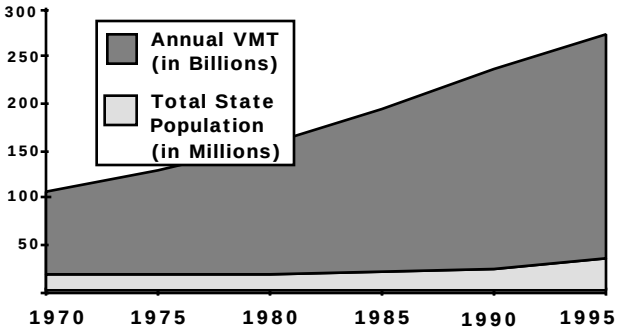


Figure 1 [2]

Half of the nation's ten most congested metropolitan areas are located in California: Los Angeles, San Diego, San Francisco, San Jose, and San Bernadino/Riverside.[3] And traffic congestion in the State's metropolitan areas is expected to continue to worsen, especially during peak-hour commute periods. Delays cost personal time, and translate into higher costs for businesses and consumers.[4]

1 Calif. Air Resources Board, *Status Report*, 1994.

2 Calif. Air Resources Board, *BURDEN 7F* Emissions Inventory, 1994; and Calif. Dept. of Finance, 1996.

3 Urban Land Institute, *Land Use In Transition*, 1993.

4 U.S. Department of Transportation, 1996.

A 1993 report by Governor Wilson's Growth Management Council pointed out:

> "California cannot support a population growing past 30 million people based on existing housing and transportation patterns without unacceptable economic, social and environmental costs. Such housing and transportation patterns use too much land, are too spread out, require too much infrastructure, create too great traffic congestion, have adverse air impacts and other environmental costs, and simply cost too much. The State cannot afford it, as a financial matter. Most people could not afford it, either, if they bore the full costs of these housing and transportation patterns."[5]

Land Use and Air Quality

The places that we drive in our daily routine, such as shopping centers, schools and universities, employment centers, and medical offices, are referred to as "indirect" sources of air pollution because of the associated vehicle travel. The numerous vehicle trips to and from such destinations produce emissions that can be quite significant when compared to the pollutants emitted by typical "stationary" sources of air pollution, such as power plants, oil refineries and manufacturing facilities.

Emissions Associated with Typical 'Indirect' and 'Stationary' Sources

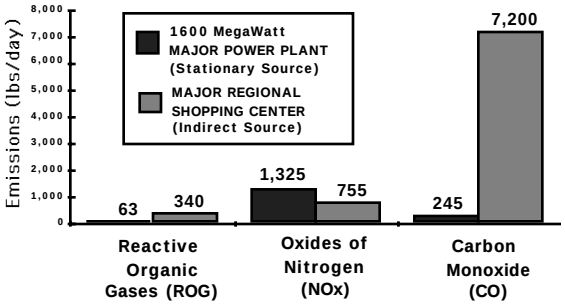


Figure 2 [6]

The location and design of buildings, streets and other land uses in part determine the distances people need to travel to reach employment sites, stores, houses, and other destinations. These factors also influence which mode of transportation people may choose -- car, vanpool, bus, train or trolley, walking, or bicycling.

For example, vehicles traveling to and from a major regional shopping center in a typical highway-oriented suburban area produce a significant amount of carbon monoxide (CO), as well as reactive organic gases (ROG) and oxides of nitrogen (NOx). However, if that center were located in a downtown, served by a good transit system and easily accessible to pedestrians, the amount of vehicle travel and emissions could be significantly lower.[7]

• Trip End Emissions

ARB's low-emission standards will continue to significantly reduce emissions from new light-duty vehicles, but it will be awhile before these vehicles dominate the fleet. Starting pre-model year 2000 vehicles produces high levels of tail-pipe emissions when the catalytic converter is not yet hot enough to efficiently treat the exhaust gases. Research has shown that the longer a vehicle's engine is shut off, the more emissions are produced when it is started again. In addition, after the engine is shut off, "hot soak" evaporative emissions continue to be released. On average, "trip end" emissions such as these comprise nearly one-half of the total pollution produced by a 5-mile trip, and 18 percent of emissions from a 20-mile trip.[8]

Making fewer short vehicle trips can help reduce these emissions. A nationwide survey indicates that most of our daily trips are less than 5 miles in length.[9] Some of these trips could be combined or made by walking, bicycling or transit if destinations are nearby.

Portion of Personal Trips 5 Miles or Shorter

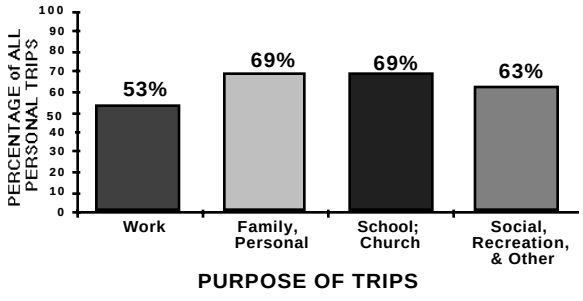


Figure 3 [9]

5 Growth Management Council, 1993, pages 11-12.

6 Calif. ARB, 1989; & Impact Sciences, 1993.

7 JHK and Associates, 1993.

8 Calif. ARB, 1996.

9 U.S. Dept. of Transportation, 1986.

Modes of Travel

According to a statewide survey of travel in California, about 86 percent of personal travel is by automobile, motorcycle or light-duty truck. Walking and bicycling together comprise about 9 percent of total travel, while public transit accounts for only approximately 2 percent overall in the state.[10] (Transit use rates within urban areas are higher than the statewide average.)

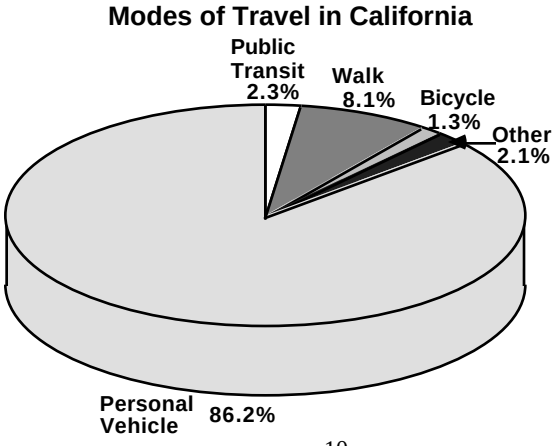


Figure 4 [10]

• Walking

Direct, safe and convenient access for pedestrians can help encourage walking and support transit use.

Most pedestrians share several preferences:

• **direct accessibility** - walkers can be easily discouraged by long distances, difficult or indirect routes, and impassable barriers such as fences and walls.

• **safety** - pedestrians are more vulnerable to traffic and other dangers. Well-lighted, well-observed and spacious walkways increase their sense of security.

• **attractiveness** - walkers prefer an interesting, attractive route, and tend to be discouraged by large areas of asphalt and uninteresting walls or buildings.[11]

How far are people generally willing to walk? According to one study, about 70% of U.S. residents will routinely walk 500 feet (about 1/10 of a mile). About 40% are willing to walk 1,000 feet to 1/4 mile on a regular basis. Only about 10% will willingly walk a half mile or more during their normal daily routines. Acceptable walking distances can be stretched by pleasant, interesting walking environments.[12] Average walking distances also tend to be longer downtown: for instance, 60 percent of walking trips in central Boston are one-quarter mile or longer; the average walking distance in Manhattan is one-third mile.[13]

• Bicycle Travel

Bicycling is a popular recreational activity and is also an attractive mode of commuting for many people, especially if safe and direct bicycle facilities are available. The City of Davis, a university-oriented town of 50,000 people located near Sacramento, California, has a high-quality, interconnected network of bicycle and pedestrian paths. A recent study found that 22 percent of employed residents typically ride their bicycles to work. In addition, 43 percent of the Davis students surveyed travel daily to school or to the nearby university by bicycle.[14] In comparison, bicycle rides comprise less than 2 percent of travel in the Sacramento metropolitan region overall.

The large proportion of bicycle use by students and non-students alike in Davis illustrates the effectiveness of a complete, interconnected network of convenient and safe bicycle facilities. The proximity of residential areas to commute destinations, as well as a limited supply of parking spaces at the university, are also important contributing factors to Davis' high rate of bicycle travel.

• Transit Use

Residents of urban areas tend to use transit at much higher rates than people who live in suburban and rural areas. However, residents of most urban areas in the United States use transit at much lower rates, on average, than in cities in most other parts of the world.[15]

10 Calif. Dept. of Transportation, 1992.

11 American Lung Association, 1981.

12 Unterman, 1984.

13 Fruin, 1992.

14 Kitamura, et.al., 1993.

15 Newman and Kenworthy, 1990.

Higher rates of transit use can be attributed to a variety of factors typically found in other countries, including: overall urban density, the level and type of transit service available, convenient pedestrian access to transit, the location and concentration of activity centers, the availability of parking, the price of fuel, and the severity of traffic congestion.[16]

Travel By Automobile and Transit in Four Metropolitan Areas Worldwide

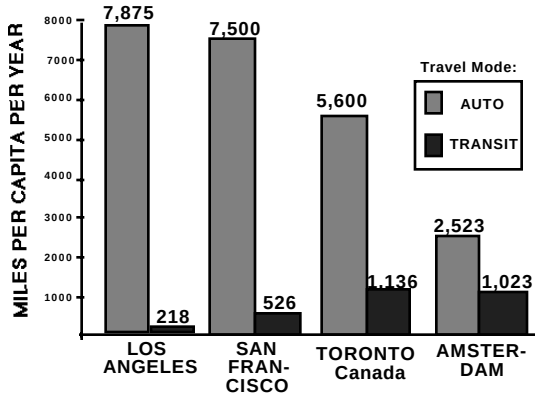


Figure 5 [16]

A certain minimum level of transit "ridership" (as it's referred to by transportation specialists) is needed in order for transit districts to provide high levels of service. This is because the quality and frequency of transit service depends in part on the number of people that use the system. Conversely, people's willingness and ability to use transit is directly related to the frequency and quality of transit service, its availability and its cost. Providing an integrated network of transit services, such as frequent local bus service, express commuter bus service, and light rail or "heavy rail" trains, can help make transit a more convenient and desirable alternative to driving.[17]

The form and configuration of the urban environment are also important to the provision and use of transit. For instance, more compact urban development located near major transit stations can result in higher ridership levels. Also, convenient and direct pedestrian access to transit can reduce the need to drive to the station. Parking availability and cost, as well as traffic congestion, are also factors.[18]

16 Newman and Kenworthy, 1990.

17 Atkins, 1992.

18 Snohomish County Transportation Authority, 1989.

OPTIMUM LAND USE STRATEGIES FOR AIR QUALITY

Land uses that enable people to walk, bike or use transit, rather than needing to rely primarily on their cars for mobility, tend to be better for air quality. Strategies that provide access to and support multi-modal transportation systems can help reduce automobile use and resulting emissions. These are available on both the community (or metropolitan) and local (district or neighborhood) levels.

This section describes several such strategies, and summarizes available data on their potential benefits in reducing vehicle travel and supporting convenient alternatives. The types of strategies suggested include:

Community-Level Strategies:

- Enhanced activity centers, including downtowns, employment and shopping centers, and transit "nodes"
- Concentrated development, especially within walking distance of transit service

Neighborhood-Level Strategies:

- Mixed land uses, including housing, shopping and employment
- Interconnected street networks
- Traditional Neighborhood Design
- Transit-Oriented Development

A similar set of strategies was also identified in a study entitled: *"Transportation-Related Land Use Strategies to Minimize Motor Vehicle Emissions: An Indirect Source Research Study,"* prepared in 1995 for the ARB. Information about how the recommendations were developed, detailed descriptions of sets of strategies for urban, suburban and rural areas, and a number of local government implementation tools are also provided.[19] (This study is also summarized on pages 19 and 20.)

19 JHK and Associates, 1995.

Community Strategies

The combination of the automobile coupled with lower-cost land in fringe areas of most metropolitan areas of the U.S. has resulted in a dispersed development pattern with reduced overall densities. This growth pattern has resulted in longer travel distances and has increased the need for reliance on vehicles, trends which continue in California.[20]

Strategies that can help produce more livable communities include: enhanced central business districts, clustered activity centers, and more compact development patterns that also help support the provision of high-quality transit systems and encourage walking. These are briefly described below.

• Enhanced Central Business Districts

Strong central business districts historically have enjoyed quality transit service and the highest rates of transit use, especially in cities that were built prior to World War II. This can be attributed to: the large number of activities concentrated within walking distance of each other and transit stations; fewer parking spaces with higher fees; traffic congestion on freeways and streets; and high-quality transit service.[21]

An early study of the New York Metropolitan area found important connections between land use patterns and a successful transit system. It confirmed that a strong central business district, compared to a more scattered land use pattern, is a crucial ingredient for creating and supporting a healthy transit system, increasing transit system use, and reducing the need for automobile travel.[22]

According to the results of a recent survey[23] of real estate investment companies nationwide:

> "Cities that work typically stand at the hubs of diversified mass transportation networks - subways, buses, suburban railroads - which funnel people in and out and offer sane suburban commuting alternatives to the car. Not only can city dwellers walk or take public transportation to work; they can find a market or a place to eat around the corner."

The central business districts of the major cities in the U.S. typically contain a large number of businesses and jobs concentrated in a fairly limited area. However, most downtowns have a relatively small amount of housing, compared to cities outside the U.S.[24] As a result, many central cities have low levels of activity after business hours or on weekends. This can contribute to increased crime, as well as reducing the economic viability of the downtown and also nearby areas. This also reduces the use and support of transit systems.

In contrast, those cities that have ensured an ample supply of good-quality housing downtown and in nearby neighborhoods often have safer, vibrant and more economically viable central cities. Housing options near downtown can also simplify commuting for people who work nearby.[25] Downtown residents also have a greater tendency to use public transit during non-commute times of the day and evening, which helps to support more efficient public transit systems.[26]

Real estate investors who were surveyed agreed that including attractive residential areas in central business districts also makes sound business sense:[24]

> "Downtowns without attractive, close-in residential areas have frequently deteriorated into shells -- the so-called '9-to-5' cities. Meanwhile, certain traditional cities with strong residential fundamentals are more than holding their own: Manhattan, Chicago, San Francisco, Boston, and Washington D.C. Thriving residential communities rooted in and around business districts are the key to preserving 24-hour environments.....we believe the premier investment opportunities will be available in the nation's 24-hour cities. These markets, whether urban or suburban, are places where people can comfortably and securely live, work and shop."

20 Sullivan, 1990.

21 JHK and Associates, 1995.

22 Pushkarev and Zupan, 1977.

23 Equitable Real Estate Investment Management Co., 1996.

24 Newman and Kenworthy, 1990.

25 Jane Jacobs, 1961.

26 Snohomish County Transit Authority, 1989.

• Clustered Activity Centers

If a variety of activities, such as shops, services, offices and other employment sites as well as higher-density residential units are clustered together, they can become lively "activity centers." Activity centers or "nodes" are also referred to as "Urban Villages" or "Suburban Village Centers." A network of such centers, or "nodes," can more easily be linked by a transit system to other similar centers and to the central business district.

Activity centers that cluster higher-density and mixed-use development can be found in both urban or suburban areas. However, it is important that such centers take advantage of transit, and that adequate pedestrian facilities are provided. Otherwise, traffic congestion can become even worse.

Centers that are served by transit can also provide access for surrounding residential areas. This can significantly enhance the efficiency of transit service and promote pedestrian activity by increasing access. The concentration of employment and other activity centers can have an even more significant influence on the level of transit service and use than the density of residential areas. [27]

A study of activity centers throughout the U.S. found that size, density, function, mix of land uses, and site design features are important factors that affect the amount and mode of travel.[28] Another analysis concluded that the concentration of development was the most important factor, followed by the mixture of different types of land uses, and the supply and price of parking.[29] These findings are also supported by results of an ARB-funded study of major regional shopping centers.

• Shopping Centers Study

In 1993, a study of travel behavior at five regional-scale shopping centers in California was conducted for the ARB.[30] This study found significantly higher levels of transit and pedestrian travel at malls located in urban areas and surrounded by fairly intense mixed-use development which are accessible to a regional transit system. In comparison, shopping centers located in low density suburban areas with limited transit service and few pedestrian facilities had much higher automobile travel rates than their more urban counterparts.

This study concluded that the most important factors affecting changes in travel patterns were: the location of shopping centers within a larger metropolitan area; the density, proximity and mixture of surrounding land uses; and easy access to a regional-scale transit system that provides frequent and convenient service.

Over 60% of 300 customers surveyed at *Horton Plaza*, a large enclosed shopping center in downtown San Diego, travel by transit or on foot.[31] In comparison, only 5% of customers surveyed at a suburban shopping center located near a freeway with limited bus service and poor pedestrian access, traveled to and from the shopping center by bus or on foot.

Travel at an Urban and a Suburban Shopping Center

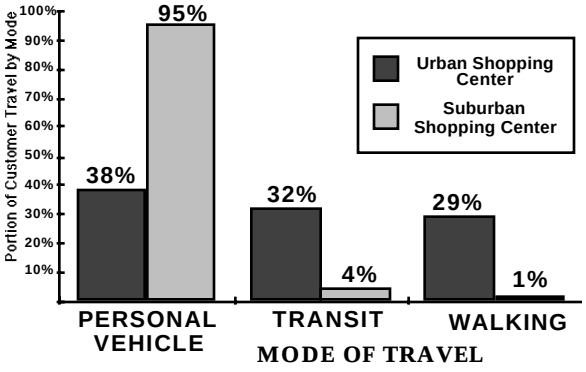


Figure 6 [32]

• Compact Development

In more compact areas, land uses are closer together, making it easier to walk to the coffee shop, dry cleaners or store. These areas also tend to have a greater mixture of housing, services and jobs. Transit service becomes more cost-effective in areas with more concentrated development, especially if buildings are clustered within walking distance of transit stations and corridors, and if safe, direct pedestrian access is available.

27 Cervero, 1993.

28 Cervero, 1989.

29 Cervero, 1991.

30 JHK and Associates, 1993.

31 Permission to cite *Horton Plaza* granted by *The Hahn Co.*

32 JHK and Associates, 1993, *Ibid*.

Governor Wilson's Growth Management Council report pointed out:

> "If the State wishes to preserve mobility, open space and a viable agricultural industry, clean air and environmental quality, and an economy that works, it cannot continue to support traditional low-density land use patterns based on large, single family detached dwellings, nor a transportation system based overwhelmingly on single-occupancy vehicle usage. It must promote alternatives."[33]

California's typically high housing costs, combined with dramatic changes in household size and other factors, have resulted in major changes in the demand for housing.[34] According to census data, the proportion of traditional "nuclear" families (with two adults and one or more children) has declined significantly during the past 20 years. Nuclear families accounted for only 26% of all households in the U.S., decreasing from 40% of households in 1970. During the same period, single adult, single parent and roommate households increased from 30% of the total in 1970, to 44% in 1990.[35]

As average household sizes continue to shrink, housing preferences and needs are affected. One developer has pointed out: "fewer households fit the traditional Ozzie and Harriet model..."[36] Because of these changes, a wider variety of housing styles, locations and prices is needed to meet size and affordability needs. More compact housing (such as townhouses, condominiums and apartments) may not be for everyone, but it has a significant and growing market niche.[37]

According to the American Institute of Architects, "the number-one growth trend of this decade will be the increased densification of the suburbs." They report that this trend especially affects the more office-oriented suburbs, which have suffered increasingly severe levels of traffic congestion on roadways that were already nearing capacity by the end of the 1980s. The architects predict that this trend could lend suburbs "a more urban flavor, combining the benefits of suburban living with an exciting urban environment." [38]

Various studies have found that there tends to be a higher rate of transit use and walking in areas with higher overall density.[39] This can be attributed to several major factors:

- Activities located closer together reduce travel distances and make it easier for people to walk or use transit;

- Concentrated land uses provide a larger number of potential transit riders and support a more efficient transportation system;

- Activities located closer together facilitate mode shifts from automobiles to walking, biking and transit.[40]

Despite the low-density development typical in the suburbs, traffic congestion has become a serious concern in many areas -- partly because of the lack of good-quality transit service and pedestrian access. However, it is very difficult for transit agencies to provide efficient, effective transit service in areas with large expanses of low-density housing, congested streets and very few consolidated activity centers. This is because the service area is very large compared to the number of people served. Also, the places people go are very scattered as companies have moved out to suburban areas, creating what are sometimes referred to as "edge cities."

The provision and use of transit, walking and other alternative modes of travel tend to be associated with more concentrated land uses. Conversely, dispersed, low density, and homogeneous land uses tend to be associated with higher rates of automobile travel.[41,42]

- ***Density and Transit Ridership***

A study of public transit use in Washington, D.C., identified key land use programs for making the best use of a transit system:

33 Growth Management Council, 1993, pg. 11.

34 Meyers, 1992.

35 1990 U.S. Census.

36 Phil Enquist cited in Martin, 1996.

37 Urban Land Institute, *Land Use in Transition.*

38 Urban Land Institute, *Land Use in Transition,* 1993.

39 Snohomish County; JHK; County of Sacramento.

40 Pushkarev and Zupan, 1977.

- Promote land uses that generate the most transit trips near stations;
- Locate these uses in close proximity to transit station entrances;
- Provide high density land development around stations, including suburban locations.[41]

According to researchers who conducted a study of transit and land use in the New York City metropolitan area:

"Urban residents will more likely use public transportation under these conditions:

- the higher the density and the larger the size of a downtown or another cluster of nonresidential activity;
- the closer their neighborhood is to that nonresidential concentration;
- the higher the residential density of their neighborhood; and
- the better the transit service."[42]

Land use decisions for the areas around transit stations and corridors are critical due to the fixed nature of rail transit and the limited supply of land near transit stops. Such decisions need to be made with a long-term view, as they will last for many years. Some land uses or site designs impede the development of subsequent, more transit-supportive projects in the future.

The Institute of Transportation Engineers has suggested the following general guidelines to support various levels of transit service. These are average *minimum* densities of residential development and intensities of non-residential floor area that can provide the ridership needed for various types and levels of transit service.

(Note: these densities may vary depending on the particular area, location and situation.)

***Minimum* Average Densities to Support Various Levels of Transit Service**

Type of Transit	Residential (du/acre) *	Commercial/ Industrial, Retail, Office (mill. sq. ft.)
Minimal level of local bus service (@ one bus per hour)	**4 to 6**	**5 to 8**
Intermediate level of local bus service (@ one bus per 1/2 hour)	**7 to 8**	**8 to 20**
Light rail transit with feeder buses	**9 & above**	**35 to 50**

**(average number of dwelling units (du) per acre)*

Figure 7 [43]

In order for even a low level of transit service (one bus per hour) to be feasible, a minimum overall density of 4 to 6 dwelling units per acre is needed. The frequency of service may be substantially improved if densities average at least 7 dwelling units per acre. When development is clustered in medium densities averaging between 7 to 15 dwelling units per acre, especially near transit stations, frequent local bus service becomes more cost-effective. If higher average densities are maintained over a large enough area, light rail transit service also can become feasible.[44]

This concept has recently been demonstrated in several growing California cities, including Sacramento and San Jose, which have installed successful light rail systems. Heavy rail transit, such as the Bay Area Rapid Transit District (BART) and *Cal Train* in the San Francisco Bay Area, is appropriate for linking destinations within major urban areas.

Several examples of the types and styles of residential development that are typically built at various densities are illustrated in Figure 8 on the following page.[45]

41 JHK & Associates, 1987.

42 Pushkarev and Zupan, 1977.

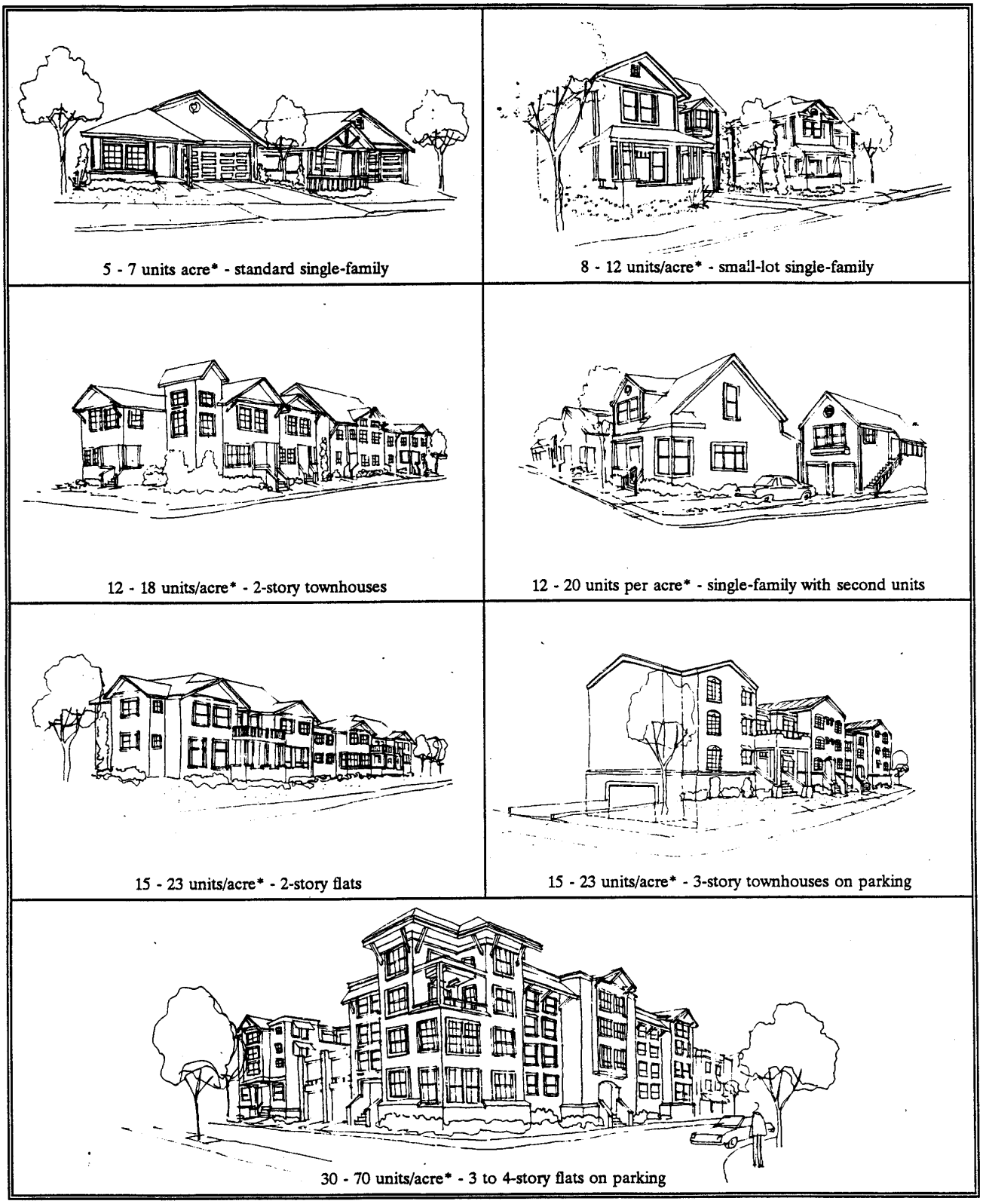
43 Institute of Transportation Engineers (ITE), 1989.

44 Snohomish County Transportation Authority, 1989.

45 Illustration by Nick Haskell of Brady & Assoc., in JHK & Associates, 1995.

Figure 8

Character of Residential Density



* Dwelling units per net residential acre: housing units per acre of land in residential use, not including streets.

• ***Employment Concentration***

The location, size and concentration of employment sites are also significant factors in the type and level of transit service that can be efficiently provided, as well as its rate of use. Between 80 to 100% of the new jobs created in the U.S. during the past two decades were situated in the suburbs of metropolitan areas.[46] Partly as a result of this trend, the average commute distance and related vehicle travel in the U.S. increased by *25%* between 1983 and 1990.[47] According to Dr. Robert Cervero, a well-known transportation and land use researcher, professor, and author:

> "Changes in how suburban workplaces are designed and built are absolutely essential if regional mobility is to be safeguarded..." [48]

Employment sites that are scattered over a large area attract enough vehicles to create significant traffic congestion, but are difficult to serve with transit or pedestrian facilities. In contrast, industrial facilities, shops and offices that are clustered closer together, connected by direct pedestrian routes and served by convenient transit, generate lower rates of auto use and can result in less traffic congestion.

Several studies show that clustering jobs closer to each other, to services and to transit is an important strategy in reducing auto use. One study found that transit use increased significantly when the density of jobs exceeds 50 employees per acre in clusters with at least 10,000 jobs.[49]

Another study reported that it takes at least 50 to 60 employees per acre on average to enable transit agencies to effectively provide good-quality transit service.[50] A third study found that the proximity of work sites to transit stations has a significant effect on transit use: each 10 percent decrease in the distance between a job site and a rail station was related to an 8 percent increase in rail use.[51]

46 Urban Land Institute, *Land Use in Transition*, 1993.

47 U.S. Dept. of Transportation, 1990.

48 Cervero, 1989.

49 Seattle METRO, 1987.

50 Pushkarev and Zupan, 1997.

51 Cervero, winter, 1994

Neighborhood Strategies

Neighborhood strategies are site-specific measures that can be applied to existing as well as new development or redevelopment projects. Combined with overall community or regional strategies, these strategies can help reduce driving rates and associated vehicle emissions.

• **Focused Infill and Renewal**

The infill, redevelopment and reuse of vacant or underutilized parcels within existing urban areas reduces walking distances and supports better-quality transit systems. Such strategies also have other benefits: lower infrastructure costs, more efficient delivery of services, increased economic viability of cities, and reduced conversion of agricultural land and open spaces to development. Infrastructure costs for sewer, water and other facilities can be one-half as high for higher-density development within existing urban areas, compared to low density projects in fringe areas.[52] (Note: this is discussed in a section on "Other Benefits," which follows on page 21).

Infill and redevelopment projects located within walking distance of transit service can be beneficial to the health of a city, as well as the environment. However, these kinds of projects are often met with neighborhood opposition. This is due, in part, to past development practices that have produced buildings that are not compatible with surrounding structures. Many of these were also of low-quality materials and construction.

As has been recently demonstrated in several communities, infill and redevelopment projects can actually enhance the quality of neighborhoods rather than detracting from them. The design, compatibility and mixture of infill projects is crucial, not only for winning acceptance by residents and businesses, but also for improving neighborhoods. This is especially true for higher-density infill or redevelopment projects situated in existing areas. Several communities have successfully used design guidelines, redevelopment agency efforts, "main street projects," and historic preservation programs to produce good quality, higher-density infill development projects.[53]

52 Frank, 1989; and Kassowski, Kevin, 1992.

53 JHK & Associates, 1995 (Chapter 7).

• Mixed-Use Development

Mixed-use development allows compatible land uses, such as shops, offices, and housing, to locate closer together and thus decreases travel distances between them. Mixed-use development, if properly designed and implemented, can reduce VMT and trips and help increase transit ridership, especially during the off-peak (non-commute) periods.

For example, a mixed-use area containing restaurants, a museum, a theater and retail stores, has a greater potential to generate walking, bus and rail use than an area with retail stores alone. Adding housing to the mix of uses improves the situation significantly. Regardless of how people arrive at a mixed-use area, they will be able to make many trips by walking; such trip linkages would not be as feasible in a single-purpose area.[54]

Mid-day trips from work for lunch or to run errands can especially be influenced by mixed-use strategies. In typical single-use office parks, people walk for only about 3-8% of such trips. However, in mixed-use areas with good pedestrian accessibility, 20-30% of mid-day travel from offices can be made by walking.[55]

One study analyzed 57 large employment sites in suburban areas. It found that the presence of retail services increases transit and ridesharing by around 3 percentage points for every 10 percent increase in floor space for retail and commercial uses.[56] Also, the Institute of Transportation Engineers have recommended reducing estimates of peak hour commute traffic generation by 2.5 percent for mixed-use employment developments.[57]

• Interconnected Street Patterns

During the past 30 years, the typical street circulation pattern in developing suburban areas has consisted of a hierarchy of local streets leading to collector streets, and then to major arterials that interconnect sections of a community to each other and to freeways.

Major collector and arterial streets, which often provide the only through connections between different sections of suburban communities, tend to be quite wide to allow vehicles to travel faster. The typical suburban circulation pattern limits the number of available routes between trip origin and destination points, placing many vehicles on major streets and at signaled intersections. The result can be high levels of traffic congestion and long waits at signals, especially during peak periods.

Wide arterials with fast-moving traffic are difficult and dangerous for pedestrians and bicyclists to cross, or to share with vehicles. Such thoroughfares typically become significant barriers to walking and bicycling, and tend to encourage driving, even for short trips.

Interconnected and Isolated Street Patterns

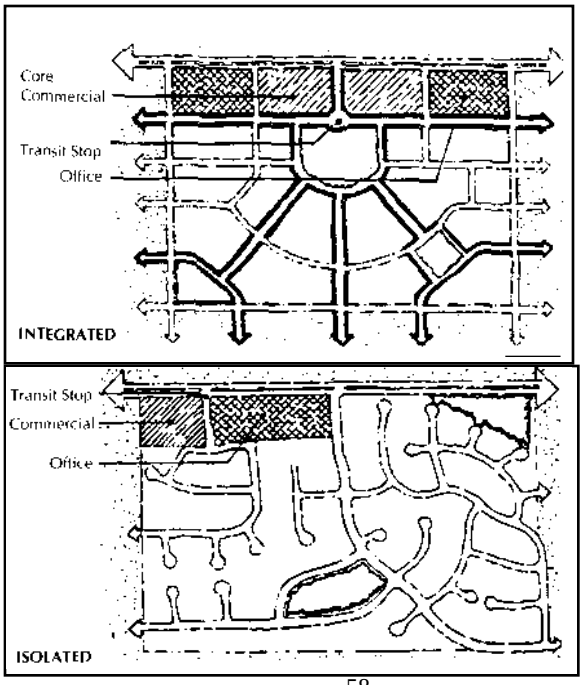


Figure 9 [58]

In contrast, more interconnected street patterns provide multiple routes to travelers and reduce travel distances. Commonly found in many older neighborhoods, downtowns and small communities, interconnected street networks can have several advantages over typical hierarchical suburban-style patterns: they provide numerous route choices instead of focusing traffic into several wide arterials; they offer more direct routes for pedestrians and

54 Snohomish County, 1989.

55 Unterman, David, 1984.

56 Cervero, 1993.

57 ITE, 1987, cited in Cervero, 1993.

58 Sacramento County, 1991.

bicyclists as well as cars; and they can help to slow vehicle speeds. Slower vehicle speeds help create a much safer street environment for pedestrians and bicyclists to share. Slower speeds are also quieter.

Even though vehicles travel at slower speeds, travel times in areas with interconnected streets can be similar to those in suburban areas with fast-moving arterials because of shorter distances and more direct routes. Researchers using standard traffic models compared vehicle travel times in areas with interconnected street patterns to those in typical suburban areas. One study found the travel times to be the same.[59] Another reported that it would take 8% less time to travel on local "neo-traditional" networks than in a typical suburban area.[60] Two other studies reported that interconnected street networks can reduce average trip lengths and vehicle miles of travel (VMT) by 10 to 15 percent, compared to standard suburban hierarchical street patterns.[61]

• Traffic Calming

"Traffic calming" is a method for designing or redesigning streets to be more pedestrian-friendly. Typical traffic calming measures include: narrowing streets, creating rougher road surfaces at pedestrian crossings, installing traffic islands and "round-abouts," planting street trees and installing pedestrian furniture, and restricting some roads to through automobile (but not pedestrian and bicycle) travel. These measures have been installed in several communities, including portions of Sacramento, California, and Portland, Oregon.

Traffic-calmed streets are designed to reduce vehicle speeds, which makes them safer for residents, pedestrians and children. When a traffic calming program was implemented in parts of Berlin, Germany, the number of fatal pedestrian-related accidents in those areas dropped by 57%. Residents of traffic-calmed streets can also be less likely to become victims of crime: neighborhoods in Dayton, Ohio, and Atherton, California, have experienced a 50% reduction in crime after the implementation of a traffic calming program and related measures.[62]

• Traditional Neighborhood Design

Traditional Neighborhood Design (TND), also known as "neo-traditional" development, is a strategy that emphasizes pedestrian accessibility and the orientation of houses towards narrower, tree-lined, gridded or interconnected streets. It is an approach that combines mixed uses and interconnected street patterns to minimize travel distances. TND makes it easier for residents to walk between their houses, jobs and commercial services.[63]

A typical neo-traditional neighborhood has a "town center" where commercial services and offices are concentrated. Most housing units are located within a five- to ten-minute walk of the town center.[64] Townhouses and other multi-family units are clustered within walking distance of the town center. Single-family homes are on somewhat smaller lots than in many suburban areas. Front porches are typically provided for the houses and are closer to the sidewalk. Garages are typically behind the houses, sometimes on alleys. "Granny flats," or second units, are generally permitted and encouraged; sometimes they are placed above the garages.

Comparison of Characteristics

Traditional Neighbor-hood Design (TND)	*Standard Suburban Development*
• Interconnected Streets	• Hierarchical Streets
• Narrower Streets	• Wide Streets
• On-Street Parking & Parking Structures	• Off-Street Surface Parking Lots
• Shallower Setbacks	• Deeper Setbacks
• Shopping on Main St.	• Strips/ Malls
• Mixture of Uses	• Single Uses

Figure 10 [64]

A study of travel in several traditional New England neighborhoods found that residents of

59 Kulash, Walter, et. al., 1990.

60 McNally, 1995/96.

61 Stone and Johnson (1992) and McNally and Ryan (1993), cited in Cervero, 1993.

62 Local Government Commission, January 1996.

63 Duany and Plater-Zyberk, 1992.

64 Bookout, 1992.

these neighborhoods generate an average of about 50 percent fewer vehicle trips per day than households in typical suburban areas.[65] Another study analyzed the relative benefits of compact, mixed-use neighborhoods that are "convenient and pleasant to walk in. Residents of such neighborhoods are at least three times as likely to walk to a store, a nearby restaurant or local park than their counterparts from neighborhoods that are more spacious and auto-oriented in their designs."[66]

Overall, researchers found a 10 percent reduction in auto trips for non-work travel in a traditional neighborhood compared to a standard suburban area. (Note: both of the neighborhoods studied had similar household income levels and access to transit service.)[67]

• Transit-Oriented Development

Similar to the traditional neighborhood development, but typically incorporating somewhat higher densities, the Transit-Oriented Development (TOD) is a development strategy that provides an alternative to typical suburban growth patterns. The TOD concept incorporates an intentional orientation to transit and pedestrian travel, clusters retail services and other uses in a "town center," and provides a range of housing densities and styles. TODs can help minimize the negative effects of new growth such as traffic congestion and air pollution. A "TOD" can be described as:

> A mixed-use community within an average 1/4 mile walking distance of a transit stop and core commercial area. The design, configuration, and mix of uses emphasize a pedestrian-oriented environment and reinforce the use of office, open space, and public uses within comfortable walking distance, making it convenient for residents and employees to travel by transit, bicycle or foot, as well as by car.[68]

Over 9,000 "transit-based" housing units were built in the S.F. Bay Area between 1985 and 1995.[69] Two California TOD neighborhoods are described in the "Community Examples" section which begins on the following page.

A growing desire for a sense of community is confirmed by results of a recent survey of 6,000 people shopping for homes. The majority said that they want "to live in a safe, neighborly place...where 'home' encompasses the physical structure but, more importantly, the community around it."[70] A housing developer has also commented:

> "People's desire for a genuine sense of community never went away. If anything, that desire is increasing. Unfortunately, today's typical stand-alone subdivision doesn't support our basic need for community....these subdivisions often are miles from schools, work, retail shops and community services. Those who drive to nearby stores encounter mostly strangers, not neighbors."[71]

According to a survey of 1,650 people shopping for homes in several states, 80% have "a nostalgia for communities with a distinct identity and character" that provide places to meet and socialize. Consumers said they also want a mixture of housing styles and densities in their neighborhood. Nearly 75% of these shoppers said they'd prefer to live "where I can walk or bicycle everywhere."[72] A sizable portion of high-tech workers surveyed in California's Silicon Valley said that they would be willing to live in attached homes or dwellings with smaller lots, if housing prices were lower or their commuting times shorter.[73]

One important benefit of "neo-traditional," clustered development can be that "residents feel they are part of a community, not just dwellers in a subdivision." According to a survey of 620 households in four new "neo-traditional" developments, residents have a high level of satisfaction. An overwhelming majority - 84% - said they prefer their neo-traditional community over a more typical suburban area. Nearly 70% said that they like the shallower front yards with houses closer to the street; more than 60% favored the narrower streets; and 80% enjoyed their front porches.[74]

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65 White Mountain Survey Co. (1991), cited in Cervero, 1993.
66 Cervero, September 1995.
67 Cervero and Radisch, July 1995.
68 Sacramento County, 1991.
69 *The San Francisco Chronicle*, 1997.
70 Mobil Land Development Corp., cited in Martin, 1996.
71 Phil Enquist, Skidmore, Owings & Merrill; in Martin, 1996.
72 *The Sacramento Bee*, June 2, 1996.
73 Santa Clara Manufacturing Group, 1993.
74 *The Sacramento Bee*, May 7, 1993.

COMMUNITY EXAMPLES

Within California

Several plans and projects that incorporate traditional neighborhood and/or transit-oriented design are being implemented in California. Three examples are presented below. These include estimates of the potential annual vehicle emission reduction benefits, as compared to more "typical" growth patterns.[75]

• 'Uptown District,' San Diego

This successful higher density, mixed use infill neighborhood was part of a city-sponsored redevelopment project completed in 1989. The site, which is situated several miles from downtown San Diego, was previously occupied by a retail facility that closed several years before.[76]

The new neighborhood includes: a commercial center with retail shops, restaurants, a major supermarket, and 310 housing units. The residential density averages 43 dwelling units per net acre, compared to about 12 units per net acre on average in surrounding residential areas.[77,78] The building design is consistent with the city's predominant architectural style, which allows the units to successfully blend in even though they are higher in density. And, the new neighborhood helps support a fairly high level of public transit service: it is served by 14 San Diego Transit bus routes.

A community center, as well as several interior courtyards, provide protected gathering places for residents. There are also pedestrian and bicycle paths. These features help increase the sense of community and security, and make it easier to walk, bicycle or use public transit. It takes only 2 to 3 minutes to walk from any of the residences to the supermarket, which has a unique underground parking structure that increases its pedestrian accessibility. This easy access for pedestrians and the dense surrounding residential area have contributed to this store's extremely strong economic success.[76]

Based on recent data on vehicle travel in various California communities, it is estimated that the location, design and density of this neighborhood may result in a reduced rate of driving and associated motor vehicle emissions of about 20 percent per household annually. The annual air pollution savings are estimated to total about 2.75 tons of reactive organic gas (ROG) and oxides of nitrogen (NOx) per year.[79] (This reduction is in comparison to typical vehicle travel from the same number of housing units in a lower density and more auto-oriented urban pattern.)

• 'The Crossings,' Mountain View

This compact, mixed-use infill neighborhood occupies an 18-acre site located in Mountain View (30 miles south of San Francisco). It replaces a shopping mall that closed in the early 1990s. *The Crossings* includes 540 single and multi-family housing units, a supermarket, several retail shops, and a daycare center -- all clustered near a *Cal Train* commuter rail station. Consumer demand for the housing units in this development has been high.[80]

The residential area averages 30 units per net acre, compared to an overall density of 7 to 10 units overall density in the rest of the city.[81] The dwellings, with front porches and rear garages, face narrower interconnected streets. There are three community parks, and many of the multi-family units cluster around courtyards. It takes residents only about 3 minutes to walk from any of the houses to the stores or to the commuter train station, and 2 minutes or less to reach a local park.

It is estimated that the density and configuration of this neighborhood, and its proximity to a commuter rail station, will reduce the rate of driving and resulting vehicle emissions by at least 10 percent (compared to the same number of housing units in a more auto-oriented suburban pattern). The annual emissions reductions are estimated to total about 3 tons of reactive organic gases (ROG) and oxides of nitrogen (NOx) per year.[82]

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75 These estimates are based on results of a research study of vehicle travel in various California communities, which is described in more detail in the "Quantitative Relationships" section, on pages 19 and 20.

76 Local Government Commission, 1995.

77 "Net residential acre" excludes streets, parks, retail, etc.

78 Holtzclaw, 1994.

79 JHK and Associates, 1995. Average pounds per household per year emissions from light and medium duty vehicles; 1995 emissions factors. Source of factors: ARB's *EMFAC 7F1.1*.

80 *San Francisco Chronicle*, 1997.

81 Local Government Commission, 1995.

82 JHK & Assoc., 1995, table 5-4. Analysis by ARB staff.

• San Diego County

In 1994, the San Diego Association of Governments' (SANDAG) Board of Directors approved a Regional Transportation Plan (RTP) that contained major investments to improve and expand the existing transit system throughout the region, including rail service and buses. In 1996, the SANDAG Board (which includes cities within the region as well as the County of San Diego) reaffirmed the objectives of the 1994 RTP by adopting an updated version with similar provisions.[83]

The RTP provides for a comprehensively planned multi-modal transportation system to meet the region's existing and future travel demand. It commits to nearly doubling the existing light rail network to a total of about 60 miles by 2010. It also contains high-occupancy vehicle lane freeway improvements. The plan includes a bicycle element that expands the existing 400-mile network by about 30 miles per year. And, the RTP also supports new technologies that will potentially reduce travel demand, such as telecommunications.

Also included in the RTP is a "Land Use and Pedestrian Element" to coordinate with and support the plan's multi-modal transportation system. This Element recommends that:

> The region's highest population and employment densities should be located within walking distance of rail transit stations and along major bus corridors. In these areas, the creation of viable, pedestrian-oriented communities is critical in making the region more livable.

To encourage local jurisdictions to implement the recommended strategies, the RTP gives priority for major transportation investments to areas where land use plans coordinate with and support the planned transportation system improvements. SANDAG staff also provide information and technical assistance to help local jurisdictions implement these recommendations.

In 1995, the SANDAG Board also approved a "Land Use Distribution Element" that provides more specific recommendations for land use strategies to support the RTP.[84] This element encourages local governments to: specify minimum densities for new development and infill; encourage a mix of land uses; ensure good pedestrian access; and provide interconnected local circulation systems - especially in the vicinity of rail transit stations and major bus corridors. The Element also suggests that major employment centers include housing and services to meet the needs of a portion of employees. In addition, it establishes "access standards" that define maximum acceptable travel times for work, shopping and service-related trips by 2010. In urban areas, such standards are provided for trips made by both transit and automobiles.

Several cities are in the process of implementing the recommendations of the Land Use Distribution Element by revising their general plans, creating "specific plans" for designated districts, rewriting zoning codes and development ordinances, and related efforts. For example, the City of Oceanside is crafting a specific plan for an area near a future rail transit station. The City of San Diego is incorporating its "Transit-Oriented Design Guidelines" into several specific plans and also revising its zoning code. Other areas that are implementing similar programs include: Chula Vista, Coronado, Lemon Grove, San Marcos, and the new "Otay Ranch" development.

SANDAG's technical staff has evaluated the potential impacts and benefits that could be expected if the Land Use Distribution Element recommendations were implemented, in coordination with the RTP's multi-modal transportation system. These impacts were compared with what could be expected from implementing currently existing local general and community plans. Overall in the region, implementation of the Element is estimated to result in: a 10 percent increase in transit use; a 5 percent decrease in the number of automobile trips; and a 10 percent decrease in the length of auto trips. In terms of air quality, this would translate to reductions in motor vehicle pollution of approximately 1.2 tons per day of reactive organic gases and nitrogen oxides (ROG and NOx), and over 7 tons per day of carbon monoxide (CO) by the year 2015.[85]

83 SANDAG, *RTP*, 1994 and 1996.

84 SANDAG, 1995.

85 SANDAG, *Final EIR*, 1994.

Communities Outside California

• Portland, Oregon

Portland is well-served by both bus and light-rail transit, and has convenient and attractive pedestrian facilities. Downtown Portland consists of relatively small blocks of buildings placed on a gridded street pattern, and is surrounded by older residential neighborhoods, sprinkled with a variety of commercial businesses. Each work day, 23% of all downtown workers commute by transit, increasing to more than 40% during peak commute periods. Partly as a result of these reduced driving rates, the city has experienced no violations of federal ozone standards since 1988, compared to a prior violation record of one day out of every three to five days.[86]

By 2010, Portland's current population of 1.4 million people is expected to grow to about 1.8 million, and is projected to nearly double by 2040 to 2.5 million. This growth has spurred concern about the potential impacts that new development in outlying suburban areas may have on the high quality of life, such as traffic congestion and air pollution. To address these issues, in 1992, the Portland Metropolitan government, "Portland Metro" embarked on a *"Region 2040"* process to plan for growth over the next 45 years.[87]

Portland Metro solicited extensive public involvement, including telephone surveys, numerous workshops, and meetings with "stakeholder" groups. Participants expressed a strong preference for: a high-quality transit system, a wider choice of living environments, and for containing new growth within the existing urbanized area and a few "satellite" suburban areas.

The final *2040 Plan* was adopted by Metro in 1994. It focuses about two-thirds of expected future development within Portland's 'urban growth boundary' through infill, mixed use and higher-density development. About one-third of this new growth will consist of compact neighborhoods and sub-regional centers. These areas will be situated near transit station and corridors that are served by high-capacity rail and bus transit systems. Another one-third of the growth will occur in smaller "satellite" cities outside the urban growth boundary.[88]

• Analysis of Alternatives

During the development of the *2040 Plan*, planners evaluated several different land use and transportation scenarios using Portland Metro's enhanced transportation demand model. The *2040 Plan* alternative that was selected for the plan was compared to other land use and transportation scenarios.

According to this analysis, Portland's *2040 Plan* is expected to result in 15 to 20% less motor vehicle pollution in the region, compared to more auto-oriented patterns.[89] Even though it concentrates new development into more consolidated areas, the selected plan is expected to produce no more traffic congestion than typical low-density growth. This plan will also require the construction of fewer new major arterials and freeways, thereby reducing impacts on existing neighborhoods and districts within the City of Portland and outlying areas.

• *LUTRAQ*

Prior to the preparation of the Portland *2040 Plan*, another land use/transportation project was conducted known as "LUTRAQ*"* (making the "Land Use, Transportation, Air Quality" Connection). It analyzed the possible effects of growth in one area near Portland on the region as a whole. The 150-square mile LUTRAQ study area is located in Tigard, 10 to 12 miles west of downtown Portland. By 2010, its population is expected to increase by 53 percent (from 290,000 to 443,000), and the number of jobs to increase by about 70 percent.

Three separate scenarios were evaluated. In the "no action" scenario, no new freeway would be built through the site. In the "freeway bypass" alternative, a major new freeway would be built, and some new transit service would also be provided. For these two scenarios, conventional suburban development densities and land use patterns were assumed.

The third scenario, termed the *"LUTRAQ Alternative,*" incorporates land use strategies

86 Portland Metro, 1993.

87 "Portland Metro" is an elected regional government encompassing numerous jurisdictions within the metropolitan area.

88 Porter, 1995.

89 Portland Metro, 1994.

that are more supportive of a multi-modal transportation system, including clustered development and a mixture of land uses. Also, higher levels of light rail and bus service would be provided. In this scenario, the new "by-pass" freeway would not be built.

An extensive analysis of these scenarios estimated that the third *LUTRAQ Alternative* would increase the regional share of walking, biking and transit use by nearly 50 percent, compared to either of the first two scenarios. Walking, biking and transit use would comprise 16 percent of total travel in the Portland region by the year 2010, compared to 11 percent in the first two alternatives.[90]

Within the proposed *LUTRAQ* pedestrian and transit-oriented neighborhoods, the portion of travel by transit, walking and bicycling was projected to be about 21 percent. This is in comparison to only about 5 percent in existing, more auto-oriented suburbs near Portland.[91]

LUTRAQ: **Projected Transit and Walking Mode Shares in 2010:**
Four Alternative Scenarios

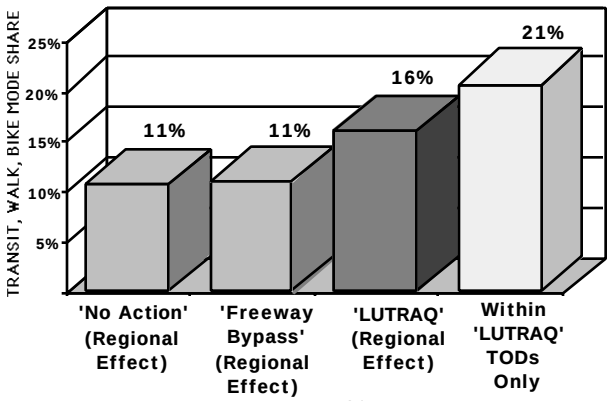

Figure 11 [90]

As a result of the LUTRAQ study, plans to build a new bypass freeway have been dropped. Instead, construction has begun on a light rail transit system to serve the area. And, several TOD neighborhoods are under construction or planned in the near future. The concepts, techniques and tools that were developed as a result of this project, became important ingredients in the subsequent development of the *Portland 2040* long-range plan for the entire metropolitan area.

• **Toronto, Canada**

Over the past 30 years, the city of Toronto, Canada, has become an example of how transit and land use planning can be effectively integrated to create a less automobile-dependent urban environment. Toronto began developing its transit system during the 1960s when traffic congestion started to become severe. Now, it enjoys one of the best public transit systems in North America, and also has one of the highest transit usage rates, despite high levels of automobile ownership. The effective linking of urban land uses to transit is one of the main reasons for Toronto's success.

Clustered, higher density, mixed uses within easy walking distance of transit stations allow easier access. A significant increase in the value of the land surrounding major transit corridors has occurred, enabling a vigorous "joint development" program that contributes funds needed to construct new transit lines.[92] The city's mixed-use neighborhoods offer diverse opportunities for residents with a minimum of travel time and cost.

• *Toronto's Strategies Are Working*

More than 80% of people who attend events at a sports stadium near downtown Toronto (the Sky Dome) arrive by public transit, despite the availability of parking close to the stadium. Several other statistics illustrate the success of Toronto's re-orientation to walking and transit:

- 17% of all travel in the city is by transit -compared to 1% in Detroit, Michigan
- 31% of all commute travel is by transit -compared to an overall average of 12% of commute trips in U.S. cities;
- Over 80% of all trips into downtown Toronto are made on public transit.
- 15% of people who live in the downtown area walk to work.

90 1,000 Friends of Oregon, *Aternatives Analysis*, 1992.

91 1,000 Friends of Oregon, 1993.

92 Kenworthy, 1991.

QUANTITATIVE RELATIONSHIPS

Several research studies indicate that higher density and mixed-use developments, located within walking distance of transit stations can result in significantly higher levels of transit use. One study found that workers who live near stations in the San Francisco Bay Area were five times more likely to commute by rail transit compared to average workers living in the same city.[93] This conclusion is consistent with another study previously conducted in the same region.[94]

Rates of Transit Use for Commuting in the S.F. Bay Area

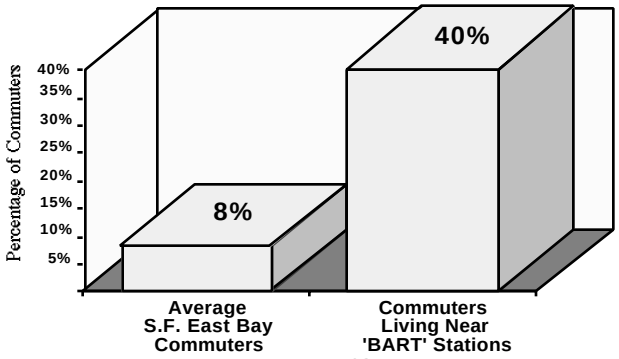

Figure 12 [93]

According to a nationwide travel survey, people who live within 1/4 mile of a transit stop or station are nearly three times more likely to use transit than those who live between 1/4 and 2 miles from a station. Residents of housing situated within 2 miles of a transit station are nearly four times more likely to use transit for commuting than those who live further than 2 miles from a station.[95]

Improved air quality can be one of the benefits of clustered residential development near transit, especially when the number of park-and-ride trips are reduced because people can more easily walk to the station. In the S.F. Bay Area, 80 percent of suburban Bay Area residents who currently use BART drive (or are driven) to the train, averaging five miles each way.[96] These short trips produce significant "cold-start" emissions.

Quantitative relationships between land use, transportation and travel behavior have also been explored in a number of community or regional-scale studies. One recent detailed analysis of 28 neighborhoods throughout California confirmed that there is a strong statistical relationship between density, neighborhood design and location, transit service, and reduced household driving rates.[97]

A region-wide travel survey conducted in the S.F. Bay Area found a quantitative relationship between population density and increased transit availability and use.[98] And, researchers who studied land use and travel in 32 major cities world-wide found vehicle use rates to be highly correlated with urban form and density, as well as the provision and extent of transit service and pedestrian facilities.[99]

Around the world, the quantitative relationship between density and travel in metropolitan areas follows a consistent pattern. Studies conducted in New York, Washington State, California, Canada, Australia, Europe and Asia, have found a similar trend: for each doubling of density, the average annual rate of vehicle travel per person (and household) tends to be reduced by *25% to 30%*. [96,97,98,99]

Relationship Between Population Density and Average Annual VMT

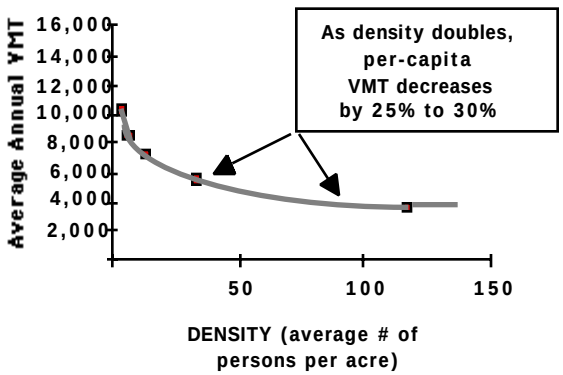

Figure 13 [96,97,98,99]

93 Cervero, 1994.

94 Deakin, Harvey & Skabordonis, 1981.

95 U.S. Dept. of Transportation, 1986.

96 Cervero, 1994.

97 Holtzclaw, 1990 and 1994.

98 Deakin, *ibid.*

99 Newman and Kenworthy, 1989.

ARB-Sponsored Research

To gain a better understanding of the relative value of pedestrian and transit-oriented development in reducing vehicle use and related emissions, the ARB has funded two significant research studies focusing on residential neighborhoods.

- **"Five Neighborhoods" Study**

The purpose of this study was to analyze the travel patterns of residents living in higher density, mixed use neighborhoods in California, and compare them to travel in more auto-oriented areas. It was conducted by the Institute of Transportation Studies at the University of California, Davis.[100] Because there were as yet few completed new 'Transit-Oriented' developments, five existing neighborhoods were selected in various parts of the San Francisco Bay Area. The study areas were chosen based on demographic, land use, and transportation infrastructure information.

Four of the five neighborhoods in the study have good-quality transit service, along with: overall higher densities, interconnected street patterns, and mixtures of residential and commercial uses. The fifth is a typical suburban low density, single-use neighborhood with little transit service. This neighborhood, which is located in San Jose, serves as a baseline for comparison with the others.

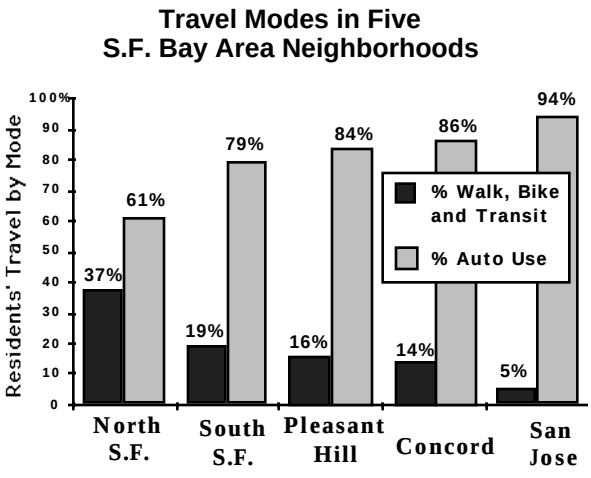

Figure 14 [100]

The results of the study indicate that there is a significant connection between neighborhood characteristics and residents' travel behavior. Rates of walking and transit use were found to be *three to four times higher* in the mixed-use, higher density neighborhoods with good transit service, compared to the standard suburban area. Residents of these neighborhoods drove for 10 to 30 percent fewer trips, although their total amount of travel was not diminished.

This study found household income to be a much less important factor in residents' travel mode choices than was previously thought, especially when land use and transit service were taken into consideration. It also confirmed that demographic factors such as income are significantly related to residents' total amount of travel, regardless of which mode they use.

- **"Transportation-Related Land Use Strategies" Study**

A second ARB-sponsored study also found a significant correlation between travel behavior and community characteristics, such as density, mixed land uses, transit service, and access-ability for pedestrians.[101] The study was conducted by a team of consultants, with significant input from members of a statewide advisory committee that included represen-tatives from local and state agencies, private businesses and environmental groups.

Data was obtained from a variety of sources, including studies of communities both within and outside of California. One of these provided a detailed evaluation of land use and travel patterns in 28 case study communities in California.[102] It quantified each community's level of: transit service, pedestrian acces-sibility, overall density, mixture of land uses, average household income, and other relevant features. It also analyzed these factors to determine their relative importance regarding travel behavior.

Summarized in the following table are average annual rates of vehicle miles of travel (VMT) from this study for typical households in several sample urban and suburban communities:

100 Kitamura, *et al,* 1994.

101 JHK & Associates, 1995.

102 Holtzclaw, 1994.

Household Travel Characteristics in Sample California Communities

	Region	Average Annual VMT per Household
URBAN Communities:		
San Francisco	S.F.	**11,300**
Berkeley (central)	S.F.	**12,500**
Santa Monica (southern)	L.A.	**14,700**
San Diego (uptown)	San Diego	**15,500**
SUBURBAN Communities:		
Pasadena (s. central)	L.A.	**17,300**
Daly City	S.F.	**19,300**
Escondido	San Diego	**21,700**
Walnut Creek	S.F.	**22,300**
Riverside (northern)	L.A.	**23,700**

Figure 15 [103]

Based on this and other available data, the project team developed a set of eight suggested "performance goals" for urban, suburban, and rural communities in terms of reduced average annual per-household driving rates and related motor vehicle emissions.

For *suburban* communities, achieving the performance goals could result in reduced annual household rates of driving and associated vehicle emissions of approximately 10 to 20 percent, as compared to more auto-oriented areas typical in suburban areas. In *urban* areas, annual per-household driving rates and related emissions could be reduced by at least 20 percent.[104]

To help communities achieve the performance goals, a set of land use strategies is also recommended in the report:

- Strong downtowns and concentrated activity centers
- Mixed-use development
- Increased density near transit stations and corridors
- Pedestrian and bicycle facilities
- Interconnected travel networks
- Strategic parking facilities

Implementing these strategies in coordination with a multi-modal transportation system can help reduce rates of driving while ensuring mobility and reducing vehicle-related air pollution. These strategies could also result in more "livable communities" by increasing the number of options available to people for housing, shopping, employment and travel.

The extent to which the transportation-related land use strategies are implemented are expected to vary depending on whether a community is urban, suburban or rural. For this reason, the report also describes eight different sets of "strategy packages" - three each for urban and suburban communities, and two for "exurban" areas. Each of these strategy packages is associated with achieving one of the eight "performance goals" described above. The packages include details about the recommended land use strategies, along with accompanying levels of transit service, pedestrian facilities, and other related factors.

In addition, the final project report also lists a number of mechanisms that can be used to implement the strategies. These include: plans, policies, documents, administrative actions, organizational tools, resources, and monitoring methods. Examples of local programs and projects that have been successfully implemented are also included. Many of these implementation tools are already available to communities.

There are many factors that can affect whether communities successfully implement these strategies, and to what degree, including: the type of community, its location within a metropolitan area, its rate of growth, the activities it accommodates, the topography, whether it is "built-out" or has room to grow, and economic activity. It is not necessary to implement these strategies throughout an entire community to realize a positive benefit. However, the extent of implementation will contribute to the amount of benefit that can be achieved. Even in cities that are already "built-out," there may be areas with redevelopment and infill potential. Or, a portion of new development in a growing area could be designed to be more transit and pedestrian-supportive. Also, in most areas, increasing the amount and quality of transit service, pedestrian access and bicycle facilities would help reduce traffic congestion.

103 Holtzclaw, 1994; cited in JHK & Assoc., 1995; table 5-1.
104 JHK & Assoc., 1995; table 5-4.

AIR QUALITY BENEFITS

Land use and transportation strategies that reduce vehicle travel have multiple benefits, including reduced air emissions. To be successful, the implementation of such programs necessitates the cooperation of local government elected officials and land use planners, as well as other decision-makers such as developers, financial institutions, transportation agencies and local residents.

Neighborhood/Community Level

In 1990, based on data available at that time, ARB staff estimated that a reduction of 20 to 50 percent in personal vehicle travel was possible at the neighborhood or community level if transportation-related land uses were implemented in coordination with a multi-modal transportation system.[105] Since 1990, several studies have found that reductions in the range of 10 to 30 percent in per-household vehicle travel and related emissions are possible at the neighborhood or community level.[106,107,108] (This is in comparison with typical low-density, single-use development.)

Regional/Metropolitan Level

On the regional level (encompassing a metropolitan area), the extent of benefits from land use and transportation strategies depends on the amount, density and location of development that occurs. Also, the type and extent of highways and transit service and the quality of pedestrian facilities are also important factors. Despite these complexities, analyses of specific regions using standard travel demand models have found that multi-modal transportation systems - supported by appropriate land uses - can reduce regional vehicle travel and associated emissions by 5 to 15 percent, compared to typical auto-oriented land use and transportation growth patterns.[109,110]

105 Calif. Air Resources Board, July 1990.

106 *Greenhouse Neighbourhood Report,* 1993.

107 JHK & Associates, 1995.

108 Kitamura, 1994.

109 Ewing, 1993.

110 1,000 Friends of Oregon, 1993.

OTHER BENEFITS

Other benefits besides air quality can result from the land use strategies listed in this report. These potentially include: decreased infrastructure costs from new development for local governments, consumers and developers; an increased supply of affordable housing and more diverse neighborhoods; reduced traffic congestion; more convenient access to stores and services; lower energy use by buildings and vehicles; the preservation of existing open space; and increased mobility for children, the disabled, and elderly residents.

Fewer Automobile Expenses

The availability of convenient transit and pedestrian facilities near housing and employment centers can reduce a household's transportation costs by decreasing the number of vehicles that are needed. On average, it costs about $6,000 per year to own and operate a typical automobile or light-duty truck.[111] This would equate to about $500 per month per vehicle that could be saved.

Economic Advantages

Researchers have explored the economic benefits to developers, retailers and local governments that can be realized from implementing transit and pedestrian-oriented development. According to a book recently published by the Local Government Commission, development near transit can: maximize public investment in transit, increase property values, and result in higher tax revenues.[112]

Several studies support these claims. An economic analysis of areas near rapid transit stations in the San Francisco Bay Area found that medium-density apartments and condominiums, as well as commercial and retail properties, have higher property values and rents compared to similar properties farther away from transit. For example, apartment complexes near the Pleasant Hill Bay Area Rapid Transit (BART) station rent for about 15 to 30 percent more than similar units that are farther away from BART.[113]

111 AAA of Southern Calif., 1992.

112 Local Government Commission, August 1996.

113 Economics Research Associates, 1995.

Analysis of rents charged for commercial space revealed that "walking distance to a BART station and office rent per square foot are linearly related."[114] Rents for retail uses were found to be almost three times higher near transit stations than further away:

> "Retail rents, on average, for businesses located less than one-quarter mile from a BART station were approximately $2.47 per square foot...Lease rents in buildings [located farther away] averaged only $0.89 per square foot."[115]

Similar trends have been found in other states. For example, a study of areas near transit stations in Atlanta, Georgia, found a significant increase in retail activity after the introduction of public transit:

> "Approximately 61 percent of businesses located at downtown stations reported an increase in monthly sales volume during the first year of transit system operation."[116]

Based on research conducted by U.C. Berkeley's "Transit Access Center," Dr. Robert Cervero agrees that combining public transit investments with private real estate projects not only supports transit, but can also help increase the value of the real estate investments. These types of projects, commonly referred to as "Joint Development," can also translate into higher sales and property tax revenues for local governments.[117]

Lower Infrastructure Costs

Infrastructure improvements for new development typically include installing and maintaining roads, water, gas and electric utilities, sewer facilities, and telephone lines. Lower density development located in suburban fringe areas typically requires facilities and services that are much more expensive to provide compared to more compact growth located closer to urban areas.

Several researchers have analyzed the costs to local governments, special districts, and private developers for infrastructure improvements. According to one study conducted in Florida, it cost an average of about $48,000 per house (in 1989) to provide infrastructure improvements to suburban fringe housing developments. The projects that were studied had an average density of 3 dwelling units per acre and were located 10 miles from central facilities.[118]

In contrast, the average cost of providing the same services for developments located closer to an urban center and averaging 12 dwelling units per acre were one-half as high, or $24,000 per unit. For development with even higher densities within central urban areas, infrastructure costs averaged $18,000.[118]

Infrastructure Costs in Relation to Residential Density and Location

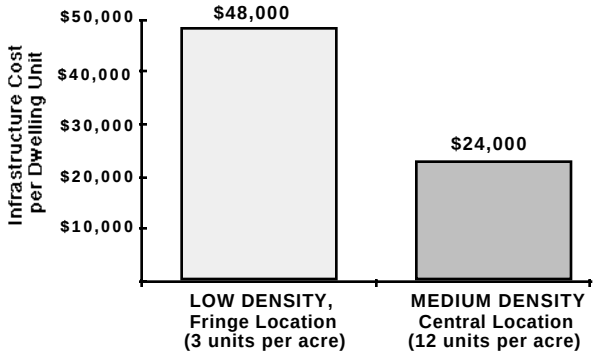

Figure 16 [118]

The City of San Jose prepared a fiscal analysis of growth impacts as part of its 1993 General Plan update. Economic consultants analyzed the costs of providing typical urban services to new development located both within existing areas and outside of the city. They estimated that locating 70,000 new residences and 126,000 additional jobs within or near existing urbanized areas would result in a net revenue gain of about $2 million.[119] In contrast, allowing the same number of residences and jobs to be locate outside the existing urbanized area would create a net loss of local revenues totaling over $600,000 per year. Partly as a result of this analysis, San Jose decided to constrain new development within or close to the existing city boundaries.

114 Economics Research Assoc., p. 25.

115 *Ibid*., p. 27.

116 Sacramento Regional Transit District, 1992; p. VI-8.

117 Cervero, Winter 1994.

118 Frank, 1989; and Kassowski, Kevin, 1992.

119 Economic and Planning Systems, Inc., 1993.

Diverse and Affordable Housing

"Area Housing Costs Hinder Efforts to Attract Businesses." [120] This newspaper headline illustrates that regions with high housing costs can find it more difficult to compete economically with areas that have a lower cost of living. A survey of 3,400 U.S. companies nationwide found that the costs of real estate and the efficiency of local transportation systems (including levels of traffic congestion) are two of the most important considerations in many corporate relocation decisions.[121]

Nearly two million additional dwelling units are projected to be needed to house California's expected population between 1995 and 2000.[122] If these units are built in suburban locations and at low densities, they will consume at least 600 square miles of additional land -- not including the associated commercial and government services, employment centers, highways, parking lots and other development.

However, if just one-half of this new growth were to be clustered into more compact, mixed-used configurations, the amount of land required could be reduced by 25 percent or more.[123] Also, this type of growth could be more efficiently served by transit and would enable people to more easily walk and bicycle, reduce air pollution impacts, and also contribute to more “livable communities.”

One of the greatest housing needs is for first-time home buyers, who in 1992 purchased nearly 50 percent of all housing units sold in California. However, many first-time buyers cannot afford traditional single-family homes located near major employment centers. For this reason, some developers in Sacramento County have been building single-family housing averaging between 7 to 10 dwelling units per residential acre, as compared to the typical 5 houses per suburban acre or less.[124] These types of new developments can make it easier for residents to use modes other than automobiles for some of their daily travel.

CONCLUSION

Land use and transportation strategies, such as those described in this report, will assist in the long-term improvement and maintenance of California's air quality.

The Air Resources Board encourages local governments and other agencies, as well as land use planners and developers, to begin implementing these strategies in new and existing communities.

Such strategies can work in combination with other air quality programs and regulations to decrease reliance on single-occupancy vehicles, reduce vehicular emissions, and control stationary sources of air pollution, as necessary ingredients in the recipe for cleaner air.

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120 *Sacramento Bee*, 1992.

121 Urban Land Institute, January 1993.

122 HCD, 1995.

123 Sharpless and Parker, 1994.

124 *Sacramento Bee*, Feb. 21, 1993.

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