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**Title**

Employment Suburbanization and the Journey to Work

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Employment Suburbanization and the Journey to Work

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## **Abstract**

Large scale suburbanization of employment has dramatically changed transportation and land use planning. Intersuburban commuting now dominates regional highway networks, and the automobile has replaced mass transit for many commutes. Planners' approaches to these developments vary from the pro-centralization approach of many environmentalists and transit advocates to the view that employment suburbanization enhances mobility. In the middle are those planners who seek a geographic match between suburban jobs and suburban housing.

This study examines one aspect of the debate on the effects of employment decentralization on regional mobility: the impact of growing suburban employment on the commutes of different income groups. The study suggests that suburban employment centers with high levels of multifamily housing will exhibit commute patterns in which household income and commute distance are largely independent. In contrast, in suburban areas where the development of dense housing has not kept pace with employment growth, it is hypothesized that new commute patterns are emerging wherein lower income households commute greater distances than their upper income counterparts. This pattern would be the reverse of the prediction of monocentric urban models for

central city employment.

These hypotheses are tested for San Francisco Bay Area communities using data from 1981 and 1989. Bivariate analyses generally supported the predicted effects of community employment base and housing stock on commute patterns by income. Nested multinomial logit models of the household residential location decision were estimated for workers in San Ramon and in northern Santa Clara County. The models appeared to demonstrate a positive effect of the availability of multifamily housing on the residential location decisions of low to moderate income households. In addition, workplace accessibility in general emerged as a powerful determinant of residential location. Forecasts of commute patterns using the estimated models indicated a potential for reducing long distance commutes by low to moderate income households through a policy encouraging multifamily housing construction in the vicinity of suburban employment centers.

## Acknowledgements

This dissertation could not have been completed without the help of many generous individuals. Each of the members of my dissertation committee, William Garrison, Robert Cervero and Elizabeth Deakin, as well as John Landis, provided needed input at all stages of the research. They have shaped my ideas profoundly. Robert Cervero and John Landis directed the project that provided the current data analyzed in this study. Elizabeth Deakin served both as my dissertation chair and advisor in the doctoral program; I benefitted enormously from her genuine concern for my progress and welfare over the past four years.

Greig Harvey spent many hours discussing with me the art of discrete choice modeling and provided the Bay Area Travel Survey files which he had processed into useable form. Uri Geva spent an entire weekend adapting Metropolitan Transportation Commission network level of service data for analysis on microcomputers. Compiling LIMDEP on the mainframes at Berkeley was a task in which Danny Dolev, Max Leavitt, Paul Chase, Rei Lin and Kathy O'Regan all gave much needed help. Jerry Berkman spent many days successfully grappling with the "impossible" task of revising LIMDEP to run correctly on the Cray supercomputer.

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My wife Noga has supported and encouraged me throughout the project, and was my inspiration for embarking on it in the first place. Her contribution has been immeasurable. My children participated as well; from Adam's concern ("Did everything go okay on the computer today?") to Shira's drive to understand what it was all about, they added life and joy to the process.

My parents, Rose and Hillel Levine, edited and proofread the drafts, but the original installment on their investment in this dissertation came many years earlier. This dissertation is lovingly dedicated to them.

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## Chapter I:

### Introduction and Background

The United States is a suburban nation. Metropolitan populations outside of central cities have exceeded both the urban and rural populations since 1960, and by the time of the 1980 Census, Americans living in the suburbs outnumbered city dwellers by nearly three to two (0). Following the population, employment has continued to decentralize as well. Between 1960 and 1980 nearly two thirds of metropolitan job growth occurred in the suburbs (Pisarski 1987). In the ten largest U.S. urbanized areas, core city employment in 1980 accounted for only 7.4 percent of areawide jobs (Gordon et. al 1987b). These processes have accelerated over the 1980's, producing an unparalleled wave of suburban office and service employment (Cervero 1989b).



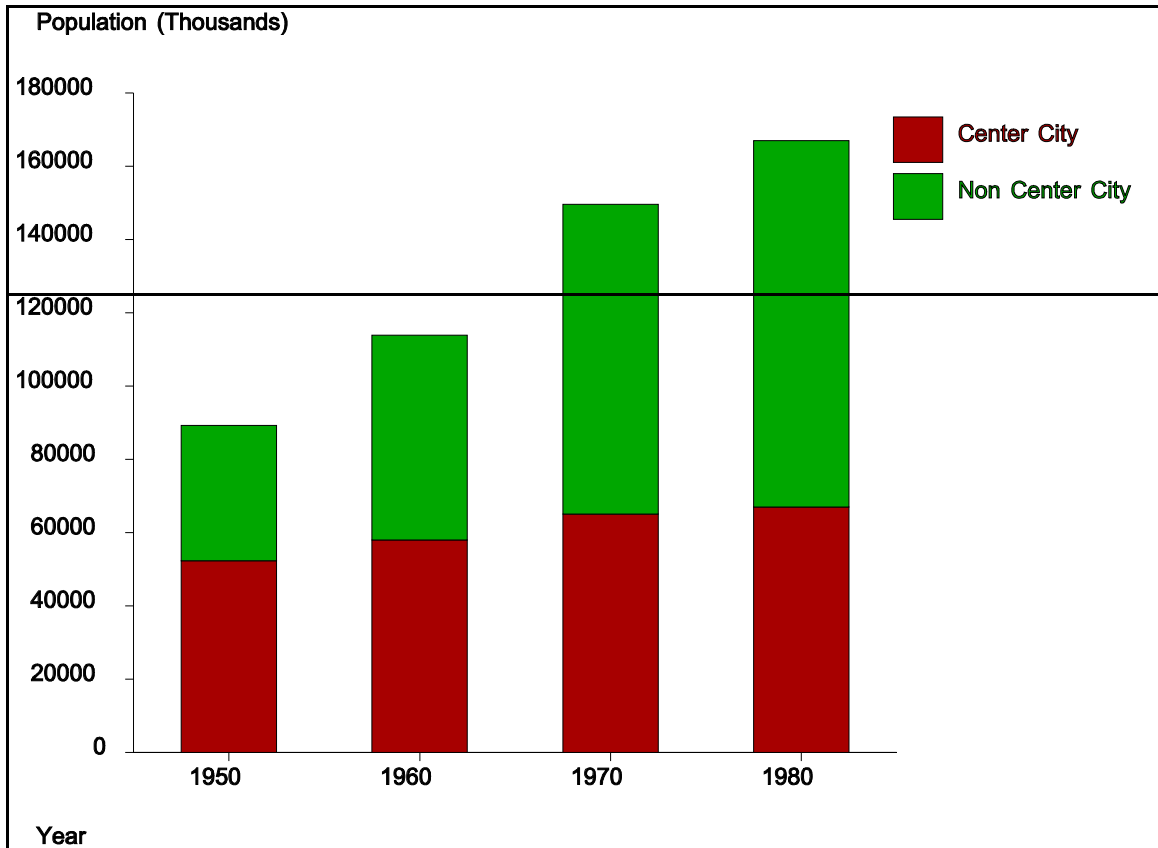


Figure 1: United States Metropolitan Population, by Center City and Non Center City Components, 1950-1980 (Source: United States Census of Population)

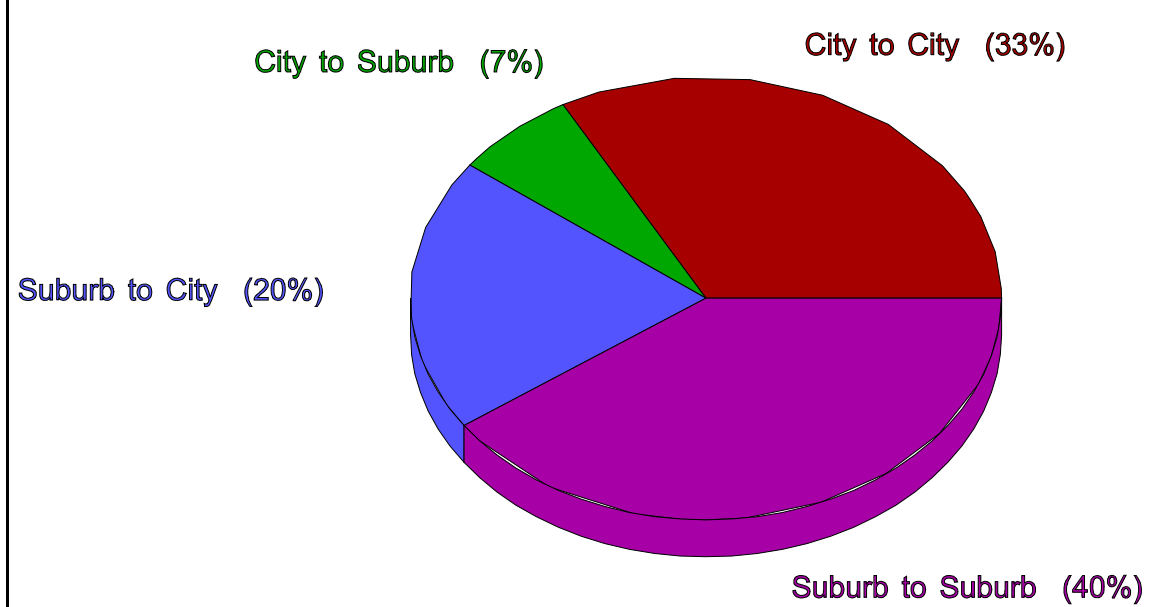


Figure 2: United States Metropolitan Commutes by Origin and Destination, 1980 (Source: Pisarski 1987)

The implications of these trends on metropolitan transportation planning have been substantial. Suburb-to-suburb commutes currently outstrip both intraurban and suburb to central city journeys to work; nationwide, a plurality of metropolitan commutes now begin and end outside central cities (2). Importantly, these suburb-to-suburb commutes grew over 17 percent in length in just five years between 1975 and 1980 (Pisarski 1987).

The second major implication of widespread employment suburbanization has been a shift toward the use of the private automobile. Transit's mode share declines sharply with employment suburbanization (Daniels 1972a, 1982b, 1981, Pisarski 1987) as suburban employment locales are virtually impossible to serve by conventional transit because of scattered trip ends. Even ride sharing may become more difficult when increasing numbers of people work in sites with fewer nearby workers than in more traditional downtown employment settings.

Trends towards intersuburban commuting and greater reliance on the private automobile associated with employment suburbanization are not in great dispute. Much more controversial are the implications of these trends for transportation and land use planning as well as for the prospects for metropolitan areas in general. Some planners

contend that large scale employment suburbanization harms the long term viability of metropolitan areas by reenforcing automobile dependency and promoting environmental destruction through excess land consumption and air pollution (Greenbelt Alliance 1989). Bolstering the position of central cities within metropolitan areas, under this view, would enhance the diversity of social and economic opportunity for both individuals and firms. The central position of downtowns within metropolitan areas is seen as a boost to overall accessibility as well, particularly as this central location supports a high mode share for mass transit.

Others argue precisely the opposite point of view. Employment decentralization, under this alternative perspective, is the very force that renders large metropolitan areas accessible. By eliminating the need to commute from the metropolitan periphery to the central business district (CBD), employment suburbanization has kept commute distances in larger urban areas from growing to unmanageable proportions (Gordon et al. 1989). The automobile's mode share for work trips may grow with continuing decentralization, but commute distances and times will shrink.

A third point of view accepts the inevitability of

employment suburbanization, but points to a systematic separation between suburban workplaces and suburban residences as a continuing impediment to regional mobility (Cervero 1986, 1989a, 1989b). Despite the traditional conception of the "suburb", some suburban communities have a large employment base relative to a limited housing stock, while others contain the reverse. Intersuburban commuting, now the dominant form of metropolitan journeys to work, is the result. The "jobs-housing balance" approach seeks to identify those economic and political forces that lead to deficits of housing in the vicinity of suburban employment centers, and to develop structures for planning and development that would generate a better geographic match between employment and housing. The geographic matching would presumably obviate the need for much of the intersuburban commuting that has been observed in recent years.

### **Research Objectives**

This study examines one aspect of the debate on the effects of employment suburbanization on regional mobility: the impact of growing suburban employment on the commutes of different income groups. The study poses three major questions: 1) Does suburban employment tend to favor the

commutes of one income group or another; 2) If income-related commute patterns are evident among commuters to suburban employment centers, is there a relationship between observed commute patterns and characteristics of the particular suburban employment center being analyzed, and 3)

Can policies allowing or encouraging development of higher density housing in the vicinity of suburban employment centers reduce long distance commutes by low to moderate income commuters?

This study suggests that the growth of suburban office and manufacturing employment of recent years has led, in some areas, to the emergence of new suburban commute patterns in which lower salaried workers commute farther to work than their more highly paid counterparts. This commute pattern is not expected to be universal, but rather to manifest itself in suburban areas that constitute major employment centers and in which the local housing stock has not kept pace with the development of employment. In particular, a lack of multifamily or other affordable housing types in the vicinity of major suburban employment centers is expected to precipitate a negative relationship between commute distance and household income.

The idea that income patterns may be evident in the suburban commute is notably controversial in the journey-to-

work literature. Gordon et. al (1987a) state: "Evidence was presented that metropolitan dispersion reduces congestion at the center and makes shorter suburban tripmaking possible, indicating that decentralizing residences and employers settle near each other. The simple idea that the suburbanization of residences prompts all or most industry to follow the labor force (as well as product markets) suggests that the cited benefits of urban decentralization are available across the income spectrum. Suburbanization, then, **would favor all income classes' commuting equally...**(emphasis mine)"

Gordon's conclusion would in fact fit well with earlier empirical studies (Kain 1962, Feldman 1981) which showed that commute distances for suburban employment were largely uncorrelated with income. As opposed to central city employment, which was characterized by lengthy commutes for the affluent and closer-in living by the poor (Kain 1962, Hecht 1974), commute distances to suburban workplaces were found to be independent of income, although housing discrimination tended to restrict blacks to central city areas.

This independence of suburban commute distance from household income may still hold in many suburban areas of smaller cities, in areas of less concentrated suburban

employment, or in areas where housing stocks have densified in response to suburban employment growth (e.g. Ley 1985). But when office or high technology manufacturing employment suburbanizes massively without corresponding residential densification nearby, competition for residential suburban land may intensify to the point that lower and moderate income households are no longer able to find pockets of affordable housing locally and are thus forced into increasing commutes.

If commute patterns in fact develop largely in response to local land use and housing stock conditions, a study of the effects of employment suburbanization on regional mobility is best conducted under a fine-grained approach that avoids blanket statements about suburbanization's effects. Within any large metropolitan area one is likely to find suburbs wherein the employment density rivals that of some central cities, as well as suburbs with virtually no employment. Some suburbs may have a dense housing stock comprised mostly of multifamily units, and others may average one home to the acre. Intersuburban income variations may be no less than the gaps found between city and suburb. The nature of the suburban employment base varies between heavy industry with serious local environmental effects, to relatively non-polluting industry,

to office and service sector employment.

The hypotheses of this study are stated in light of this diversity of suburban conditions:

Hypothesis #1: In suburban areas containing concentrated<sup>1</sup> employment but low levels of multifamily or other dense housing forms, higher income households will tend to live nearer to work than lower income households.

Hypothesis #2: In suburban areas containing concentrated employment and high levels of multifamily or other dense housing forms, commute distances will be independent of household income, or may be positively associated with household income (i.e., upper income households commute farther).

Hypothesis #3: The availability of multifamily housing in a suburban community increases the chances of a low to moderate income household selecting that community.

Hypothesis #4: Increased availability of multifamily housing in the vicinity of suburban employment centers can stem some long distance commuting by low to moderate income households.

These hypotheses are explored in four steps. The study initially examines San Francisco Bay Area communities for differences in employment and housing stock conditions. Then, income-related suburban commute patterns are analyzed through a descriptive analysis of disaggregate commute and location data for the San Francisco Bay Area in 1981 and San

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<sup>1</sup>No theoretical dividing lines between "sparse" and "concentrated" suburban employment, or "low" or "high" levels of multifamily housing, are proposed. Variations in suburban employment levels and housing stock will be explored empirically in Chapter IV.



Ramon and northern Santa Clara County in 1989. Third, discrete choice models are constructed that attempt to identify and measure those aspects of households and communities that determine residential location decisions. The discrete choice models are designed in particular to estimate the utility of the availability of multifamily housing in a particular community to households of low to moderate income. Finally, the estimated models are used to predict effects on commutes of policies encouraging multifamily housing development in the vicinity of suburban employment centers.

#### The Diverse Suburbs: An Analytical Framework

The hypotheses discussed above suggest a classification of suburbs according to employment and housing stock. Three typologies are suggested: these patterns will be referred to as the sparse employment suburb, the low residential density suburban employment center (or low density center), and the high residential density suburban employment center (or high density center)<sup>2</sup>. The typologies are not presented as competing or mutually exclusive; indeed, different

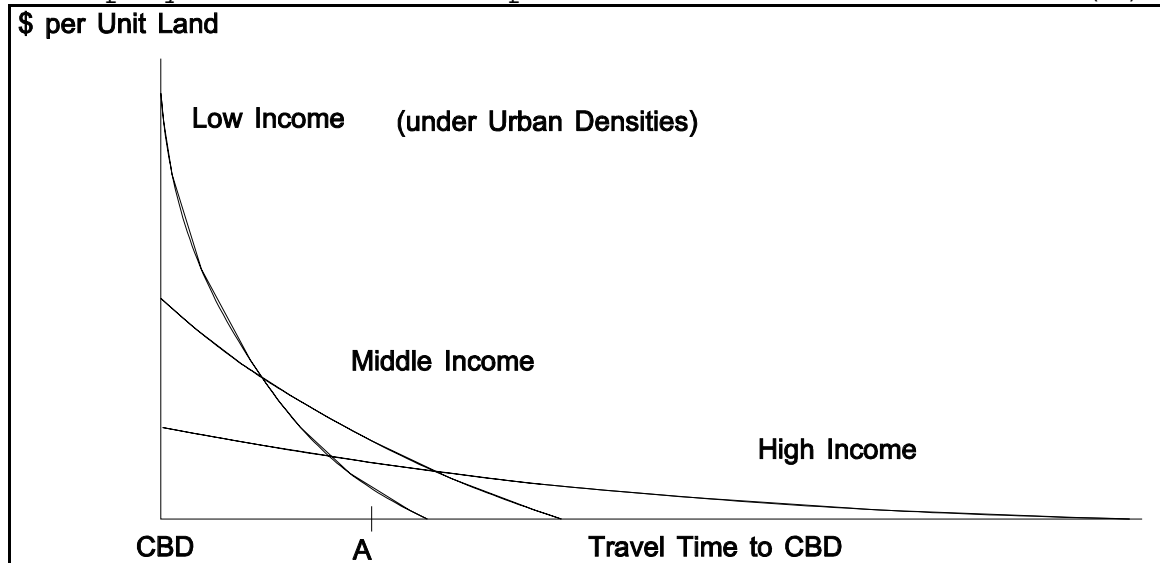
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<sup>2</sup>Excluded from this classification would be suburbs with high residential densities but little employment, and suburbs with no employment whatsoever.

metropolitan or sub-metropolitan areas may be best approximated by one or another of the models. In larger metropolitan areas, it is reasonable to believe that the different patterns may coexist. Moreover, the line between the typologies is blurred, and none represents a perfect fit in any area. Yet it is suggested that the interaction of employment and housing stock, as described in this section, has a significant effect on the suburban commute.

#### Sparse Employment Suburb

The sparse employment suburb arises where suburban employment is insufficiently concentrated to command a local land rent premium. The metropolitan rent surface is primarily determined by accessibility to the concentration of employment in the metropolitan center or a subcenter (3).



**Figure 3: Bid Rent Curves by Income Class Under Sparse Suburban Employment**

Suburban employment locations (A) are not sufficiently large to perturb significantly an overall negative rent gradient from the center to the metropolitan periphery. Under these conditions, if the standard assumptions of the monocentric model hold (Alonso 1960), i.e., if the income elasticity of households' housing demand exceeds the income elasticity of marginal commute costs, the bid rent curves of high income populations will be flatter than those of lower income groups. The resulting settlement pattern will be concentric rings of increasing income radiating outward from the metropolitan center.

This pattern of settlement has important implications for commutes by income. With scattered employment sites located between the metropolitan center and its periphery, both low and high income workers may be expected to commute long distances to a particular site, while some middle income workers may have a short commute (4). Thus when suburban job sites are relatively scattered and

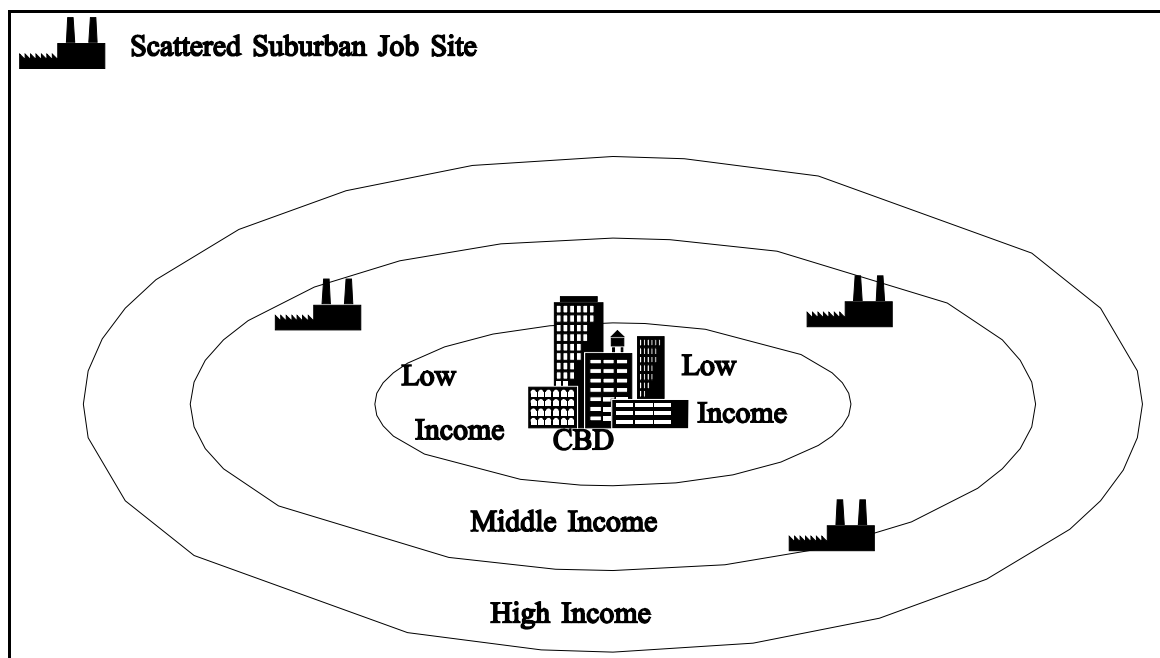


Figure 4: Schematic Drawing of Sparse Suburban Employment

inconsequential compared to the employment concentration at the metropolitan center or a subregional center, monocentric models of location would predict commute distance to these

centers to be largely independent of household income. This prediction is not tested empirically in this study, but presented as background to the two alternative typologies below.

In practice, this prediction of the monocentric approach may often be confounded by environmental effects of dispersed suburban employment. Industrial suburbs may suffer from localized externalities of air pollution, industrial odors and noise. These effects can spur upper income households who can afford more remote housing (and the commute it entails) to locate farther from work than lower income households. In these instances the expected independence between income and commute distance may give way to a positive relationship.

#### Low Residential Density Suburban Employment Center

In contrast, consider a metropolitan area with significant centers of suburban employment. No longer are land rents determined primarily by access to center city or a subcenter; instead, access to major suburban employment centers (defined as larger scale, concentrated areas of suburban employment) commands a rent premium as well. In central cities, high priced residential land with great accessibility to employment concentrations tends to be

developed with dense housing. In contrast, these suburban communities utilize their power of land use regulation to restrict the development of denser housing. The housing stock remains dominantly of a large lot single family character, principally as an outcome of planning and public decision making processes that encourage the development of employment while avoiding the construction of housing affordable to local workers (Danielson 1976).

Where public policy prevents close-in land from being divided in to smaller pieces through dense forms of residential construction, lower income households are unable to outbid higher income households for residence near job

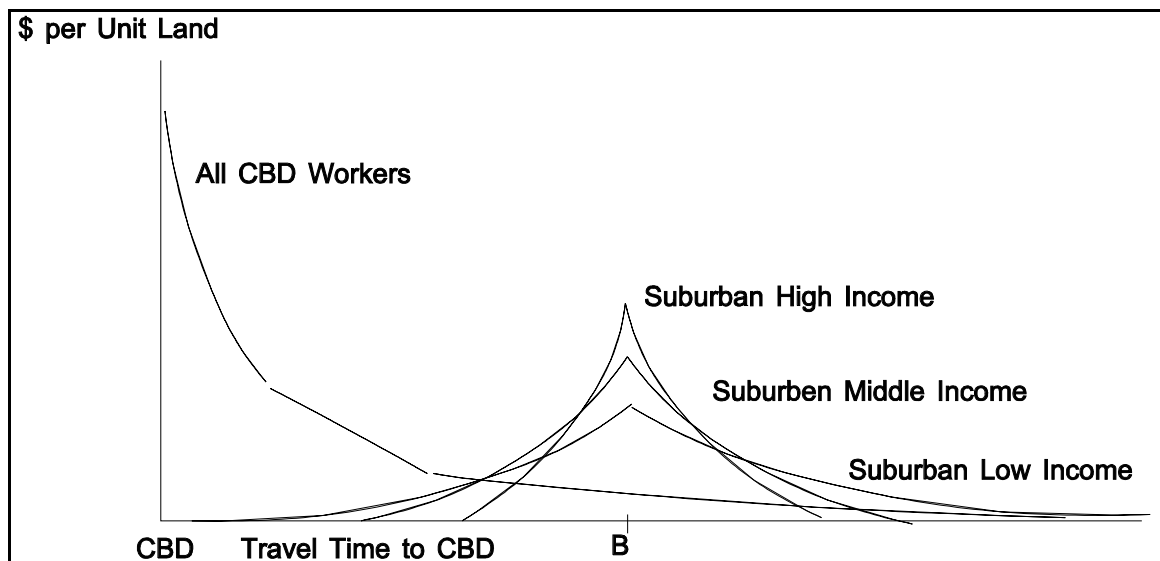


Figure 5: Bid Rent Curves by Income Class for Workers in Low Density Centers

centers (5) as they tend to in the central city context. Instead, the highest price for land near suburban employment centers (B) is offered by the wealthier households, because the normally steep bid rent curves of lower income households have been flattened by the unavailability of affordable housing near their suburban employment center.

Conditions such as these are likely to lead to a different relationship between commute distance and household income. Historically, middle to upper income groups have accepted longer commutes in order to enjoy cheaper land costs. In contrast, in the context of the low residential density suburban employment center, these groups live within several miles of suburban employment centers, and low to moderate income households opt for longer commutes, usually from more remote suburbs or exurbs, to

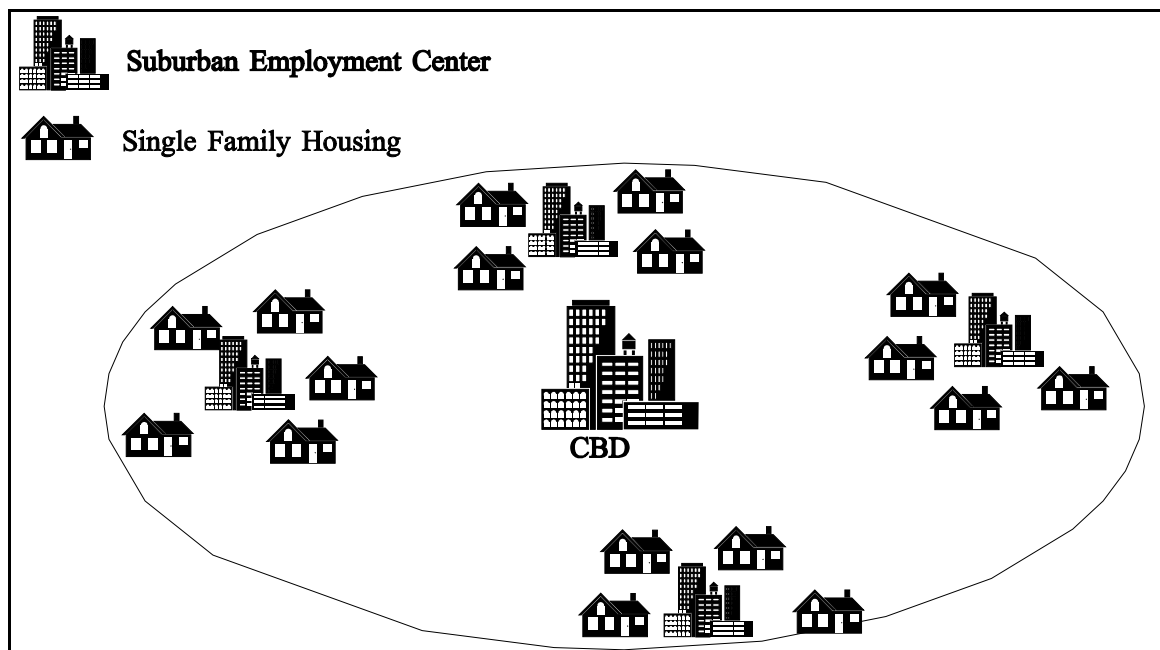


Figure 6: Schematic Drawing of Low Density Center Typology

reach affordable housing.

Given high priced land in the vicinity of major suburban employment centers, close in affordable housing will generally have to be built more densely than the standard single family home. Thus a pattern of longer commutes by lower income households is precipitated largely by local political preferences against growth in more dense and affordable housing types. But local land use policy is not the sole force behind a failure of some suburban housing stock to respond to employment development with residential densification. There is much more "stickiness" to the residential property market than presumed by the standard model. Buildings are among humans' most durable creations, and the housing stock does not change quickly, even in response to changed economic conditions (Wheaton 1979). Central cities developed densely for historical reasons; when suburban living became possible, the suburbs became the feasible locale for housing characterized by a single family, large lot style. The early development of the suburbs in a low density mode tended to preclude or delay intensification of residential development even with the growth of local employment.

The hypothesis of lower income workers commuting long distances to suburban workplaces appears to contradict some



of the original motivations of firms in suburbanizing. Nelson (1986) describes attributes of the desirable community for back office location; among them is a relatively large supply of low cost "starter" homes. Yet firms can collectively accomplish what few individual firms could have; large aggregations of employment can drive up the cost of real estate to the point that the supply of low cost homes is eliminated. The likely result is a decline in the ready availability of local low cost work forces; in-commuting from more remote areas may result (Daniels 1981 found this for suburban London).

#### High Residential Density Suburban Employment Center

The response of local land use policy to large scale and concentrated employment suburbanization has not always been to restrict housing density. A number of suburban communities have responded to employment growth by allowing significant residential densification and development of multifamily housing. In this scenario, the initial condition of intense suburban employment is the same as in the low density center described above. The significant difference lies in local land use policy. In these communities the policy allows (or even encourages) development of a mix of housing densities response to

employment concentrations and rising land values (7). In many communities these processes may be a function of the age of the community, with older suburban centers containing larger stocks of dense housing.

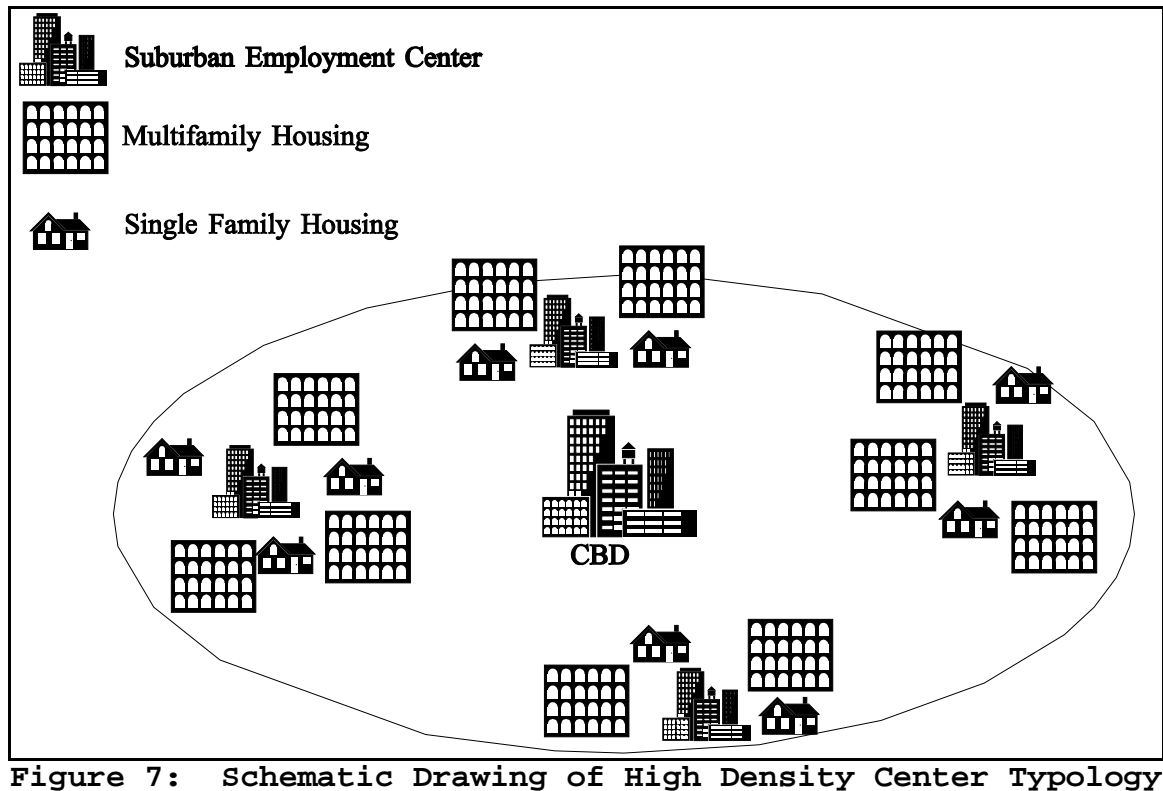


Figure 7: Schematic Drawing of High Density Center Typology

Under this scenario, moderate income households are able to afford housing near major suburban employment centers despite high land prices. In a fashion similar to that of the central city, the division of expensive land into small units allows low or moderate income households to

compete successfully with higher income households for close in land. This may be accomplished through the development of multifamily housing, or potentially through single family housing on small lots. The result may then be a positive association between a households' income and commute distances in a fashion reminiscent of the classic central city pattern. Perhaps a likelier result, given the nature of the suburbs and the remaining prevalence of the single family home, would be a lack of significant relationship between income and commute distances.

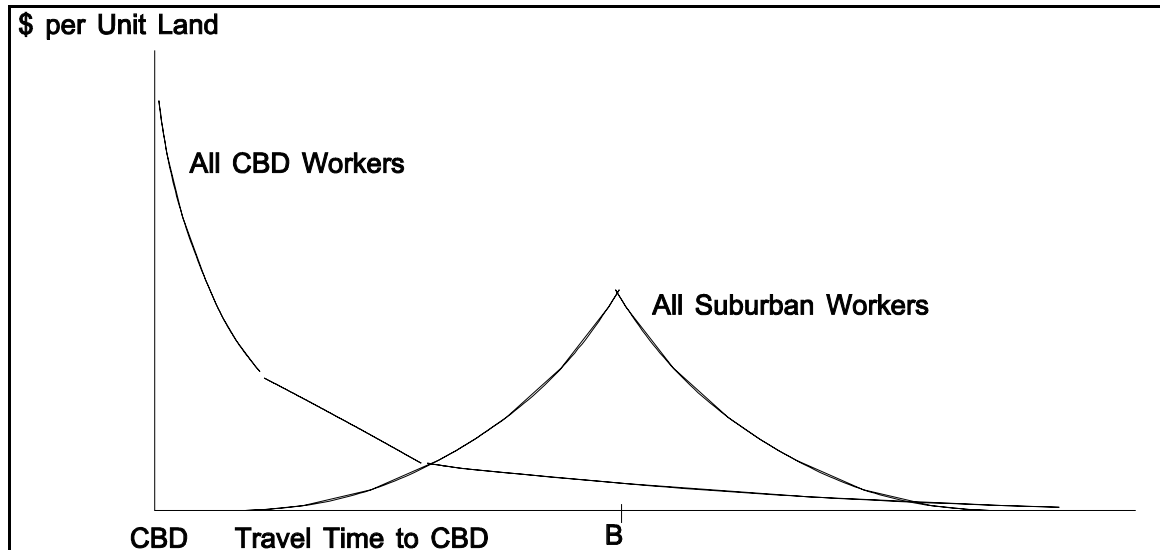


Figure 8: Bid Rent Curves for Workers in High Density Centers

Under these conditions the bid rent curves of different income classes might overlap (8), as a mix of dense and sparse housing near the major suburban employment center (B) would enable lower income households to compete with upper income households for expensive, close in suburban land. The economic condition for this overlap is the equality of the income elasticity of housing demand and the income elasticity of marginal commuting costs. In practical terms, the reason for the overlap is the expectation that despite the introduction of dense, affordable housing in the suburbs, the large lot single family house will continue as a major suburban housing type.

For this scenario to function as described, significant numbers of low or moderate income households would have to opt to forego the remote large lot single family home and accept relatively dense living close to their worksites. In many cases, moderate income households may not even consider multifamily nearby housing as an alternative; these households set their sights on traditional single family homes, and resolve to commute as far as necessary to reach that goal within their budgets. The attractiveness of multifamily housing to low or moderate income households is an empirical question that will be addressed in Chapter V.

## **Organization of Remaining Chapters**

This study is organized in three main parts. The first part (Chapters I and II) presents theoretical perspectives on the effects of employment suburbanization on commutes by income. The second part (Chapters III and IV) provides a descriptive analysis of communities and households relevant to this study, and the third (Chapters V and VI) describes the results of a discrete choice analysis that combines community and household level analysis into descriptive and predictive models.

Chapter II reviews some of the recent literature on metropolitan decentralization. The discrete choice approach to urban modeling is presented as a possible empirical bridge between differing theoretical perspectives on urban land use.

Chapter III reviews characteristics of San Francisco Bay Area cities and suburbs relevant to an analysis of emerging suburban commute patterns. These commute patterns are analyzed in Chapter IV using data from 1981 and 1989.

Results of the nested multinomial logit modeling are presented in Chapter V, together with assumptions and procedures. Chapter VI draws both statistical and policy implications from the models.

## **Summary of Chapter I**

Large scale suburbanization of employment has dramatically changed transportation and land use planning. Intersuburban commuting now dominates regional highway networks, and the private automobile has replaced mass transit for many commutes. Planners' approaches to these developments vary from the pro-centralization approach of many environmentalists and transit advocates to the view that employment suburbanization enhances mobility. In the middle are those planners who seek a geographic match between suburban jobs and suburban housing.

The study suggests that in suburban areas where new affordable housing has not kept pace with employment growth, new commute patterns are emerging wherein lower income households commute greater distances than their upper income counterparts. In contrast, it is hypothesized that suburban employment centers that have developed a denser housing stock in response to job growth are able to stem much long distance commuting by low or moderate income households.

## **Chapter II:**

### Approaches to Understanding Metropolitan Decentralization

Many microeconomic models of location share a common lineage including Von Thunen's (1826) model of agricultural land use and price, Alonso's (1964) formulation of the urban case, and Muth's (1969) extension to housing markets.

Collectively this approach will be referred to as the "monocentric" or "classic" model. This literature has been ably reviewed (e.g., Wheaton 1979, Anas 1982b, Fujita 1986, De La Barra 1989) and no attempt will be made to review it here. Rather, this chapter will focus on empirical and theoretical approaches to understanding decentralized or polycentric metropolitan areas. Three overall research approaches to understanding these areas are discussed here:

1) Research within the monocentric tradition that accords primacy to the distance-affordability tradeoff; 2) Alternative approaches wherein the distance-affordability tradeoff is not the driving force for urban location decisions; and 3) Discrete choice approaches to understanding locational choice.

Often, in reviews of previous work, a clear line is drawn between theoretical and empirical studies. It is clear that some research is data-based, while other studies

are constructed on mathematical or logical reasoning alone.

But this divergence is secondary to the extent to which available methodology restricts both theoretical and empirical thinking on urban areas. As is discussed in this chapter, somewhat of a dichotomy exists (e.g., Stegman 1969, Brown 1975) between those who would understand urban areas primarily in terms of the distance to work-affordability tradeoff and those who emphasize other factors such as local amenities, service levels, or accessibility to non-work travel opportunities. And, in fact, using traditional methodologies, the concurrent analysis of these competing factors has proved to be a herculean task (see Straszheim 1975). As shown in this chapter, the techniques of discrete choice modeling, developed within the past two decades, offer urban modelers the opportunity to analyze concurrently attributes of a locational choice that are particular to an individual (e.g., distance to work) with attributes that are more commonly felt (e.g., municipal service levels). In this way it may be that a particular methodology and empirical world view can bridge theoretical disputes.

### **Decentralized Models in the Monocentric Tradition**

The land use model of polycentric or dispersed cities that would have the power and intuitive appeal of the



monocentric model has not been developed. To a great extent this is attributable to the intractability of polycentricity (Ogawa and Fujita 1980). In order to maintain the models' theoretical elegance some researchers continue to derive strictly monocentric models (e.g., Brown 1986, Cremer 1990) while others define dispersed or polycentric metropolitan areas in monocentric terms:

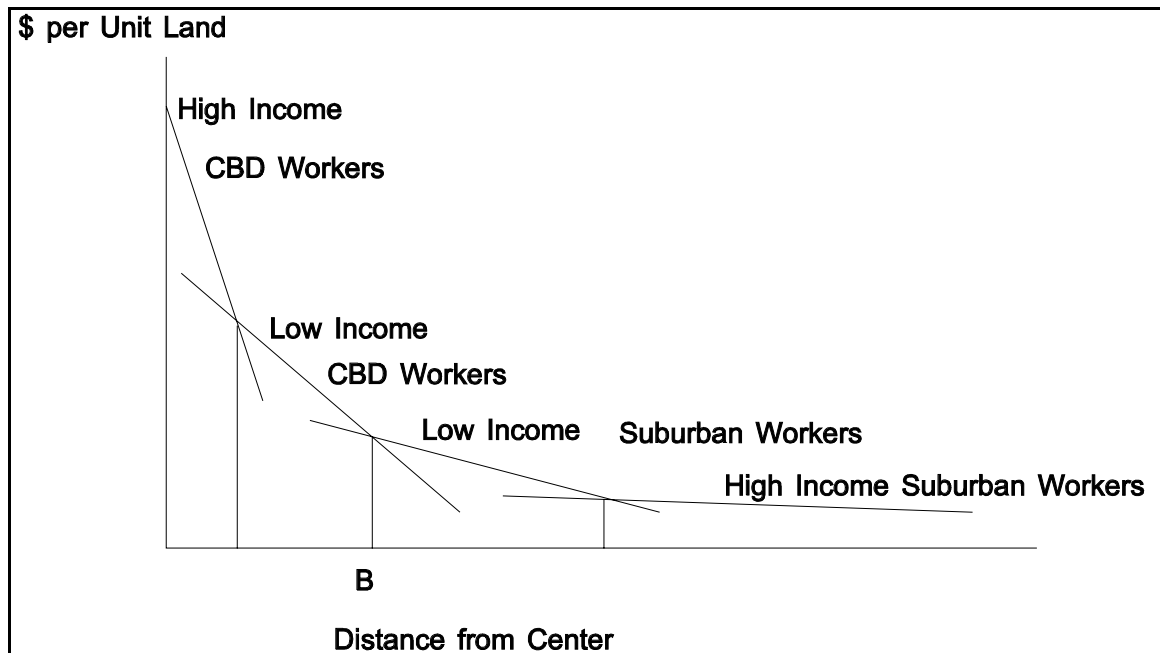
"To a great extent, non-CBD employment might be characterized as local. By the latter I mean occurring in such small concentrations that everyone so employed could live adjacent to his/her workplace and incur no commuting costs. Housing prices would still have to decline from the CBD, of course, to compensate CBD commuters (Muth 1985)."

Another approach to dealing with the large scale violation of the monocentric assumption is to add restrictive alternative assumptions to allow for more than one center. In a throwback to the Hotelling's (1929) work on commercial location, some modelers (Beckmann 1976, Ogawa and Fujita 1980) restrict their prototypical city to one dimension. Others allow for only two centers (Wieand 1985).

With the exception of White (1988) most non-monocentric modelers ignore the question of geographic distribution of residences by income, a feature that was so prevalent in their monocentric precursors.

For White, suburbanization of employment derives primarily from a firm's desire to locate closer to a

potential labor pool than is available at a CBD location. An employer's move from the center to a non central location will lower commuting costs (presumably without affecting residential land costs) for all potential workers who live on the ray extending from the center through the new location (but on the non-CBD side of the new location). By suburbanizing, firms thus shrink their potential labor pool (commuting becomes more expensive for some workers residing on the CBD side of the ray), but potentially moderate wage demands of workers whose commute has been improved. According to the White model, it is the smaller firms that will suburbanize, and these will not agglomerate into such large centers as to exhaust the labor supply on the non-CBD side of their ray. In this way, circumferential commuting will be avoided.

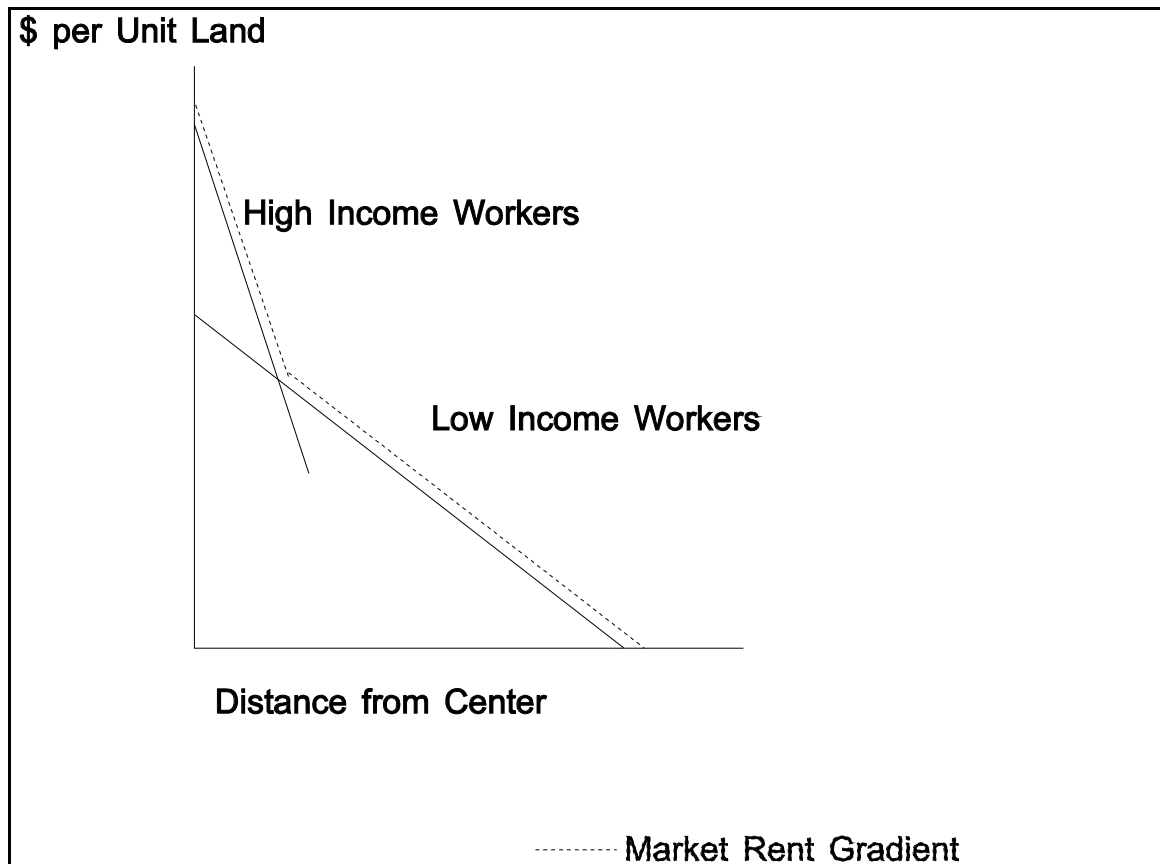


**Figure 9: Bid Rent Curves with Two Income Classes and Suburban Employment (White 1988)**

White describes a possible outcome of this model as regards residential location by income class. She assumes that bid rent curves flatten as employment suburbanizes and lower income households' bid rent curves are steeper than those of higher income households for both urban and suburban employed households (9). The result is a pattern of settlement in which income levels do not change monotonically from the center to the periphery. Instead, given two classes -- skilled and unskilled workers -- and two employment locations -- the CBD and the suburbs --

workers will locate themselves in four concentric rings. Starting from the center, these rings would be CBD-employed low income workers, CBD-employed high income workers, suburban low income workers and suburban high income workers. The boundary between CBD-employed high income and the suburban-employed low income workers would occur at some point at or beyond the location (B) of the suburban employment. These conclusions are dependent on her assumptions about amounts of residential land demanded by each group at each location:

"Skilled workers' households have higher demand for housing than unskilled workers' households at any u (distance from center), which tends to make their rent curves flatter. However skilled workers' time is more valuable at the margin, which tends to make their rent offer curve steeper. **In general the first effect is usually assumed to be more important, making the rent offer curve flatter for skilled than unskilled workers** (emphasis mine)."



**Figure 10: Bid Rent Curves of High and Low Income CBD Workers under Standard Monocentric Assumptions**

Thus White restates standard monocentric assumptions about the relative steepness of bid rent curves (10), and supposes a continuation of these patterns when suburban employment is introduced. Importantly, she explicitly assumes no land use control. But it may be that in the suburban context land use controls are in fact at the core of the processes shaping urban form. If land use controls in the vicinity of suburban employment centers preclude residential densification, it may be that low income groups would be incapable of outbidding higher income groups for

nearby land (assuming no significant externalities such as pollution or noise). If one adds land use control to White's model, the relative angles of the bid rent curves of the two income groups may change; the model would more resemble the low density center described in Chapter I.

Leroy and Sonstelie (1983) suggest that the current situation of transportation technology is the driving feature behind segmentation of residential property markets by income. Historically, when a new, faster mode appears that is affordable for the rich but too expensive for the poor, the income elasticity of marginal commuting costs is driven down for the rich. This flattens wealthy households' bid rent curves and drives them to choose locations farther from employment centers than the poor. When that mode becomes widely affordable (as the automobile did in the 1950's and 1960's) the relative advantage of suburban locations for the rich begins to evaporate as congestion drives up the cost of commuting. The wealthy households then begin return to the central city, a phenomenon the authors detect during the 1970's. The model predicts continuing gentrification of inner city areas so long as "1) no new, faster mode of commuting appears, and 2) the real material cost of car commuting continues to decline."

The authors assume a great deal of fluidity in housing

markets in which housing for the poor can be transformed into housing for the well-to-do and vice versa. While gentrification of poor urban neighborhoods supports this view, for the most part the markets reveal a great deal of inertia (Wheaton 1979). Moreover, the model's explanation of a return to the city movement strictly in terms of the land-accessibility tradeoff ignores perhaps more convincing factors related to life cycle and cultural preferences.

Nevertheless, the model can provide part of the answer why many suburbs have not become like the central cities of yesteryear, with employment and poorer workers living in close proximity and higher income commuters commuting in from the outside. The automobile has become a very democratic mode of travel, affordable by the vast majority of households. With no dramatic improvement in commuting technology, the congestion faced by all tends to steepen the bid rent curves of the wealthy households with the highest commuting costs, at least in the short run.

In a related study, Boyce and Kim (1987) describe potentially positive effects of congestion on transportation networks, pointing out that through a process of negative feedback, congestion can lead to shorter distance journeys to work. While this assertion is correct theoretically, it is insufficient from a policy aspect. Whose journeys to work are being shortened? By lumping different groups together with vastly differing capacities for congestion avoidance, Boyce and Kim have ignored what may be one of the most significant policy implications of suburban congestion. Congestion will steepen bid rent curves for all commuters, thus tending to shorten commutes, but the greatest effect will be evident for those commuters with the highest value

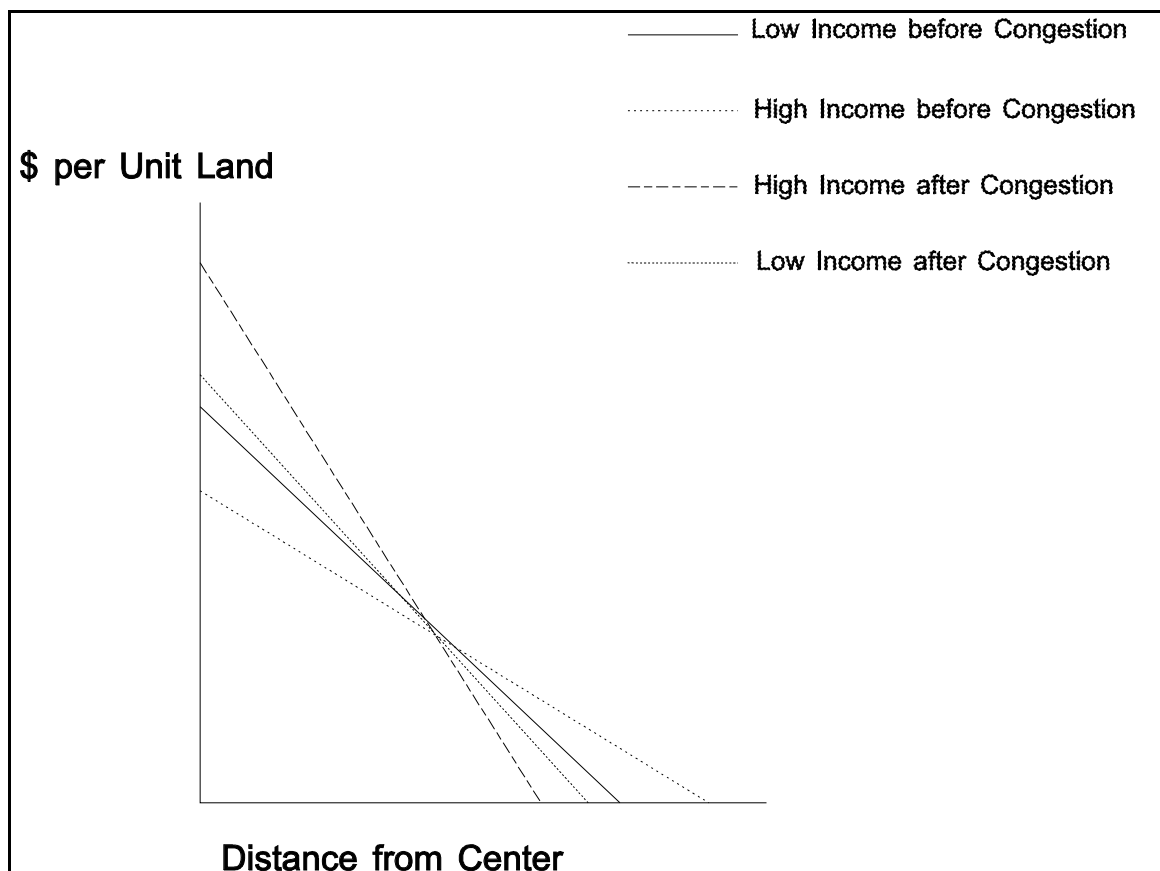


Figure 11: Effects of Congestion<sup>23</sup> on Bid-Rent Curves of Different Income Groups



of commute time, i.e., upper income commuters (11).

Where Boyce and Kim argued that congestion will lead to shorter commutes, Beckman's (1976) model shows employment suburbanization having the same effects. His work is supported empirically by Gordon et al. (1989) who argues that the lack of any strong correlation between journey to work times and city size is evidence of the beneficial effects of decentralization. The reason that suburban residents of larger metropolitan areas do not commute longer than those of smaller is that they commute largely to decentralized jobs rather than to the hub of a vast metropolitan area. Gordon's work raises several questions, however. First, he relies chiefly on trip medians rather than means, without any examination of the "outliers" that supposedly bias the means upwards. If, as this study suggests, these are largely poor and moderate income families unable to cope with congestion by locating closer to work, the use of the median ignores a major equity issue.

In fact, for central city residents, commute time does rise in larger metropolitan areas, and Gordon's focus on suburban commutes tends to blur this.

Moreover, Gordon's evidence of decentralization benefitting the larger metropolitan areas is strictly circumstantial; he notes the phenomenon of relatively

constant suburban commutes between different metropolitan areas and explicitly rejects alternative explanations of peak spreading, ride sharing, constant travel budgets, and varying levels of highway investment. The remaining explanation of decentralization is thus accepted as the dominant factor by default.

Finally, Gordon's focus on trip times rather than distances masks the fact of transit's declining mode share as employment suburbanizes. The higher speed of the automobile relative to most forms of public transit could easily lead to a decline in overall average trip times with suburbanizing employment, even with increasing commute distances.

Mean commute times and distances (and for the most part, medians as well) grew in virtually all categories between 1977 and 1983 despite undisputed continuing decentralization of employment (Federal Highway Administration 1984). This was true not only for central city residents, but for residents of the suburbs as well -- exactly the people whom employment suburbanization ostensibly benefits. The assertion that "businesses and households are not only decentralizing, they are locating close to each other" (Gordon 1987a) thus may not be universally correct. Even if the hypothesis is true for

suburban households (the subject of Gordon's study) it appears to be false for the metropolitan area as a whole; Izraeli (1985) found significant positive correlation between SMSA size and mean travel distances (and times).

Due to the aggregate nature of the analysis and a lumping together of metropolitan areas differing widely in age, economic environment and housing prices, the conclusions of Gordon et al. are speculative and subject to many alternative interpretations. The National Personal Transportation Study data base they utilized was not fine-grained enough even to analyze results by individual metropolitan area, let alone any detailed disaggregate analysis of data. Rather, the authors were forced to analyze broad classes of metropolitan areas, such as those under 250,000 or over 3 million in population. Their statement that "suburbanization, then, would favor all income classes' commuting equally (1987a)" seems particularly unfounded. In fact no data were presented on commutes by household income, whether urban or suburban. It appears that the assertion stemmed from the authors' theoretical approach rather than from any empirical analysis.

Pivo (1988) studied Bay Area suburban employment concentrations for evidence of an influence on

characteristics of the concentrations on journeys to work. Consistent with earlier studies, he found a suburban commute shorter than center city-directed journeys to work. The urban-suburban difference in commute distance was found to be dichotomous rather than continuous; the hypothesis of lower commute distances for suburban employment centers farther removed from the metropolitan core was rejected. On the other hand, positive correlations were found between the size of the suburban employment center and the distance of the commutes of their workers; workers in larger suburban concentrations tended to live farther from work than those in smaller concentrations. Apparently larger concentrations of suburban employment became regional subcenters in their own right; when this occurred their commute patterns started to appear more urban.

### **Non Journey-to-Work Approaches**

Despite the differences in the theoretical approaches of the studies described above, they share a thread common with the monocentric tradition: a focus on the importance of the journey to work and the accessibility-affordability tradeoff in shaping urban form. Another line of thinking emphasizes alternative factors, such as nonwork travel or municipal service differentials. However, lacking the

common accessibility-affordability theme, this literature tends to be less cohesive than that emanating from the monocentric tradition.

Among researchers in this non-monocentric tradition Tiebout (1956) is prominent; he showed how competition between communities within a metropolitan area represents a market for public goods within which individuals could fulfill their tastes for low tax, low service communities or high tax, high service communities.

Rossi (1955) writes that "previous literature...laid heavy stress on residential mobility as a mechanism whereby households minimize their distances from place of employment...Perhaps the stress laid upon the 'journey-to-work' expresses the former importance of this factor in days when mass transportation was relatively poorly developed and more expensive." Rossi thus recognizes the potential of transportation costs to influence service decisions, but counts on technological improvements to all but erase those costs, at least relative to other forces. Other researchers finding that factors such as housing and neighborhood quality outweigh accessibility in neighborhood choice include Stegman (1969) and Halvorson (1970).

The approach emphasizing neighborhood and community factors derives support from surveys (e.g., Varady 1990,

Stegman 1969) in which households consistently rank factors such as quality of schools, safety, and general appearance of neighborhoods as more important than workplace accessibility in determining their choice of residential location. But this relative ranking by individuals does not necessarily imply a lesser importance to the price-accessibility tradeoff in aggregate. It may be that the location of neighborhoods and communities of particular types is largely rooted in this tradeoff, even if an individual's choice from among those communities is determined primarily by factors related to the local environment.

Moreover, many of these studies compare central city with suburban living without adequate methodology to account for the qualitative differences between the two. In particular, the multicollinearity between neighborhood quality and commute distance from central employment makes separating out the relative effects of each factor on residential location decisions difficult. In contrast, comparisons that are largely intersuburban can allow a cleaner analysis of the price-accessibility tradeoff without the confounding effects of the urban-suburban dichotomy.

Persky (1990) argues that given the major assumptions of the monocentric model, one would expect suburban

communities with high levels of employment to contain more diverse populations (in income terms) than bedroom communities. This is due to the expectation that the concentration of workers in an area combined with relatively low-priced suburban land would create residential demand by lower income suburban workers eager to avoid commuting. In suburbs of reasonable size, Persky reasons, this demand would be insufficient to displace upper income central business district commuters. He asserts "(t)hese differences should hold **whatever the nature of the stock of local housing** (emphasis mine)."

Using data from suburban Chicago, Persky shows no correlation between Gini coefficients based on community income distributions and employment per capita in these communities. He claims that the lack of correlation is evidence that the "journey-to-work approach can offer us slight help in explaining income inequality within and/or between suburbs."

Persky's results may be interpreted differently. Lack of correlation between the Gini coefficient and local employment per capita is not necessarily evidence of lack of explanatory power of the "journey-to-work" approach; indeed no journey-to-work data were included in the calculations. An alternative explanation is that income diversity in

suburban employment centers rests upon diversity of the housing stock. Where political and planning processes preclude the development of affordable housing near suburban employment centers, there is little reason to expect lower income workers to be able to reside close to their workplaces. Persky acknowledges the potential for these forces to constrain the diversity of local housing supply but fails to acknowledge their implications: "...the considerable literature on racial segregation in the suburbs and especially that on large lot zoning has long suggested that the residential choices of lower income workers have been very much constrained by political and social processes. Still none of the above should be interpreted as a blanket indictment of the journey-to-work logic."

The fact that suburban communities may exert strict land use controls that have the effect of restricting residential densities is not an indictment of the journey-to-work logic. Rather, Persky is looking for evidence of the price-accessibility tradeoff while not accounting for the very important fact of suburban land use controls. The idea that shortages of affordable housing may have been the factor precluding the expected correlations from emerging may draw support from Cervero's (1989b) finding of severe spatial mismatches between jobs and housing in suburban



Chicago, the area studied by Persky.

Other studies emphasize the importance of accessibility to destinations other than work. Gordon et al. (1988) point to the increase in non-work travel between 1977 and 1983 as indicating the declining importance of the work trip. This information is useful to the extent it designed to counteract a tendency of transportation planners to focus on the peak hour CBD commute as the major object of transportation policy. But the fact of growing nonwork travel does not necessarily diminish from the importance of work access in residential location decisions. Nonwork travel opportunities (e.g., shopping, school, church) tend to be spread in a much more ubiquitous fashion over the metropolitan area. Thus while trips to these destinations grow, it does not follow that these trips will exert much of an influence on residential choices.

### **The Discrete Choice Approach to Urban Modeling**

It has been suggested (Wheaton 1979, Palumbo et al, 1990) that urban decentralization models need to fuse the tradition of Alonso (1964) emphasizing elasticities of commute cost and space with that of Tiebout (1956) emphasizing local service differentials. An empirical study attempting to achieve this goal would have to analyze

jointly three sets of characteristics: 1) attributes of individual households such as income; 2) attributes of potential residential locations such as public service levels; and 3) attributes that arise from the interaction of individuals with potential locations, such as travel time to a given workplace.

The goal of the discrete choice approach is the modeling of an individual's selection of a single choice from a family of alternative choices. As such, a discrete choice analysis may make explicit reference both to the characteristics of the individual as well the choices from which he or she will select. This important characteristic is an crucial difference between the discrete choice approach and the family of regression-based approaches which tend to focus either on the individual or the geographic unit, but rarely both simultaneously.

The second major strength of the discrete choice modeling approach is implicit in its name. Traditional regression approaches to urban modeling assume that consumers are able to choose along a continuum of attributes. Under classical formulations, consumers in their locational decisions determine simultaneously the optimal amount of space, travel distance and urban services and amenities. Such a procedure is a weak approximation of

reality; when a locating household selects a particular location it is in fact selecting a "package deal." It selects the bundle of price, location and amenity attributes offered by that location. Thus the discrete choice family of models offers an appealing behavioral interpretation; the individual selects from a limited set of actual choices.

The assumption is that the observed choice was optimal for that individual (given a budget constraint and given the set of available choices), but not that the individual was able to optimize all factors in all dimensions.

The idea underpinning discrete choice approaches to urban modeling is that observed outcomes, such as traffic flows, are the result of choices made by individuals. Those decisions may pertain to location, such as which house, neighborhood or community in which to locate.

Alternatively, they may center on transportation mode, or in fact any other decision among competing alternatives. The rational consumer selects the alternative from all available alternatives that maximizes his or her utility. Thus each alternative carries a utility function for that individual, where attributes of the alternative may be positive or negative arguments. Importantly, the attributes are bundled, such that decision makers choose the utility maximizing alternative from among all available

alternatives, rather than choosing optimal quantities for all attributes.

Stated in mathematical terms, an alternative  $i$  is chosen if:

$$U(X_{is}) > U(X_{js}) \text{ for all alternatives } j \text{ in } C$$

where

$U$  = Utility

$X_i$  = One available alternative

$X_j$  = Other alternatives

$S$  = A given individual decision maker

$C$  = The set of all alternatives from which individuals choose, or "choice set."

The utility function includes as its arguments attributes of the alternative as well as the individual selecting or rejecting that alternative. In this fashion a single utility function can describe the preferences of diverse individuals.

This utility function is never completely specified. The analyst's knowledge of the components of an option's utility function is only partial, and the information available to the individual making the observed choice is itself incomplete. Excluded variables and measurement error further preclude precise specification of utility functions.

As a result, apparently similar individuals facing apparently identical choice sets are observed to make

varying choices. Utility functions are thus at best specified up to an error term; the presence of this error term precludes any deterministic predictions about individual behavior. Instead, models should be able to formulate any predictions in probabilistic terms.

Due to the practical impossibility of specifying complete utility functions, the functions will have a deterministic component which is the function of observed attributes, and an error term which renders the outcomes of a comparison of utilities uncertain. Despite this uncertainty, the probability of a choice being selected should increase when the deterministic component of its utility to a particular individual increases, or when the deterministic components of the utility functions of other alternatives to that individual decrease.

It has been shown (Domencich and McFadden 1975) that under certain assumptions regarding the distribution of the error terms (i.e., that they are independent and identically distributed according to the Gumbel-Weibull distribution), the probability that the utility of alternative  $X_i$  exceeds the utilities of all other alternatives  $X_k$  for individual  $S$  (i.e., the probability that  $X_i$  is the chosen alternative) equals

$$\frac{\exp(V_i)}{\sum \exp(V_k)} \text{ for all } X_k \text{ in the choice set (including } X_i)$$

where  $V$  = the deterministic component of a choice's utility

which constitutes the multinomial logit model.

#### Independence from Irrelevant Alternatives

An important limitation of the multinomial logit model is its independence from irrelevant alternatives (IIA) assumption (Ben Akiva and Lerman 1985). The property states that the ratio of the utilities of two alternatives is independent of the presence or absence of any other alternative. When this property of the model does not match reality, as is the case when there is a structure of perceived similarities among the non-observed attributes of alternatives, the multinomial logit model will generate biased and misleading results.

The classic example of a violation of the IIA assumption is the "red bus-blue bus" paradox. Say a mode choice model was calibrated under multinomial logit with the choices being automobile and bus, with choice probabilities for a particular individual estimated at 0.5 for automobile and 0.5 for bus. If the specification of the choice set were not "automobile, and bus" but "automobile, red bus and blue bus," logic would have it that the probability of that individual choosing the bus mode would not grow, since color is not relevant to mode choice. Thus one would expect a

0.25 probability of selecting the blue bus and the same probability of selecting the red bus. Due to the multinomial logit's IIA property, the predictive use of a model estimated on the same data would yield a 0.33 probability for each of the modes.

#### The Nested Multinomial Logit Model

The red bus-blue bus paradox is an extreme case of violating the IIA assumption. But as will be shown in Chapter V, subtler cases exist as well. In the case of this study, it was shown that communities can have a structure of perceived similarities in unobserved attributes that preclude their modeling through simple multinomial logit. For this reason the related technique of nested multinomial logit analysis is employed.

The nested multinomial logit model seeks to determine the probability of an individual selecting a particular higher level choice (in this study, cluster of communities) and a lower level choice within that selection (in this study, the individual community). Nested multinomial logit models may find a wide range of applications. In the extreme red bus-blue bus paradox described above, an appropriate structure would have been to create "bus" as a higher level nest together with "automobile." Then a test

could have been conducted to determine whether there were any attributes of the red bus that led to a different utility function from the blue.

In order to estimate this structure, the nested logit model calculates two probabilities:  $P_{j|i}$ , or the probability of a particular selection within a lower level nest given that the upper level nest has been selected, and  $P|i$ , the probability of the selection of the upper level nest. It

can be shown (Maddala 1983) that

$P_{j|i} = \exp(V_{ij}) / \sum \exp(V_{kj})$  for all alternatives  $k$  within upper level nest  $j$ . This is equivalent to a multinomial logit model for alternatives within a particular nest.

$P_i = \exp(V_j + (1-\sigma)I_i) / \sum \exp(\exp(V_m + (1-\sigma)I_m))$  for all alternatives  $m$ , representing the upper level nests.

where

$I_i = \log(\sum \exp(V_{ik}))$  for all alternatives  $k$  within upper level nest  $j$ . This term is also called the logsum of the nested multinomial logit model.

$(1 - \sigma)$  is an estimated parameter of the logsum.

The  $(1 - \sigma)$  term ranges from 0 to 1 and may be treated as an index of similarity between elements of the lower level nest, with elements perceived as identical in their unobserved attributes yielding an estimated parameter of 0.

Such should be the case, for example, if a nested multinomial logit model were calibrated for the red bus blue bus paradox as described above. Elements in a lower level



nest that lack any structure of perceived similarity in unobserved attributes would lead the  $(1-\sigma)$  term to equal unity, in which case the nested multinomial logit model reduces to the simple multinomial logit model.

#### Maximum Likelihood Estimation

Utilities of a multinomial logit (or nested multinomial logit) model are most commonly estimated through an iterative process of maximum likelihood estimation (MLE). MLE first constructs a likelihood function equivalent to the probability of observing the actual sample results, then uses a gradient search technique to determine the value of the estimated coefficients at which the value of the function, or more particularly, its logarithm, is maximized.

For example, assume that choice of a given community is a function of the distance of that community from the individual's work place and median housing price in the community. Given that the individual  $S$  chose community  $i$ , we know from the multinomial logit model that

$$P(i|s) = \frac{\exp(\beta_1 \times \text{DISTANCE}_{i_s} + \beta_2 \times \text{PRICE}_{i_s})}{\sum (\beta_1 \times \text{DISTANCE}_{k_s} + \beta_2 \times \text{PRICE}_{k_s})} \quad \text{for all cities } k \text{ in the choice set}^3$$

---

<sup>3</sup>A single parameter is represented as the scalar  $\beta$ ; the entire set of parameters is the vector  $\beta$ . Estimated parameters are denoted with an apostrophe (e.g.  $\beta'$ ).

The next individual (T) was observed to choose community h. In a similar fashion,  

$$P(h|t) = \frac{\exp(\beta_1 \times \text{DISTANCE}_{th} + \beta_2 \times \text{PRICE}_{th})}{\sum (\beta_1 \times \text{DISTANCE}_{tk} + \beta_2 \times \text{PRICE}_{tk})} \text{ for all cities } k \text{ in the choice set}$$

where  $\beta_1$  and  $\beta_2$  = coefficients to be estimated.

The probability of selecting those two observations together equals  $P(i|s) \times P(h|t)$ . When the probabilities of each selection by each individual in the sample are similarly combined into a single multiplicative function, the result equals the probability of obtaining the actual sample. The gradient search technique then iteratively determines those values of the two unknowns,  $\beta_1$  and  $\beta_2$ , that maximizes this likelihood function. These values then become the estimated utilities associated with attributes of each of the choice set elements.

#### Shortsightedness of Multinomial Logit

A significant weakness of the multinomial logit model is its presumption that individuals choose between choice set elements with fixed characteristics. As multinomial logit is not primarily an equilibrium model, it does not generate internally changes in the elements of the choice set that might arise from the processes it models. Rather it generally takes attributes of the choice set as given and

models individual choice under a particular regime of choices. Used in this fashion, multinomial logit is best viewed as a short- to medium-term modeling tool. Longer term forecasts would require a separate modeling of change in the choice set elements -- for example price or congestion effects -- that may arise due to the aggregate choices of many individuals.

#### Urban Models Using Discrete Choice

Quigley (1985) identified three distinguishing characteristics of the housing market: a consumer selects usually one and only one good out of a large population of alternatives; the bundle of services provided by any one dwelling is extremely heterogeneous; and consumer choice involves the selection of a price as well as the other characteristics associated with dwellings. Whereas his reasoning was directed to the choice of an individual dwelling unit, it applies equally well to the selection of a community in which to live. These characteristics of residential location decisions make them particularly amenable to modeling under a multinomial logit framework.

Not surprisingly, multinomial logit has gained a great deal of acceptance as an urban modeling tool. Perhaps its most common use in the urban context is in mode choice

modeling, but a number of locational models have employed the technique as well. Although none of the previously estimated multinomial logit models of residential location were specifically designed to test hypotheses regarding decentralized metropolitan areas, each is interesting for the modeling structure it adopted.

In the first major extension of the multinomial logit model to the residential location and mobility decision process, Lerman (1975) modeled jointly the residential decision process in the Washington, D.C. area, together with vehicle ownership, housing type and mode to work characteristics. Lerman's approach supposed a choice between an enormous number of alternatives. First, his primary geographic unit was small -- the census tract -- leading to a very large number (145) of locational choices.

Compounded with this was his modeling of choice between two transportation modes, three auto ownership levels and four housing types, and the number of possible alternatives reached very high levels, even after eliminating some logically implausible combinations.

In an attempt to deal with the vast number of alternatives, some of Lerman's models were "conditional" in that they took vehicle ownership and mode to work as given, modeling only residential location and housing type

decisions. Still others modeled all decisions together in a joint structure. Lerman identified the joint models as superior due to the lower variance of their parameter estimates.

Lerman's work was a pioneering application of the new technique of multinomial logit modeling to the urban context. But its vast number of alternatives and joint structure strained the plausibility of both the IIA assumption and any behavioral interpretation that may be assigned to the decision making process. While not strictly necessary for the valid estimation of multinomial logit models, a behavioral interpretation whereby individuals are presumed to consider all alternatives "offered" to them is a desirable feature that can lend credence to the parameter estimates.

In an early extension of the nested logit structure to transportation and land use modeling, Weisbrod et al. (1980) modeled the location and accessibility choices of recently moving households in the Minneapolis-St. Paul area. The primary choice regarded the decision to move, with options being no move, move and own, and move and rent. The second level of the model was a joint location, housing type and auto ownership model, with mode to work modeled as the third level of the nested structure. The nested structure

assumed may have been incorrect; the coefficients of work trip access logsum variable within the location, housing type and auto ownership choice nest significantly exceed unity.

The model was designed to isolate the effects of transportation versus other factors in the locational decision of recent movers. Workplace access was shown to have a strong, but not dominant effect on residential location. Household composition exhibited a stronger influence than other factors in residential location decisions; in particular, the preference of households with children for single family homes overshadowed factors such as housing cost, taxes, accessibility and crime level.

Shin (1985) explored similar mode, auto ownership and residential location decision in a three level nested structure in which residential location formed the top level nest, within which vehicle ownership decisions were made. The lowest level of the decision structure was the mode to work decision, occurring within the vehicle ownership nest.

Additionally, the number of geographic units was greatly reduced to eleven communities within Santa Clara County, California.

The nested structure was an important improvement on Lerman's joint logit models, and in most cases the

coefficient of the logsum variable indicated the validity of the nesting. From the standpoint of this study, the most important level of the nested structure -- that representing the locational choice -- lacked important information. Shin estimated two locational models, one based exclusively on dummy variables for each location (except one) and another model based on attributes of the locations. Since the models were stratified by single worker versus dual worker households, the utilities of the location-specific dummy variables were interpreted as revealing the preferences of each of these groups for each possible location. The model when specified in this form yielded little information that could not have been derived from crosstabular analysis. For example the utility of a Palo Alto/Los Altos location was found to be negative for both single worker and multiworker households. It is clear that the negative aspect of this location rests on its high cost, a fact masked by the use of a full set of location specific dummy variables.

Shin derived an alternative, more revealing model of the location decision, this time based on attributes of the various communities, such as crime rate or per capita local public expenditure. He did not include any accessibility variable that would capture the tradeoff between local costs and service levels and accessibility to important travel

destinations, especially work. In this way he constructed an empirical model entirely in the Tiebout tradition, ignoring the potential of the multinomial logit model to fuse that approach with the one that emphasizes home-work accessibility in the locational decision.

Harvey (1988) developed nested logit models of the location and mobility choices of households in Santa Clara County. The modeling was accomplished within a three level structure of city of residence, auto ownership and mode to work. The samples were extensively segmented by lifestyle in order both to test hypotheses regarding alternative model structures and to assess the effect of policy variables on households of different types. Using utilities of the automobile ownership nest as a proxy for workplace accessibility, Harvey analyzed subsamples based on number of workers in the household. Results suggested the equal importance of workplace access to both workers in two worker households.

Quigley (1985) used the nested multinomial logit model to examine the housing market in the Pittsburgh metropolitan area. The model was a three level structure, with housing unit selection modeled within a choice of neighborhoods. The neighborhood choice was in turn modeled within a choice of town. The study was principally designed to demonstrate



how using a combination of the nested logit model and a technique for reducing large numbers of alternatives (discussed in Chapter V), models could be estimated on the choice of so fine grained a decision as individual dwelling units.

One set of variables in Quigley's model of selection of community raises questions. He defined community level variables to be school expenditures per pupil, and public expenditures per capita. After estimating the model, the coefficients of both emerged as negative, apparently implying that households prefer fewer public services over more services. In all likelihood, the effect captured was the city-suburb dichotomy, where both urban tax rates and per capita spending exceed those found in the suburbs. An additional variable equalling the tax rate or median property tax bill in a community may have been needed to clarify these effects.

Anas (1982) developed a model of the Chicago area rental market that differed from those referred to above in two important ways. First, the model used United States Census data aggregated into quarter square mile zones over the Chicago metropolitan area rather than the disaggregate household level data used in other studies. Comparisons with models estimated on disaggregate data reveal, according

to Anas, a lack of bias in the aggregate models. Based on these results Anas suggests that current trends towards disaggregate analysis may overlook the potential for the use of discrete choice tools in readily available data sources that may be aggregated into relatively fine geographic units. The second difference of Anas' work is its analysis of both the demand and supply sides of the rental housing market. Using a utility maximizing model for households and a profit maximizing model for landlords, Anas derived a partial equilibrium model of the housing market, an accomplishment that had previously been the domain of bid rent analyses primarily.

#### **Summary of Chapter II**

Theoretical and empirical models of metropolitan decentralization have been hampered by the mathematical intractability associated with polycentricity. This difficulty has been compounded by empirical approaches that emphasize analysis of characteristics of households or of locations, but rarely both simultaneously.

These factors have led to a dichotomy among urban models between those emphasizing the accessibility-affordability tradeoff and those stressing other factors, such as local service quality. The multinomial logit model, because of its ability to analyze concurrently attributes of

individuals and of the locations from which they choose, is uniquely positioned to bridge the two traditions.

Multinomial logit's assumption of independence from irrelevant alternatives represents a major limitation of the technique. Land use and transportation models have begun to employ a variant of the multinomial logit model known as nested logit in order to overcome this limitation. Another limitation is the fact that logit is most commonly used as a non-equilibrium model. Because of this, any changes arising in the choice set must typically be modeled separately if the analysis is to capture long run effects of the processes it attempts to simulate.

### **Chapter III:**

#### **Study Area Overview and Data Sources**

In Chapter I it was suggested that the relationship between household income and commute distance to suburban workplaces is largely determined by the concentration of the suburban employment center and the mix of the housing stock in its vicinity. This hypothesis is examined using data from the nine county San Francisco Bay region. The first half of this chapter presents an overview of large scale Bay Area employment, housing and transportation congestion patterns in order to serve as background for analysis in later chapters. The second half describes the data sources that were assembled in order to complete this analysis, as well as some of the problems involved in data definition and variable selection.

#### **Overview of Study Area**

By convention, the San Francisco Bay Area (population 5.9 million) consists of the nine counties bordering the San Francisco Bay (Figure 12), although in recent years linkages with bordering areas, notably Santa Cruz County and the Central Valley, have grown as these areas have begun to suburbanize with Bay Area commuters (Kroll and Morris 1988).

The area contains three major cities. San Francisco (1990



**Figure 12: San Francisco Bay Region<sup>4</sup>**

population 741,000<sup>5</sup>), located at the tip of a peninsula at the region's center, has historically dominated the area economically and culturally. During the 1980's San Francisco was surpassed in population by San Jose (1990 population 798,000), located fifty miles to the south. The area's third major city is Oakland (1990 population 356,000), located opposite San Francisco on the eastern shore of the San Francisco Bay.

Together with the urban centers, the Bay Area contains major areas of concentrated suburban<sup>6</sup> employment (13)<sup>7</sup>. The largest of these is the "Silicon Valley" of northern Santa Clara County, and includes the cities of Palo Alto, Mountain View, Sunnyvale, Cupertino, Santa Clara, and Milpitas. Other suburban concentrations include the Bay shore communities of San Mateo County, San Rafael and surrounding

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<sup>4</sup>Map courtesy of Maps to You, Oakland, CA.

<sup>5</sup>Population figures are Association of Bay Area Governments (1989) estimates.

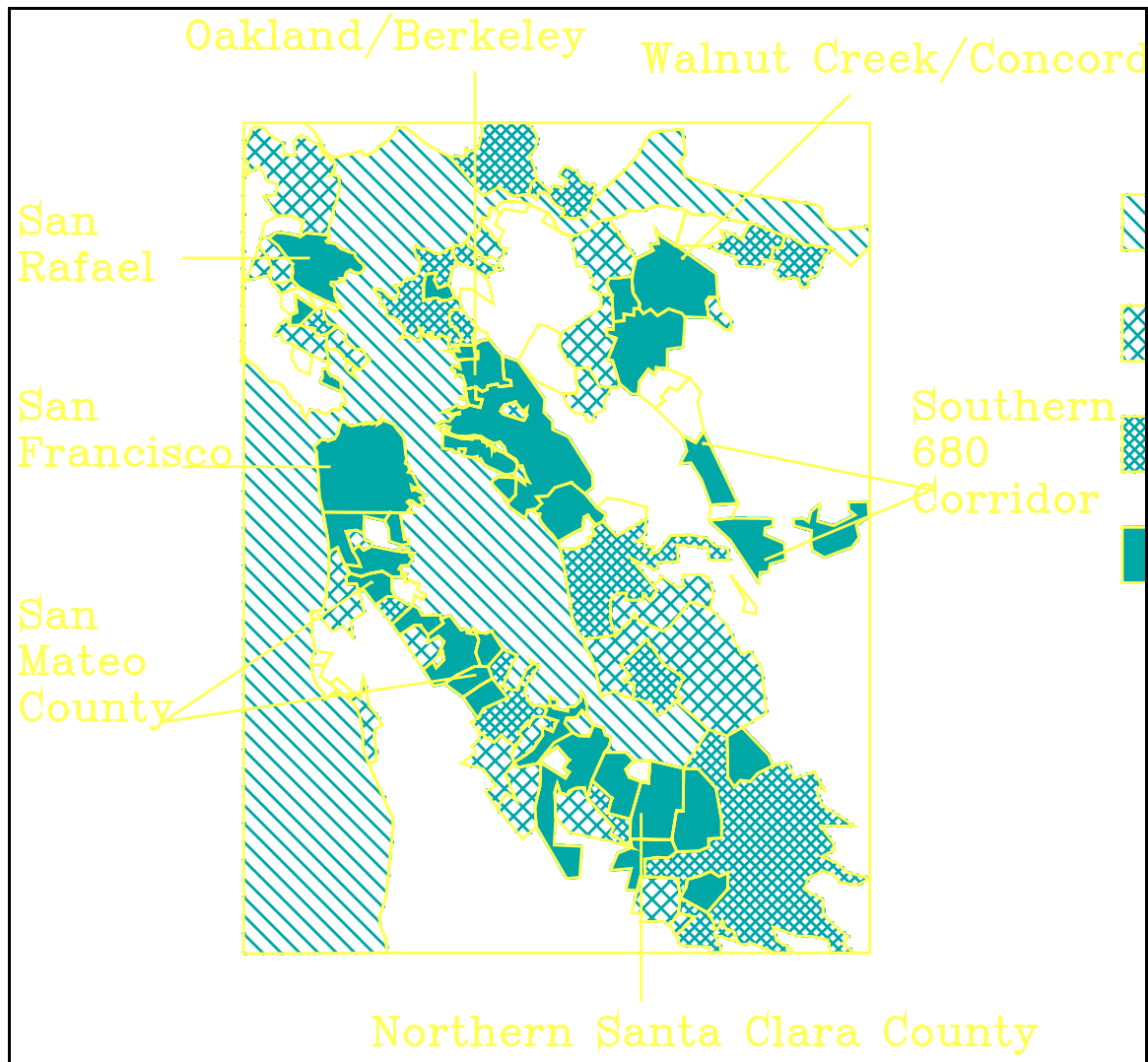
<sup>6</sup>"Urban" as used in this study refers to a central location within a metropolitan area; communities are "suburban" when they are peripherally located, even if they have employment levels rivaling those of the center cities.

<sup>7</sup>Pivo (1988) defined as a "cluster" groupings of at least two buildings separated by no more than one quarter of a mile. He identified 103 suburban office clusters in the Bay Area outside the central business districts of San Francisco, Oakland, and San Jose.

communities in Marin County, and the Interstate 680 corridor in Contra Costa County, consisting of Walnut Creek and Concord in the north, and San Ramon, Pleasanton and Livermore in the south.

The region has been shaped strongly by its topography, notably the San Francisco Bay itself and ranges of hills running roughly parallel to the Bay shore. The region's historic core is along the plains between the Bay and the hills, from Vallejo in the northeast, south to San Jose and Palo Alto, and north through San Francisco to San Rafael. In recent years the role of areas beyond this inner ring has grown.



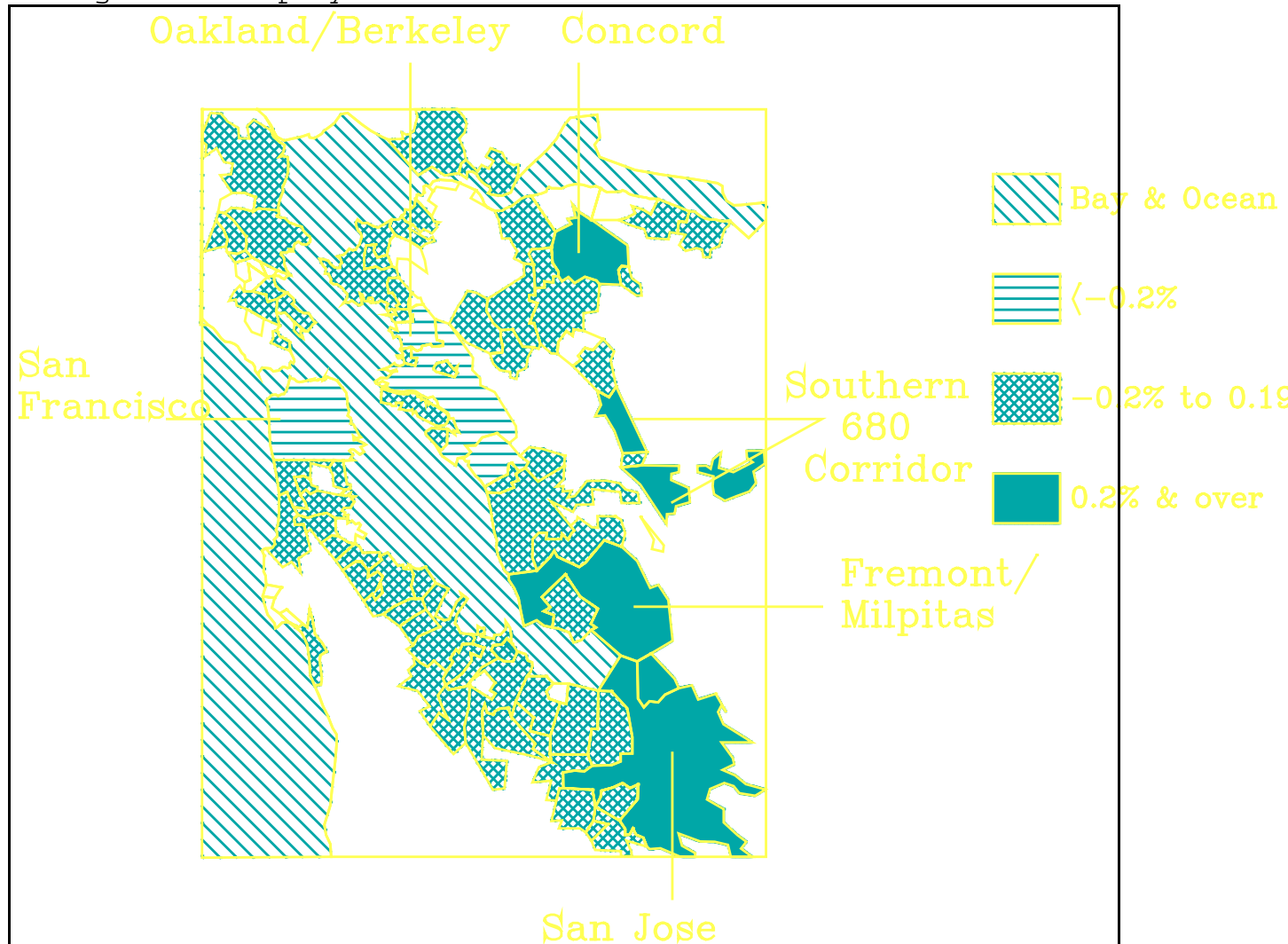


**Figure 13: Jobs per Square Mile by Community, San Francisco Bay Area 1990 (Source: Association of Bay Area Governments 1990) (White areas are open space or no data)**

In particular, the 1980's saw a marked shift of the distribution of regionwide employment towards the eastern Bay Area suburbs during the 1980's. 13 maps the percentage point change in regionwide employment between 1980 and 1990 by community<sup>8</sup>. Cities losing significant shares of

<sup>8</sup>The measure selected for analysis in 13 -- percentage point change in the share of regionwide employment -- overcomes much of

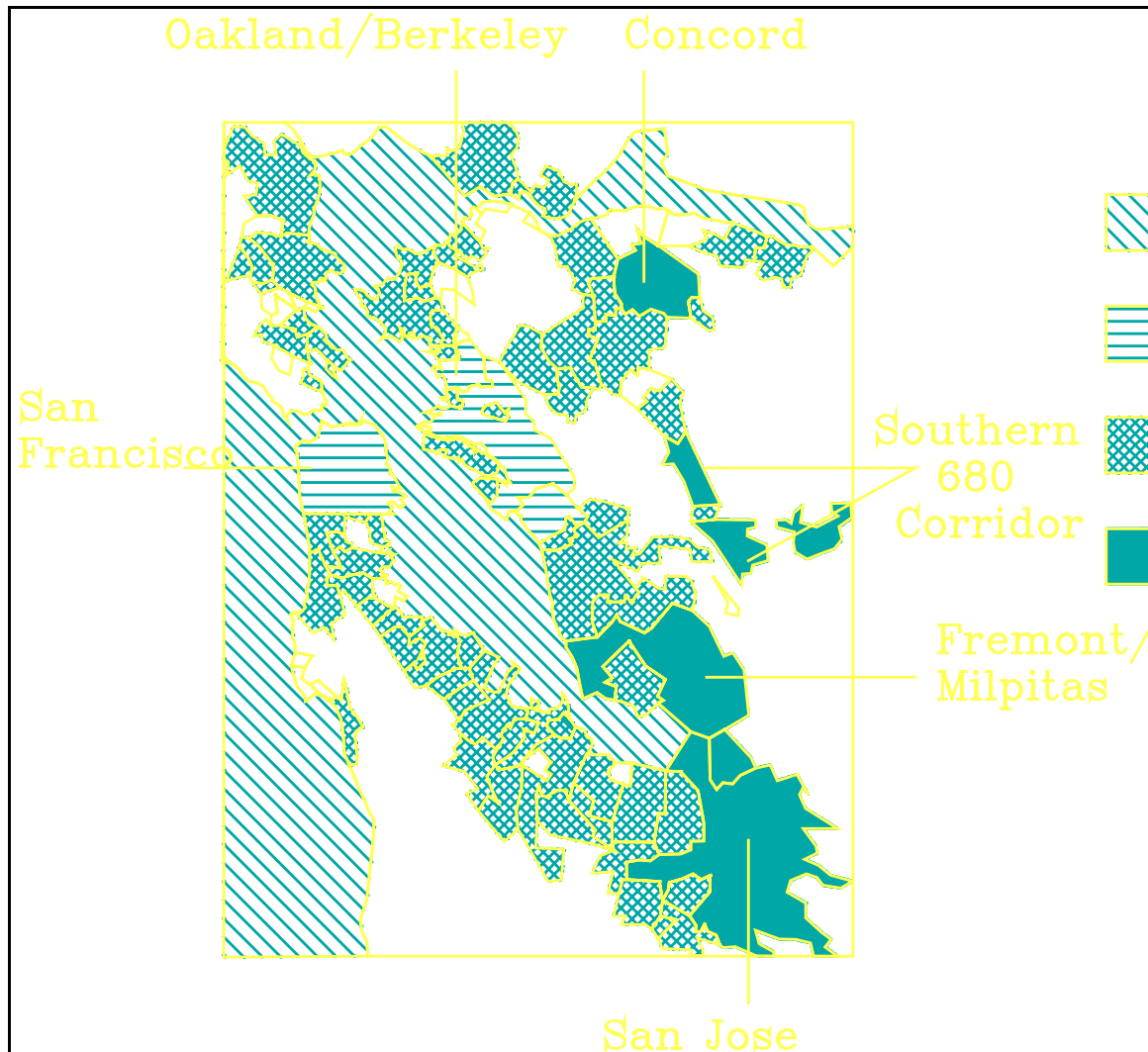
the tendency of change measures to overstate growth at the periphery. Studies of metropolitan development often analyze percentage change in some attribute by community. Inasmuch as communities at the metropolitan fringe are smaller than those at the center, virtually any growth translates into very high percentage change relative to percentage growth at the center. In contrast, under the measure used here, growth in communities must be significant relative to regionwide employment as a whole in order for the community to be viewed as gaining important shares of regionwide employment.



**Figure Error! Main Document Only.: Percent Point Change in Share of Regionwide Employment by Community 1980-1990, San Francisco Bay Area (Source: Association of Bay Area Governments 1987, 1990)**

regionwide employment included the central cities of San Francisco (dropping from 21.8 percent to 18.8 percent of regionwide employment) and Oakland (from 7.2 percent to 6.3 percent) and the inner ring suburbs of San Leandro and Berkeley. A common element between those locations dropping in regional employment share is their central location within the Bay Area.

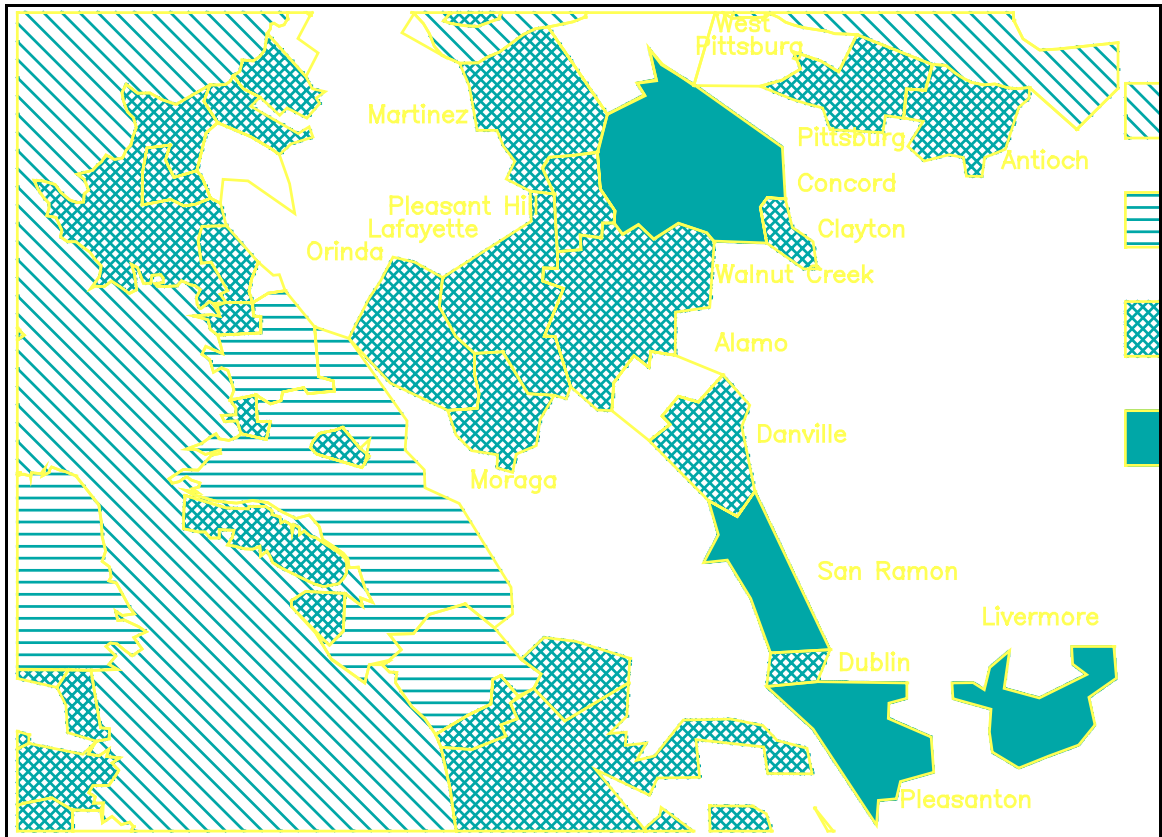
Conversely, communities gaining significantly in



**Figure 14: Percent Point Change in Share of Regionwide Employment by Community 1980-1990, San Francisco Bay Area**  
(Source: Association of Bay Area Governments 1987, 1990)

regional share were more peripheral communities to the south and east; San Jose, Milpitas and Fremont (at the periphery of Silicon Valley), the southern Interstate 680 corridor communities of Livermore, Pleasanton and San Ramon, as well as Concord in the northern 680 corridor (14) (Association of

Bay Area Governments 1989).



**Figure 15: Percentage Point Change in Regionwide Employment 1980-1990, Interstate 680 Corridor Communities (Source: Association of Bay Area Governments 1987, 1990)**

Of the two suburban employment concentrations selected for more detailed study and modeling -- San Ramon and northern Santa Clara County -- San Ramon in the southern 680 corridor is the newer, having realized its most rapid growth in the latter part of the 1980's (15). Much of this growth is attributed to the development of the Bishop Ranch business park beginning in 1984 (Sunset Development Company 1989), as well as its attendant spinoffs.

In contrast, much of the employment growth of northern Santa Clara County occurred during the 1970's (17).

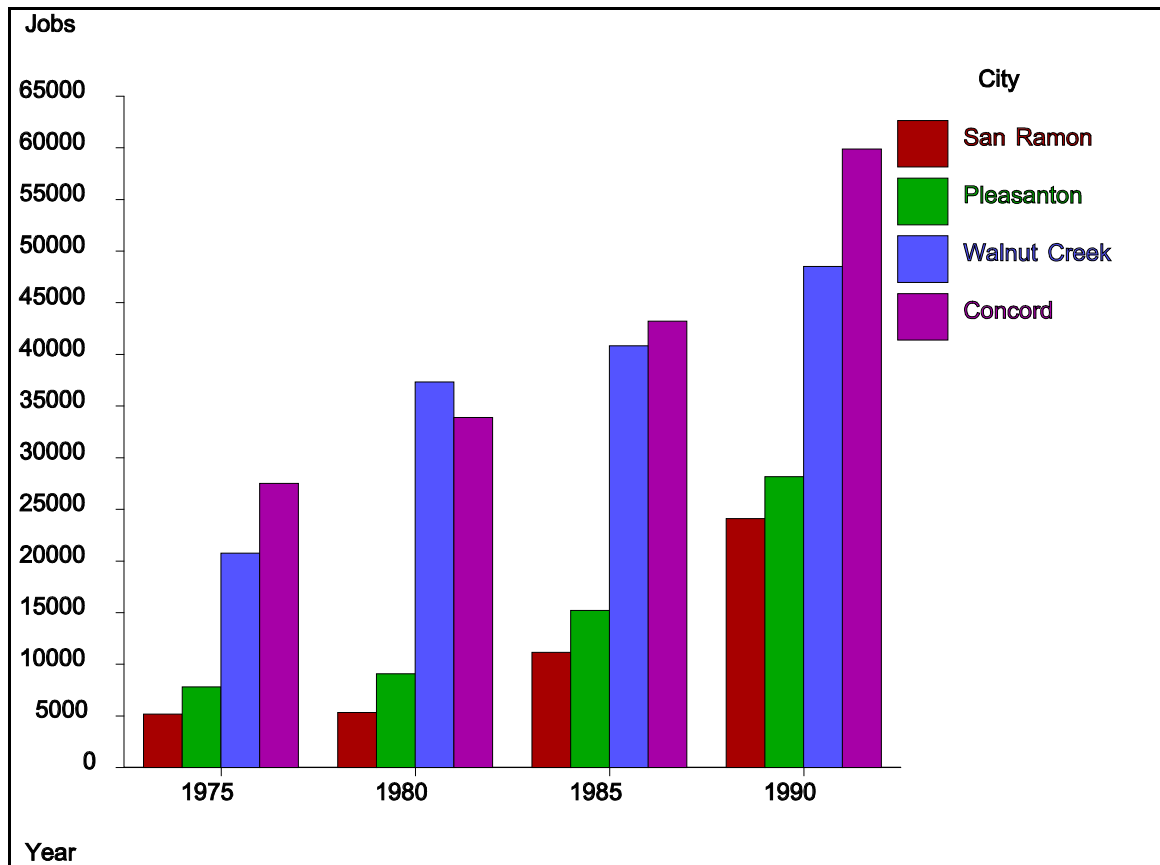
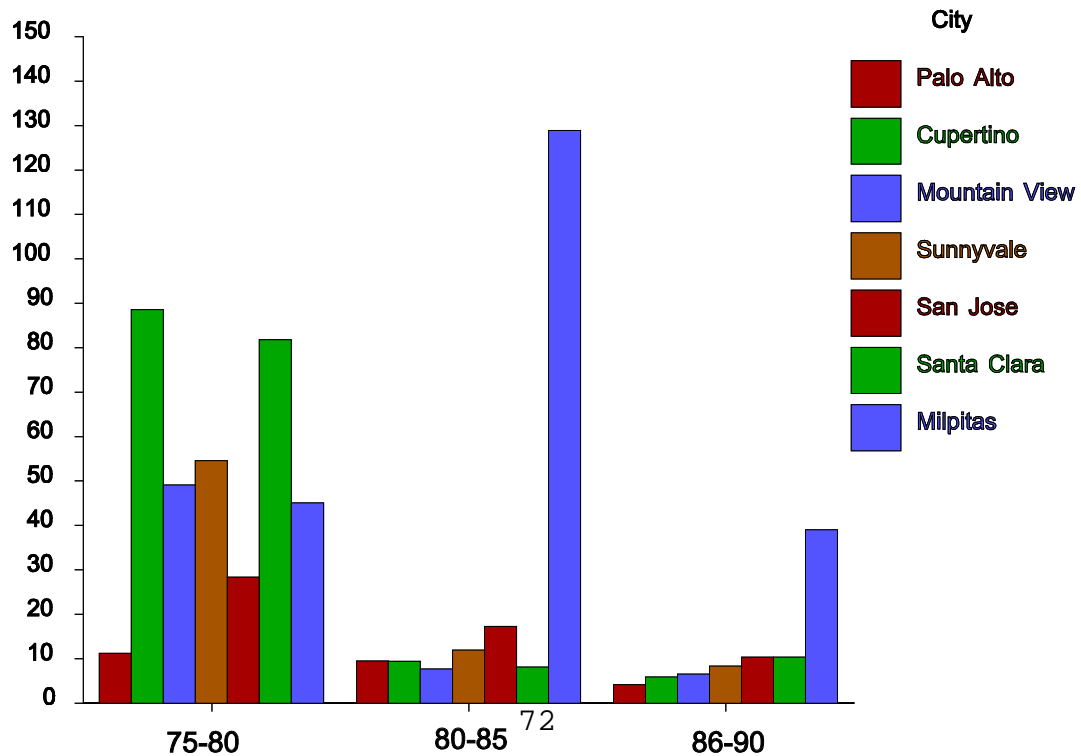


Figure 16: Employment Growth by Community, Interstate 680 Corridor, 1975-1990 (Source: Association of Bay Area Governments 1987, 1990)

East of the major concentration of Silicon Valley employment, Milpitas grew rapidly throughout the 1980's (17, 17). Thus the employment pattern of the Bay Area as a whole -- relative stability in more developed employment centers versus rapid growth on the eastern fringes -- is mimicked in



Percent Change in Employment



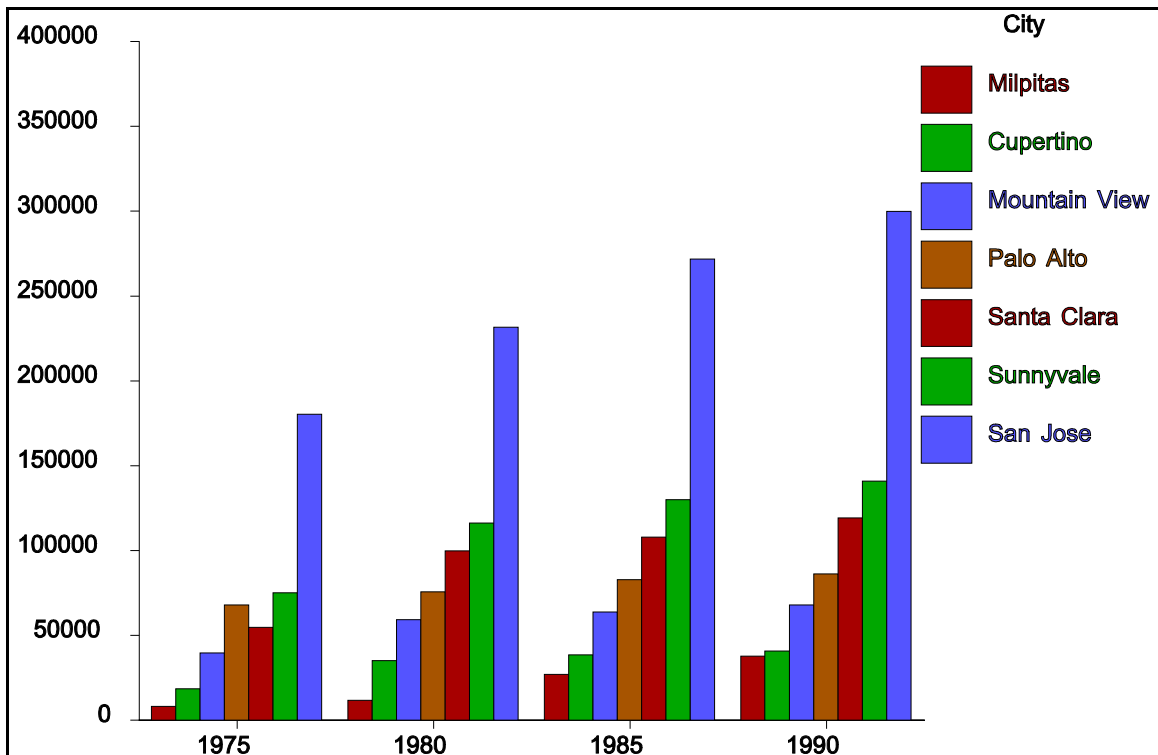
Five Year Period

Figure 17: Five Year Percent Growth in Employment by City, Northern Santa Clara County, 1975-1990 (Source: Association of Bay Area Governments 1987, 1989)

smaller scale in the Silicon Valley.

#### Housing Deficit near Suburban Employment

Contiguous with most, but not all, of these suburban employment concentrations are areas of relatively dense residences (19). Suburban concentrations of housing stock consisting of at least 50 percent non-single family housing units<sup>9</sup> appear in northern Santa Clara County, at scattered sites in San Mateo County, in San Rafael and in Walnut

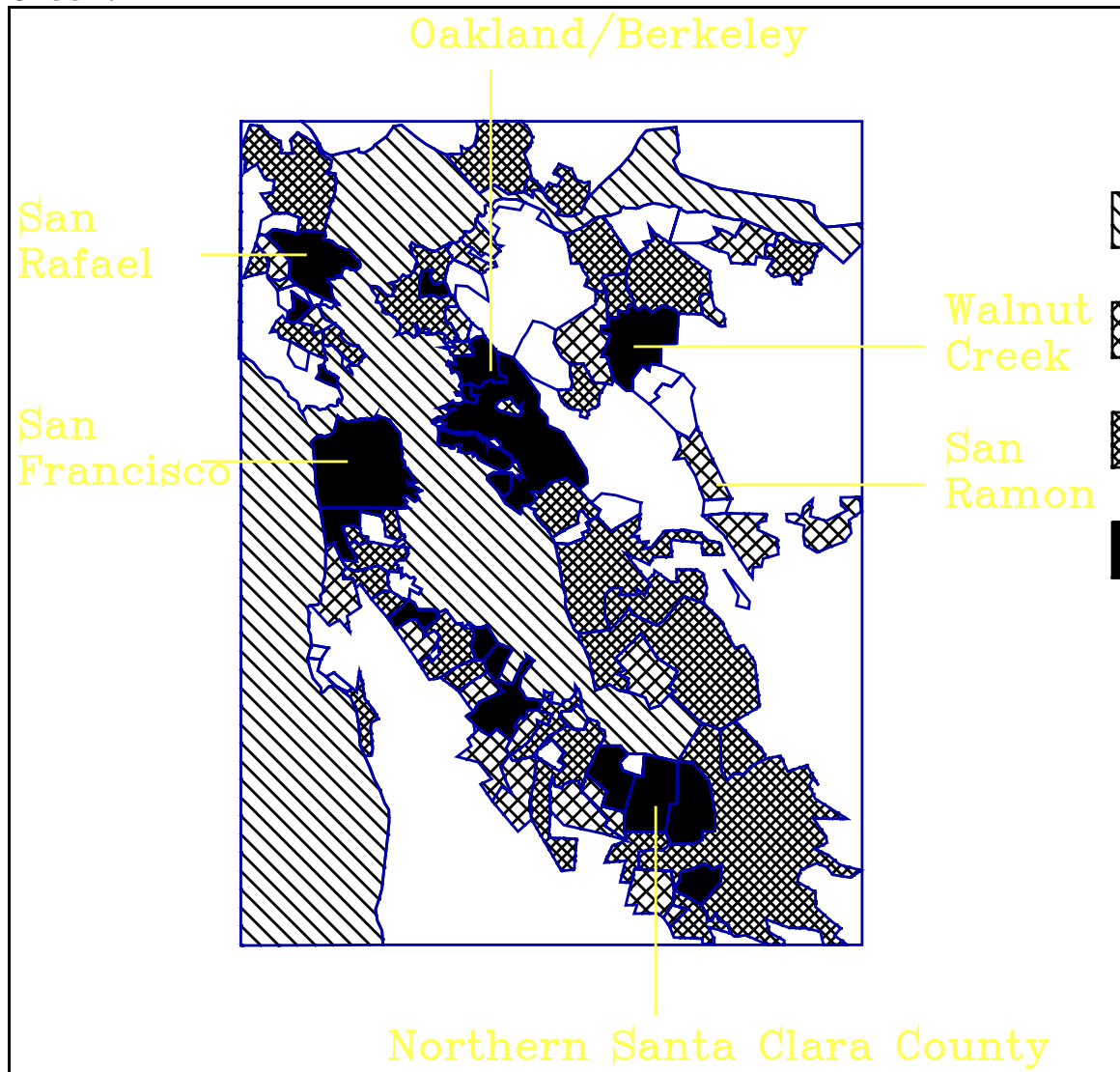


**Figure 18: Employment Growth by Community, Northern Santa**

**Clara County, 1975-1990 (Source: Association of Bay Area Governments, 1987, 1990)**  
<sup>9</sup>Non-single family refers here to all types of housing units apart from the single family detached dwelling. These include single family attached, condominiums, apartments, and mobile homes. As used in this study, multifamily housing is synonymous with non-single family housing.



Creek.



**Figure 19: Percent of Bay Area Housing Stock in Multifamily Housing, by Community, 1989 (Source: California Department of Finance 1989)**

Notably absent from this list of suburban communities having achieved significant residential densification are the southern 680 communities of Livermore, Pleasanton and San Ramon. The relative lack of multifamily housing in these communities, given employment concentrations there, is

the product of a number of factors, one of which is the later development of these areas as compared with other Bay Area suburban employment concentrations. Local policy and politics appears to play a role in restricting residential densification as well. Examples of these policies may be found in the San Ramon Housing Element (City of San Ramon, 1990). The Element sets as a guiding policy the development of "small lot single family units and single family attached units in order to decrease per unit land costs and provide lower cost single family units." The goal of this policy was a mere 20 units outside of Downtown; by 1990 no units were constructed under the policy. Policies encouraging affordable housing notwithstanding, higher density housing is restricted to only one of eight planning subareas of the community, the Crow Canyon area encompassing San Ramon's downtown.

San Ramon's housing stock was predominantly single family in nature in 1989 (73 percent, or 8,450 units). But the stock has changed significantly over the decade; in 1980 83 percent (5,689) of San Ramon's housing units were single family detached (California Department of Finance 1989). The city may in fact be on a development path towards a greater mix of single family and multifamily units. Thus San Ramon is not nearly an exclusive single

family community in the sense of the Bay Area's upper class suburbs such as Piedmont, Orinda or Hillsborough. But unlike these communities, San Ramon has high employment levels. Among those Bay Area communities with high density of employment, San Ramon and its neighbors in the southern Interstate 680 corridor have a relatively homogeneous single family housing stock. These communities appear to have the closest fit with the "low residential density suburban employment center" typology discussed in Chapter I.

In contrast, the other major suburban concentrations -- Northern Santa Clara County, San Rafael, the Bay shore communities of San Mateo County, and the northern Interstate 680 corridor -- contain higher levels of multifamily housing, including a number of communities in which multifamily housing accounts for over half the housing stock. These areas appear to match best the high density center typology of Chapter I. It should be noted that these concentrations are older than that found in the southern Interstate 680 corridor. It may be that the higher share of multifamily housing found there is a result of age and not just policy; as suburban employment centers mature they may tend to densify their housing stock.

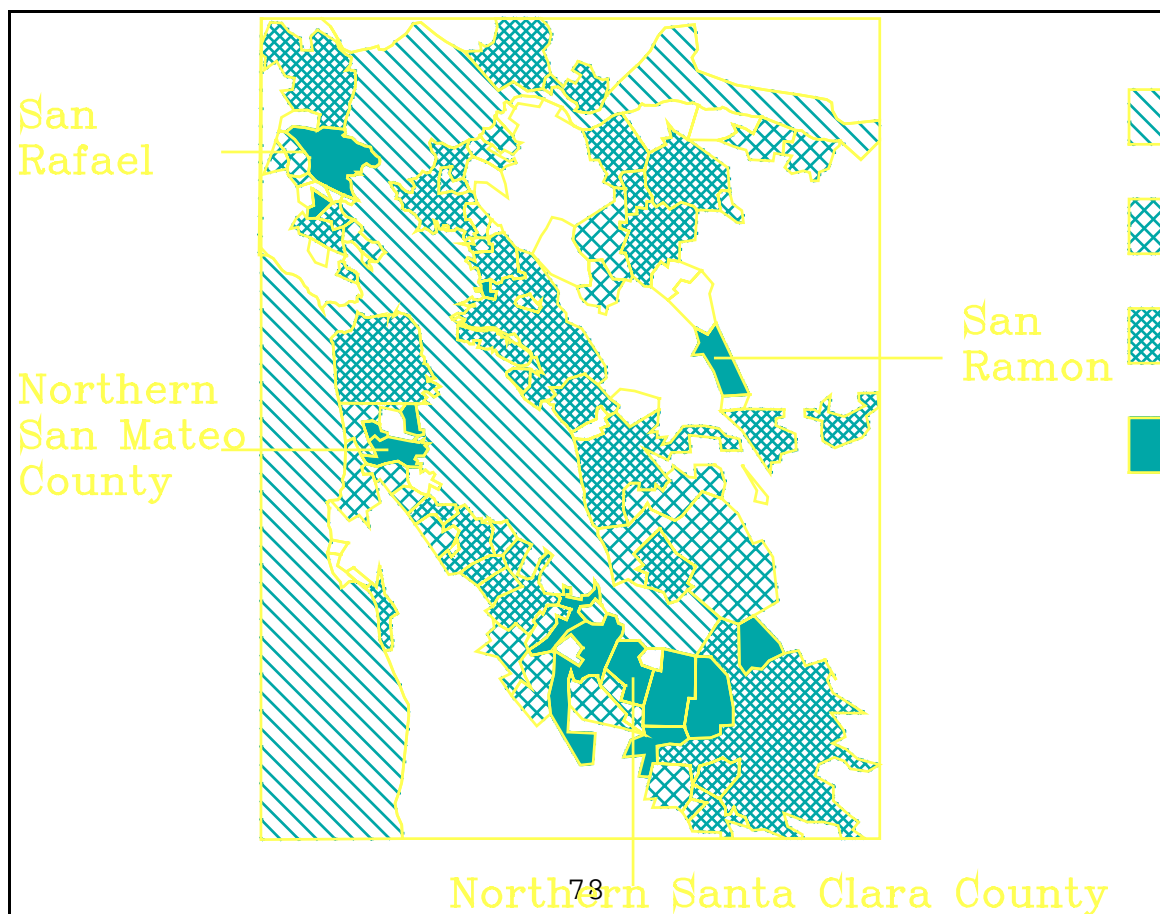
The concentration of dense housing in many of the region's suburban employment concentrations contributes to

the attainment of a geographic match between jobs and housing, and in fact much more of a match has been achieved than would have under lower housing densities. Nonetheless, geographic mismatches of jobs and housing remain, necessitating much in-commuting to the suburban employment centers. Although no standard ratio of jobs-to-housing is generally accepted as "balanced," one would expect to find net in-commuting (the difference between the number of commuters to a community and out-commuters from that community) in any given area to be minimized when the ratio of jobs to housing is in the range of 1.0 to 1.5, representing an average of 1 to 1.5 workers per household. Ratios of jobs to housing units exceeding two would represent egregious gaps exacerbating the need for in-commuting.

Much debate has centered around the issue of jobs-housing imbalances, and particularly around the appropriate geographic area within which a balance between jobs and housing units is to be measured. 20 presents the ratio of jobs to housing units by community in the Bay Area, while using the community as the unit of analysis. Thus the severity of any geographic mismatch between jobs and housing must be judged geographically by the contiguity of large areas of surfeit of jobs over housing units. For example,

the mismatch between jobs and housing is particularly severe in northern Santa Clara County, due to the contiguity of a number of communities in which jobs exceed housing units by a large margin.

The severest mismatches between jobs and housing units occur in the suburbs, while the central cities of Oakland and San Francisco hold ratios of 1.24 and 1.77, respectively (Association of Bay Area Governments 1989, California Department of Finance 1989). Even San Francisco, the region's central city and the site of a serious surfeit of jobs over housing units, contains a better geographic match between jobs and housing than does northern Santa Clara County. It is important to note that central cities such as



**Figure 20: Ratio of Jobs to Housing Units by Community, San Francisco Bay Area, 1989 (Source: Association of Bay Area Governments 1989, California Department of Finance 1990)**

Oakland and San Francisco are larger in area than most suburban communities; hence the jobs-housing ratio is not directly comparable between city and suburb. However, the contiguous area of communities having a jobs-housing ratio of over 2.0 in northern Santa Clara and southern San Mateo counties is approximately 99.8 square miles, or double the land area of San Francisco.

#### Suburbanizing Congestion

The housing and employment conditions described above have, not surprisingly, led to a marked increase in congestion regionwide. This increase has been particularly felt in the counties of Alameda and Contra Costa, whose suburban portions contain much of the employment growth referred to above.

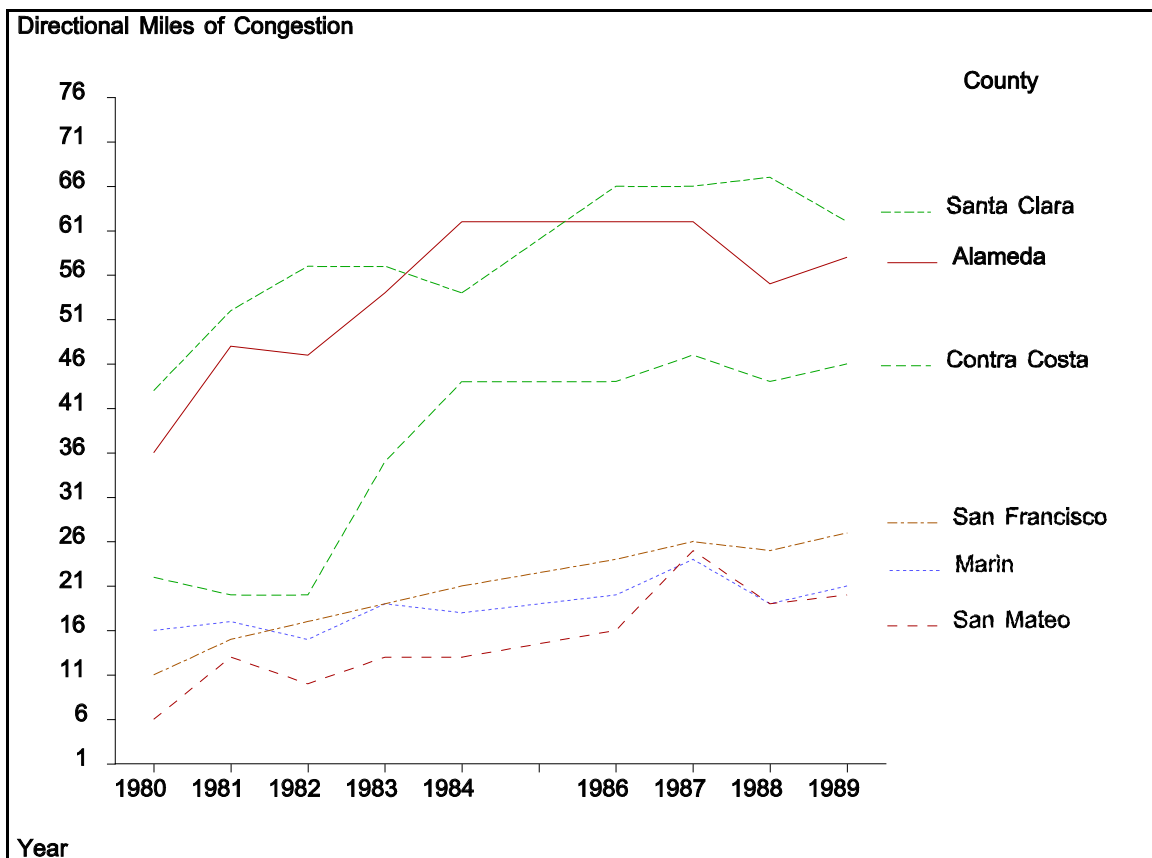
Congestion is a difficult phenomenon to measure, particularly over different areas and periods, for three principal reasons. First, congestion is largely a matter of perception. Its onerousness depends on the time and place in which it occurs; people generally expect (and therefore accept) greater delays during the journey to work than in recreational travel, and more in urban areas than in suburban or rural. Second, congestion can be measured in a number of ways, including average speeds, miles of congested

roadway, or vehicle hours of delay. Different measures can seem to exaggerate or diminish from the seriousness of worsening congestion over time. Finally, even given a particular approach to measurement, techniques for measurement are generally coarse and the numbers they generate should be viewed as approximations.

The California Department of Transportation monitors freeway congestion through two measures; average daily vehicles hours of delay, and miles of congested roadway. Both of these measures are estimated by introducing test vehicles into the traffic stream on several different days.

The latter measure is less sensitive to traffic volumes and is thus somewhat more conservative; for this reason, this measure is used in this section to track congestion's growth in the Bay Area over the 1980's. The measure defines as "congested" freeway stretches on which mean speeds drop below a certain standard for 15 minutes or more on a typical weekday. Perhaps in accord with deteriorating expectations of highway service, the standard speed was lowered in 1986 from 40 to 35 miles per hour. Thus information presented in this section may slightly understate the growth in congestion over the decade.

Despite this downward revision in the definition, congestion regionwide has increased markedly since 1980 (21). From 134 directional miles of congestion in 1980, the



**Figure 21: Directional Miles of Congestion by County, San Francisco Bay Area, 1981-1989 (Source: California Department of Transportation 1981-1989) (1985 data missing)**

region's clogged highways nearly doubled, reaching a peak of 250 congested directional miles in 1987. It should be noted that the steepness of the increase does not indicate a twofold increase in traffic volumes over the period. Rather, as roadways approach capacity, deterioration in levels of service occurs rapidly with increasing vehicle



density.

The Bay Area's peripheral counties appear to be congesting rapidly relative to their more centrally located counterparts. (In the cases of Alameda and Contra Costa Counties which contain both urban and suburban areas, growth in congestion in the suburban regions has outpaced that in the urban areas for all years except 1981). Santa Clara County, already the region's congestion leader in 1980 continued to congest rapidly over the decade.

Though the data support the premise of growing suburban congestion in Marin, Contra Costa, Alameda and Santa Clara counties, the congestion one would expect during a suburban trip would still probably be less than that encountered traversing a central city. Still, given that congestion is largely a matter of perceptions and expectations, individual locational decisions in the suburbs will be increasingly affected by the growing prevalence of suburban congestion.

### **Data Sources**

A test of the hypotheses stemming from the relationship of suburban commute patterns and suburban housing stock and employment characteristics requires the assembly of information from disparate data sources. First, as the primary unit of analysis is the household, a source of

disaggregate household level data is needed that provides information on employment, commuting, residential location, and socioeconomic characteristics such as household income and number of household workers. Second, since specific hypotheses are made regarding the effect of local conditions on individuals' commutes, a community level information source is required that would include data on local housing stock and price, as well as some measure of local amenities or municipal service quality. Finally, data on commute times and distances are required that link the workplaces of the individual household with potential residential communities. This section describes the sources of these categories of data.

#### Employment, Commuting and Residential Location Data

This study relies on two information sources for household level data. The first is a large scale home based travel survey conducted throughout the Bay Area in 1981 (Metropolitan Transportation Commission 1981). This source serves two functions in this study; it enables an analysis of broad geographic scope covering the entire San Francisco region, and it serves as a baseline against which changes in land use and transportation patterns may be compared. However it predated much employment suburbanization in the

southern 680 corridor. For this reason, the modeling phase of the study relies on a workplace survey conducted in the latter half of 1989 in selected San Ramon and northern Santa Clara County firms.

#### BATS 1981 Data Set

The 1981 Bay Area Travel Survey (BATS) consisted of 7,235 home based interviews completed by telephone using a random digit dialing sampling process. The geographic coverage was the entire nine county San Francisco Bay Area, with half the sample being drawn from San Francisco residents and the other half distributed throughout the remaining eight Bay Area counties proportionate to the households in the county.

The survey instrument was virtually complete with regard to items of interest (Appendix A). The question regarding the household's income was answered in 80 percent of the cases, though no salary data were available on individual household workers. Importantly, the data are complete with regards to all workers in the family; frequently workplace travel surveys conducted locally ask about a single worker only. The study was a Bay Area wide home based survey; as such it did not include in-commuters to the Bay Area, notably from areas of the Central Valley.

This in-commuting was rare in 1981 compared to current levels, and its non-inclusion may not severely skew results.

The file analyzed was an extensively cleaned and processed data set based on the raw BATS data (Harvey 1984) consisting of unlinked trips by individuals. Individuals were first grouped into their respective households using the Paradox 3.0 relational database manager. The time and distance of the automobile commute from each household's home zone to the work zone of the primary worker were matched through queries merging the main database with data from Metropolitan Transportation Commission peak hour skim trees. This was necessary to standardize commutes and to render them comparable; the actual trip data from the BATS dataset varied by mode, route, and number of trip links between home and work.

#### 1989 Workplace Survey

During the latter half of 1989 a smaller scale workplace survey was carried out to determine household location and commuting characteristics of employees of selected major Bay Area employers (Appendix B). The survey was designed with several purposes: 1. To determine differences in commute patterns between employees of offices remaining in downtown areas and those that had relocated to

suburban centers; 2. To examine factors governing an household's predilection to move given a change of workplace location; and 3. To allow analysis of determinants of suburban commuting and location patterns.

The study was conducted as a workplace survey of major employers (as opposed to other potential designs, such as home based surveys) for several reasons. Most important was the desire to target certain urban and suburban areas of large scale employment for analysis. Given existing resources, the most efficient method for accomplishing this goal was to survey employees at their place of work; a home-based survey of similar proportions would only have yielded tiny samples of workers at any given community of employment. Larger employers were surveyed for similar considerations of efficiency. Each employer contact involved weeks of logistical arrangement and negotiation; the larger employers were able to provide a larger employee samples. Thus the current study involves a tradeoff between freshness of the data and survey design; the 1981 Bay Area Travel Survey provides a more comprehensive design but would ignore important changes that occurred throughout the Bay Area over the course of the 1980's.

**Table 1: Employees and Response Rates by Location**

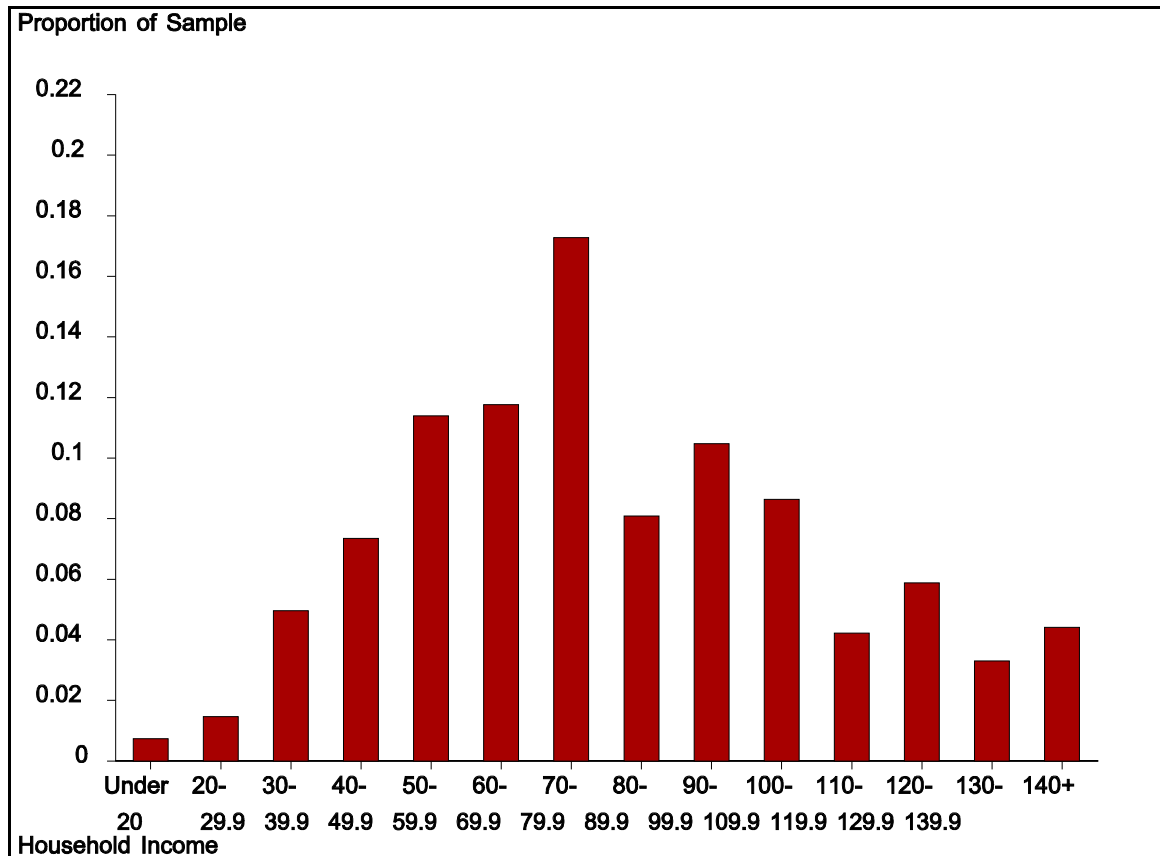
Firm	Loca- tion	Total Empl.	Surveys Distr.	Useable Surveys Returned	Response Rate
Chevron	SF	2,889	500	232	46.4%
Chevron	SR	3,867	500	374	74.8%
G.E.	SJ	1,600	300	159	53.0%
PG&E	SF	7,500	300	175	58.3%
Pac.Bell	SR	7,000	2,000	1,101	55.1%
Sun	MV	3,321	300	163	54.3%
Tandem	CU	3,167	200	106	53.0%
Tandem	SC	292	50	28	56.0%
Tandem	SV	174	50	24	48.0%
Misc*.	Misc.			36	
Total			4,200	2,362	56.2%
SF=San Francisco			SR=San Ramon	SJ=San Jose	
MV=Mountain View			CU=Cupertino	SV=Sunnyvale	
*Employees of firms not working at the firms' primary location					

Firms surveyed by this study are listed in 1 together with their total employee population on site, surveys distributed and response rate. This study makes use of data from the following firms: Pacific Bell and Chevron in San Ramon; Tandem Computers in Cupertino, Sunnyvale and Santa Clara; Sun Microsystems in Mountain View and General Electric in San Jose. Within firms, employee samples were generated randomly by the firm's own management information system departments, and the surveys distributed within the firms' internal mailing systems. The response rate of 56.2 percent, though good for a self-administered survey, still

leaves open the possibility that systematic biases may pervade the sample based on the characteristics of non-respondents. This, combined with an oversampling of upper income households (discussed below), requires that statistical and policy inferences based on the data be viewed with caution.

The sampling frame of the 1989 survey differed from the 1981 BATS. First, the geographic scope was much more limited, restricted as it was to employees in two suburban job markets. Second, the survey was only designed to include households with at least one employed member; the unemployed and retired populations were not included. Third, only workers of certain large suburban employers were surveyed. Thus the data set is not a sample of the population as a whole, but of employees of major suburban employers. As such, one would expect a higher income distribution in the sample than in the population at large.

The income distribution for the Santa Clara sample is



**Figure 22: Income Distribution for Northern Santa Clara County Sample, 1989 (x \$1,000) (Median = \$75,000)**

presented in 21, and the slightly lower San Ramon distribution in 22. The expectation of a sample income distribution higher than that of the population is borne out through a comparison of sample data with Association of Bay Area Governments' estimates of mean household income by city for 1990 (1989 dollars). 1 presents the comparison for cities (including unincorporated communities) having 10 or more people in the combined Santa Clara County-San Ramon (unweighted) sample. The greatest proportional differences

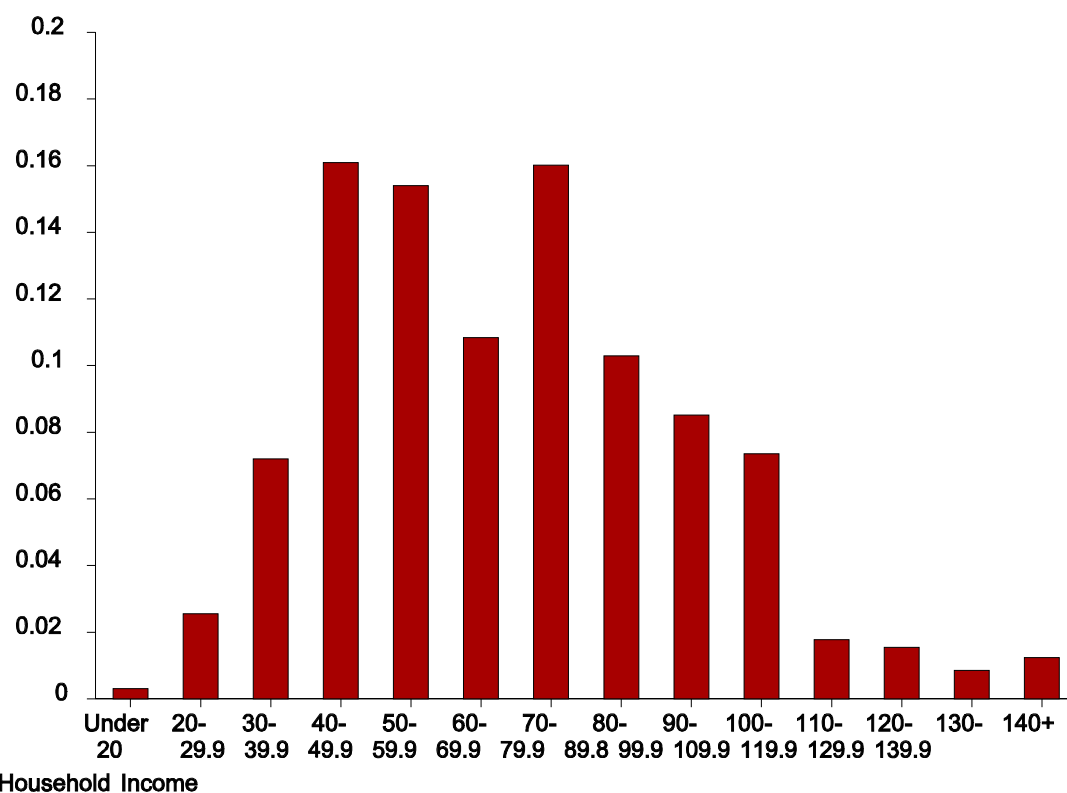


are found in for residents of Oakland and Berkeley, communities notably split between rich and poor. It is not surprising, given demonstrated barriers to suburban employment for lower income inner city residents, to find a lack of these populations represented in the suburban workplace based sample. But for other communities as well, mean incomes of the survey population were consistently higher than the actual estimated household incomes. Apparently within the employees of the firms, those with higher paying jobs were more willing to complete and return the survey forms. This was exacerbated by the fact that Pacific Bell was undergoing a labor dispute at the time the survey was conducted that precluded the survey's distribution to union members. It also appears that the employers were more willing to distribute the surveys to more highly salaried employees. The combination of these factors led to a sample in which high income households are clearly overrepresented. As this study is especially interested in the lower income households -- the least represented group in the sample -- conclusions must be viewed with caution.

**Table 2:** Comparison of Sample Mean Income with ABAG Estimates, by Community (1989 dollars) (Source: Association of Bay Area Governments 1989, California Department of Finance 1990.)

Community	Mean Income, Sample	Mean Income, ABAG Estimates	Ratio: Sample to Estimate	Sample Size
ALAMEDA	\$68,600	\$41,600	1.6	26
ALAMO	\$82,500	\$96,000	0.9	10
ANTIOCH	\$72,800	\$45,200	1.6	24
BENECIA	\$67,900	\$47,900	1.4	17
BERKELEY	\$70,800	\$35,900	2.0	26
CASTRO VALLEY	\$77,400	\$49,300	1.6	34
CONCORD	\$68,600	\$46,400	1.5	135
CUPERTINO	\$70,000	\$64,100	1.1	21
DALY CITY	\$58,000	\$47,800	1.2	14
DANVILLE	\$83,100	\$80,200	1.0	144
DUBLIN	\$63,300	\$51,500	1.2	42
FAIRFIELD	\$57,000	\$39,200	1.5	10
FOSTER CITY	\$86,900	\$64,500	1.3	12
FREMONT	\$76,100	\$51,700	1.5	62
HAYWARD	\$73,000	\$41,300	1.8	33
HERCULES	\$65,500	\$62,500	1.0	10
LAFAYETTE	\$82,200	\$71,500	1.1	37
LIVERMORE	\$63,900	\$48,100	1.3	42
LOS GATOS	\$87,800	\$66,600	1.3	17
MARTINEZ	\$74,100	\$48,400	1.5	49
MILPITAS	\$72,700	\$53,700	1.4	11
MORAGA	\$72,500	\$75,500	1.0	17
MOUNTAIN VIEW	\$76,700	\$46,100	1.7	12
NEWARK	\$61,900	\$49,300	1.3	13
NOVATO	\$79,600	\$65,500	1.2	14
OAKLAND	\$69,400	\$34,300	2.0	103
ORINDA	\$97,300	\$95,800	1.0	12
PALO ALTO	\$86,500	\$62,000	1.4	21
PINOLE	\$70,300	\$51,800	1.4	10
PITTSBURG	\$53,100	\$37,100	1.4	21
PLEASANT HILL	\$70,000	\$49,300	1.4	35
PLEASANTON	\$73,000	\$55,300	1.3	87
RICHMOND	\$56,700	\$38,000	1.5	13
SAN BRUNO	\$63,500	\$50,600	1.3	10
SAN FRANCISCO	\$68,300	\$43,200	1.6	128
SAN JOSE	\$69,300	\$51,700	1.3	268
SAN LEANDRO	\$62,200	\$39,800	1.6	17
SAN MATEO	\$72,100	\$53,600	1.3	13
SAN RAFAEL	\$77,400	\$61,600	1.3	19
SAN RAMON	\$73,800	\$70,300	1.0	179
SANTA CLARA	\$64,600	\$49,100	1.3	23
SUNNYVALE	\$92,400	\$52,000	1.8	23
VALLEJO	\$58,100	\$35,700	1.6	19
WALNUT CREEK	\$76,000	\$55,900	1.4	117

Proportion of Sample



**Figure 23: Income Distribution for San Ramon Sample, 1989**  
(x \$1,000) (median = \$65,000)

Another potential difficulty with the 1989 data lies in the fact that both Chevron and Pacific Bell are relatively new in San Ramon; both firms began operations in San Ramon in 1984, and both transferred many employees from previous job sites in San Francisco. Thus San Ramon might be seen as a special case of a new suburban employment center in which commute patterns are still in a state of flux; some long commutes may remain because households have not yet had a chance to relocate. To test for the effects of household relocating versus staying in place, the commutes of relocating households were analyzed in Chapter IV.

#### Choice Set Data

Many studies (e.g. Varady 1990, Shin 1985, Quigley 1985, Lerman 1975, Halvorson 1970, Stegman 1969) have attempted to measure those characteristics of communities that define their power to attract or repel as places for a household to locate. These characteristics can generally be broken down into four major categories: affordability, municipal service, housing characteristics and neighborhood amenities, and accessibility. Measurable variables, of course, fail to capture the full range of community characteristics relevant to the locating household; instead the development of successful models relies on a small

handful of variables that appear to capture key factors in a household's decision. In many cases, measured variables may successfully serve as proxies for other unmeasured or unmeasurable characteristics.

The unit of analysis of the choice data set was the community, defined as city or as unincorporated area generally recognized as a community. The exception to this was the City of San Jose, which was broken up into eight entities because of its vast size, heterogeneity and importance to the two suburban work places studied. San

**Table 3:** Definition of San Jose Sub-Areas for Choice Set Development

<u>San Jose Subarea</u>	<u>ZIP Codes</u>
SJ: Almaden	95120
SJ: Alum Rock	95116, 95127, 95133, 95122
SJ: Berryessa	95131, 95132, 94134
SJ: Cambrian/Blossom Hill	95118, 95119, 95123, 95124, 95136, 95139
SJ: Downtown	95110, 95112, 95113, 95126
SJ: Evergreen	95111, 95121, 95135, 95148
SJ: Westgate	95117, 95128, 95129, 95130
SJ: ZIP Code 95125	95125

Jose was divided as described in 3 by ZIP code area.

### Affordability

The goal of housing affordability measures was to represent a generalized price level for a given community while recognizing the diversity of housing types and prices within that community. For this reason both median price per square foot (in single family homes) and median price per single family home were used. An argument may be made for use of either measure. The median price per home measure captures affordability fairly well in cases where there is relative homogeneity of size of homes within a community, as with many newer suburban communities.

In contrast, consider the two East Bay communities of Albany and Piedmont. Albany is known for its small homes; Piedmont for its spacious homes. The price per square foot of residential space between the two communities is similar, but because of housing size differences between the communities, Albany homes are affordable to households with incomes considerably lower than those of Piedmont residents.

In this case price per square foot fails to capture differences in affordability, and median price best measures affordability differences between these communities. Use of both measures can account for both price and size variation

within and between communities.

Both price per square foot data and median price data were developed by the Center for Urban and Real Estate Economics at the University of California, Berkeley, from databases maintained by the Damar Corporation, a real estate information service. The prices used are median prices for sales occurring during the summer of 1989.

The 1989 prices thus described are used throughout the model, even for households who purchased their homes earlier. It is assumed that people purchasing homes in earlier years faced at least an ordinal ranking of affordability similar to that found in 1989. This assumption appears reasonable inasmuch as a large majority of the homeowners in the study (74.2 percent) were living in homes purchased in 1980 or later. To control for the effect of long term residence in an inflating market, a tenure variable was tested.

It should be noted that no explicit variable is used to represent rents for those families opting against home ownership (31.1 percent of the Santa Clara County sample, and 23.8 percent of the San Ramon sample). Rather it is assumed that a ranking of localities on the basis of rents would not be significantly different than the same ranking on the basis of housing price. Reliable data on rents by

community are rare, but this assumption appears to be supported by county level data collected by the Bay Area Council. Figures in 4 reveal an  $r^2$  of 0.91 between median rents and mean sales prices by county.

**Table 4:** Mean Sales Price for All Homes, and Median Advertised Rents for Two Bedroom Apartments, by County, 1989 (Source: Bay Area Council 1989a, Bay Area Council 1989b)

---

<u>County</u>	<u>Sales Prices</u>	<u>Rents</u>
San Mateo	\$288,133	\$795
San Francisco	\$286,843	\$950
Marin	\$273,060	\$800
Santa Clara	\$211,235	\$700 <sup>1</sup>
Contra Costa	\$183,142	\$590
Alameda	\$174,444	\$640 <sup>2</sup>
Sonoma	\$151,854	\$550
Solano	\$122,115	\$448

<sup>1</sup>San Jose Area

<sup>2</sup>Southern Alameda County. Oakland area median rents = \$630.

---

## Municipal Services

Most studies agree on the importance of local school quality as a component of municipal service levels. But the most commonly used measure of quality is an input measure that may not be relevant to public perceptions of quality differences; i.e., school spending per pupil (Lerman 1975).

Spending per pupil may have little relevance to the Bay Area context. First, statewide school financing has evened



out per capita spending to a large extent; in fact in some cases greater per capita spending may reflect a need for more educational and social services in the schools and thus would fail to capture perceptions of school quality. Moreover, households have little direct perception of spending per student; they are most likely influenced by other aspects of the schools.

An output measure of school quality is needed that would in some way capture public perceptions. The measure of school quality most regularly cited in real estate publications is the results of the standardized testing of third, eighth and twelfth graders of the California Assessment Program (CAP), a program of the California Department of Education. Regardless of whether standardized testing does in fact measure school district quality, it is likely that publicly reported standardized test scores are a reasonable measure of public perceptions. Accordingly, the school quality measure was developed as follows: the CAP generates ranks for school districts in percentile terms for the three grades tested in a number of subjects; reading and mathematics were common to all three grades. The school quality measure was equal to the median percentile score of the six scores thus generated (i.e., two subjects by three grades).

The primary purpose of using standardized test scores as a measure of school quality was the assumption that they matched public perceptions better than alternative measures.

A further advantage of using test scores rather than public spending per student is the fact that test scores are readily disaggregated to individual schools, whereas spending must generally be considered uniform across a district. This is particularly important when (as is usual) school districts do not overlap the geographic units of study.

Where necessary in this study, schools were disaggregated from their districts and reaggregated into the appropriate geographic units. This was particularly important in Santa Clara and Contra Costa counties, where virtually all school districts overlap city boundaries. In cases such as these, individual schools in a community were isolated, sometimes from three or four school districts, and reaggregated into a fictitious "school district" representing all the schools in that community. The school quality measure then took on the value of the median test score for the three grades and two subjects within that community, as if it were a free standing school district. In the case of San Jose, such measures were developed for each of the eight subareas of the City.

The second measure pertaining to municipal service quality was crime rates, measured by residential and commercial burglaries per capita (Office of the Attorney General 1989). Burglaries were selected because of their frequency and their perception as somewhat more of a regularly occurring and less random event. Another possible crime measure would have been an index combining all crimes occurring in a community; this measure was rejected due to the arbitrariness of any weighting scheme that would be imposed to render disparate crimes comeasurable.

In general, measures of municipal service levels would include data on property tax rates in order to capture fully the effect of local policies on the desirability of a particular community. However in the case of California, tax rates are very nearly identical between communities and will thus not be included in this study.

#### Housing Characteristics

Since the choice set unit in this analysis -- the city -- is relatively large, a measure of housing characteristics was sought that would be both meaningful throughout large and somewhat disparate areas, as well as useful as a policy variable. The breakdown of the housing stock into single and multifamily components is a significant attribute that

varies distinctly by community. Moreover, the availability of alternatives to the single family home is central to this study's policy relevance, since the study seeks to determine whether a jobs-housing balance policy of affordable housing in the vicinity of suburban employment centers can shorten commutes. For the most part affordable housing in these areas of high priced land is denser, attached housing.

Thus a community's housing attributes were measured using the community's percentage of non-single family housing. The primary source for these data was a database maintained by the California Department of Finance (1989), though in several cases it was supplemented by the Housing Vacancy Survey (Federal Home Loan Bank Board of San Francisco 1986, 1987).

### Accessibility

An important aspect of multinomial logit analysis is its operation on two separate types of variables; in this case the types are those pertaining to the individual household, and to communities from which these households choose. The data element that bridges the two units of observation is the measure of accessibility of chosen and not chosen residential communities to the household's places of work. A measure of accessibility had to be developed for

every accepted and rejected community specific to each individual household.

Since the primary focus of this study is the relationship between employment suburbanization and the journey to work, accessibility is defined primarily in terms of the workplace. The workplace measure is used notwithstanding the relative importance of numerous other potential destinations in determining accessibility (Gordon et al. 1988). As discussed in Chapter II, the growth in nonwork trips does not necessarily imply their growing strength in determining residential location, particularly when one considers the relative ubiquity of nonwork destinations. It is reasonable to expect, and in fact the models presented in Chapter V support, that within the entire commute shed of an employment center, the journey to work remains a significant, if not dominant factor in locational decision making.

Two measures of workplace accessibility were considered; travel distance and travel time. The former has the advantages of simplicity of measurement as well as relative consistency over space and time. But travel distance as a measure of accessibility can mask important differences due to variations in highway quality and service levels. For this reason, the community-to-community

automobile travel time was selected as the accessibility measure for the modeling component of this analysis. It is important to note that estimated automobile time was used regardless of the actual mode chosen. In this way, travel time becomes a standardized measure comparable between individuals.

Since a standardized time was needed, reported times from the workplace survey were not considered useable. First, in many cases people may have reported round trip travel times, rather than one way times as the questionnaire requested (Cervero and Landis, 1990). Second, reported times vary due to perceptions and travel behavior. Finally, reported times were mode-specific; a transit commuter would have reported longer times than an automobile commuter over the same route.

In order to match standardized travel time data with individuals and communities, Metropolitan Transportation Commission zone-to-zone level of service data were acquired in the form of skim trees and transformed into a Paradox 3.0 data base. Peak hour highway travel times between the household's workplaces and communities of potential residence were entered into the survey data through a relational matching of the two databases. As the geographic scope of the analysis is broad, and the smallest

geographic unit of analysis is the community, times used were based on manually determined community centroids rather than zone centroids.

### **Summary of Chapter III**

The San Francisco Bay Area is used as a case study to analyze hypotheses suggested in Chapter I. The Bay Area is characterized by three urban employment concentrations together with major concentrations of suburban employment. Those suburban concentrations on the Bay Area's eastern fringe grew particularly rapidly over the 1980's and increased their share of regionwide employment, while centrally located communities declined in share.

In the newest suburban employment concentrations in the southern Interstate 680 corridor, the housing stock remains dominantly single family in nature. Communities in this area appear to match the "low residential density suburban employment center" typology described in Chapter I. In contrast other suburban employment centers -- northern Santa Clara County, San Mateo County, San Rafael and the northern 680 corridor -- contain high proportions of multifamily housing. These communities may be better described as high density centers. Differences may be due in part to the age of the suburbs, with suburban employment centers tending to

densify as they age. Local land use policies may also influence the development of denser housing.

Even in those suburban employment concentrations containing a large proportion of multifamily housing, excesses of jobs over housing units necessitates a large net in-commute. This problem is most acute in northern Santa Clara County where contiguous areas exceeding the size of the central cities of Oakland or San Francisco experience a ratio of jobs to housing units of over 2.0. In part as a result of these employment and housing trends, freeway congestion grew significantly over the 1980's, particularly in the region's suburban areas.

Issues of job location and commuting behavior will be analyzed using two data sets on household location and commuting behavior, the first from 1981 and the second from 1989. Data on communities forming the choice sets faced by individuals are assembled from a variety of sources, including the California Department of Finance, the California Assessment Program of the Department of Education, the Damar real estate data base, and the Office of the Attorney General.



## **Chapter IV:**

### Commute Patterns by Income and Area

In Chapter I, two relationships were postulated between commute distance and income in suburban areas: a negative relationship in areas of dense employment but low levels of dense housing; and independence or a positive relationship in areas of dense suburban employment and a dense housing stock. This chapter examines the relationships between commute distance, income and location of employment through a descriptive analysis of the 1981 BATS data set and the 1989 workplace survey. The questions will be analyzed initially with simple correlations and median trip lengths for the 1981 data set. The 1989 data set will provide the basis for a more detailed analysis of commute distributions by location.

In all cases, the commutes analyzed are those of the household head alone; secondary workers' commutes will be analyzed within the modeling framework presented in Chapter V. The descriptive analysis presented in this chapter focuses on commute distance rather than time in order to enable a comparison of residential patterns between areas with differing traffic conditions. Commute distances were developed for the 1981 data set on the basis of Metropolitan

Transportation Commission (MTC) travel analysis zone-to-zone skim tree distances; distances for the 1989 data set were computed on the basis of community centroids, as discussed in Chapter III.

#### **Commute Patterns by Location: 1981**

The view that large scale employment suburbanization benefits overall metropolitan accessibility (Gordon 1989) is based on two premises. First, it is assumed that commutes to suburban locations are shorter in distance than those ending at the metropolitan center. The second premise is that employment suburbanization benefits all income classes<sup>10</sup>. Stated otherwise, the second premise is that the ability of a household to reside close to its suburban workplace is largely unaffected by its income status.

#### Shortened Commutes in the Suburbs?

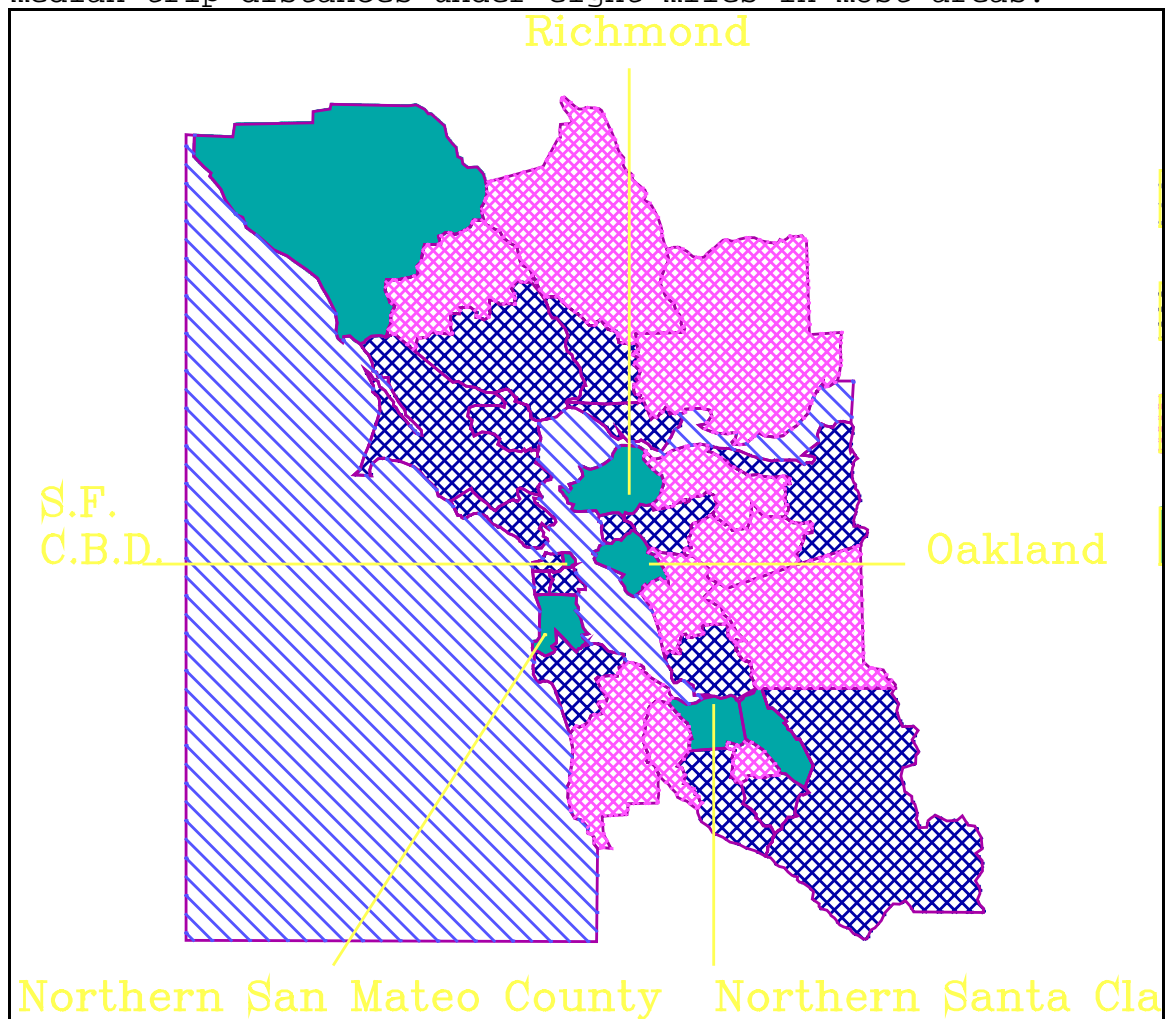
The first premise, that of shortened commutes in the suburbs, is in general supported by the 1981 data set. 24 presents median commute distances by MTC superdistrict (34 aggregations of travel analysis zones encompassing the

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<sup>10</sup>Another implied premise is that shortened commute distance will be sufficient to overcome the congestion engendered by a large scale shift from transit to automobile commuting.

entire Bay Area). As expected, the longest commutes end in downtown San Francisco, with a median distance of 19.3 miles. The San Francisco CBD's position at the tip of a peninsula lengthens commutes significantly; the commutes of the Oakland workers represent more typical center city commutes, with a median distance of 12.2 miles.

Workers in suburban areas enjoy shorter commutes, with median trip distances under eight miles in most areas.



**Figure 24: Median Commute Distance (Miles) by Superdistrict of Employment, 1981**

The commute benefits of suburbanization are not universal, however. Commutes of near center-city length are found among workers in the industrial suburbs of northern San Mateo County (12.1 miles) and Richmond (9.5 miles). Both of these areas contain concentrations of heavy industry and populations of low or lower than average incomes (4). In contrast, the longer commutes among workers employed in northern Santa Clara County (median=8 miles) occurs against a backdrop of relatively cleaner electronics manufacturing and a higher income population (4). It may be that the long median commute in this area is affected by the surplus of jobs over housing in the area and the necessity for much in-

commuting (Chapter III).<sup>11</sup> Still, Silicon Valley commutes were shorter than those ending in the center city and those to the industrial suburbs described above.

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<sup>11</sup>The other exception to the rule of reduced commutes away from center cities was in the Healdsburg/Cloverdale in the Bay Area's northern reaches. The area's long commutes seem related to its sparseness rather than to any connection with urban or suburban job centers.

**Table** Error! Main Document Only.: Mean Household Income by Selected City, 1980 (Source: Association of Bay Area Governments 1987)

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Northern San Mateo Communities

Colma	\$32,540
Brisbane	\$33,245
Daly City	\$35,241
San Bruno	\$36,796
South San Francisco	\$35,226

Richmond Area Communities

El Cerrito	\$40,131
Hercules	\$46,104
Richmond	\$27,911

San Pablo	\$23,763
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Northern Santa Clara County Communities

Milpitas	\$38,170
Santa Clara	\$35,284
Sunnyvale	\$37,573

Regionwide mean:	\$35,720
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### Suburban Employment and Commutes by Income

The prediction of the monocentric model of increasing incomes of central city commuters as one moves away from the

**Table 5:** Mean Household Income by Selected City, 1980  
(Source: Association of Bay Area Governments 1987)

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#### Northern San Mateo Communities

Colma	\$32,540
Brisbane	\$33,245
Daly City	\$35,241
San Bruno	\$36,796
South San Francisco	\$35,226

#### Richmond Area Communities

El Cerrito	\$40,131
Hercules	\$46,104
Richmond	\$27,911
San Pablo	\$23,763

#### Northern Santa Clara County Communities

Milpitas	\$38,170
Santa Clara	\$35,284
Sunnyvale	\$37,573
Regionwide mean:	\$35,720

---

center of the metropolitan area is supported by the 1981 BATS data. 24 maps the Pearson correlations ( $r$ ) between household income and commute distances for primary workers employed in each of the Bay Area's 34 superdistricts. A positive correlation indicates that higher income workers tend to commute farther to a particular community than lower

salaried workers. As expected, the correlation between commute and income is positive for the downtown areas of San Francisco ( $r=0.28$ ) and San Jose ( $r=0.21$ ) and for the City of Oakland ( $r=0.08$ ). The magnitude of the correlations indicates that income has little explanatory power in predicting commutes. Although downtown workers' incomes do increase with increasing distance from their workplaces, there remains a great deal of unexplained variation of income over the entire commuting range.

While the three central cities all exhibit the expected positive correlation between commute distance and income, the pattern of relationships between income and commute

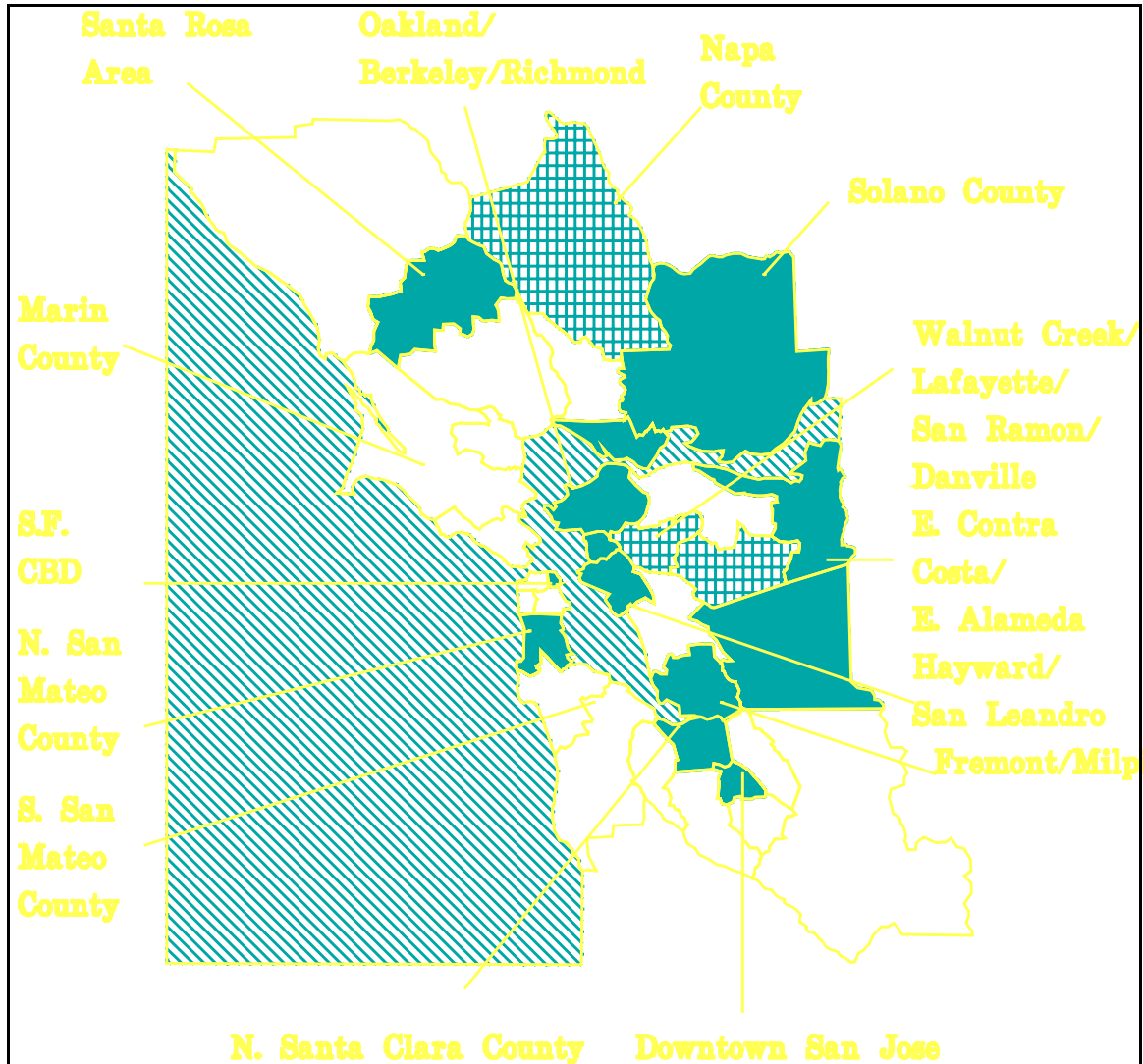


Figure 25: Correlations between Household Income and Primary Worker's Commute Distance, by Superdistrict of Employment, 1981 (85% confidence or greater)



**Table 6:** Mean 1980 Income, Selected Peripheral Communities (Source: Association of Bay Area Governments 1987)

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<u>Community</u>	<u>Mean 1980 Income</u>
RUSSIAN RIVER	\$25,117
COTATI	\$26,612
CLOVERDALE	\$27,209
PITTSBURG	\$27,651
SEBASTOPOL	\$28,674
RURAL SONOMA VALLEY	\$29,177
SONOMA	\$29,258
HEALDSBURG	\$29,749
RURAL ROHNERT PARK	\$29,899
ROHNERT PARK	\$29,971
RIO VISTA	\$30,346
SUISUN CITY	\$30,526
SANTA ROSA	\$30,771
RURAL NORTH EAST	\$31,384
FAIRFIELD	\$31,384
DIXON	\$31,633
BRENTWOOD	\$31,649
COASTAL-GUALALA	\$31,692
RURAL HEALDSBURG	\$32,193
RURAL EAST CONTRA COSTA	\$32,277
ANTIOCH	\$32,376
PETALUMA	\$32,483
RURAL SEBASTOPOL	\$32,664
VACAVILLE	\$32,801
REGIONWIDE AVERAGE	\$35,720
RURAL PETALUMA	\$35,898
RURAL SANTA ROSA	\$36,137
LIVERMORE	\$37,771
PLEASANTON	\$43,738

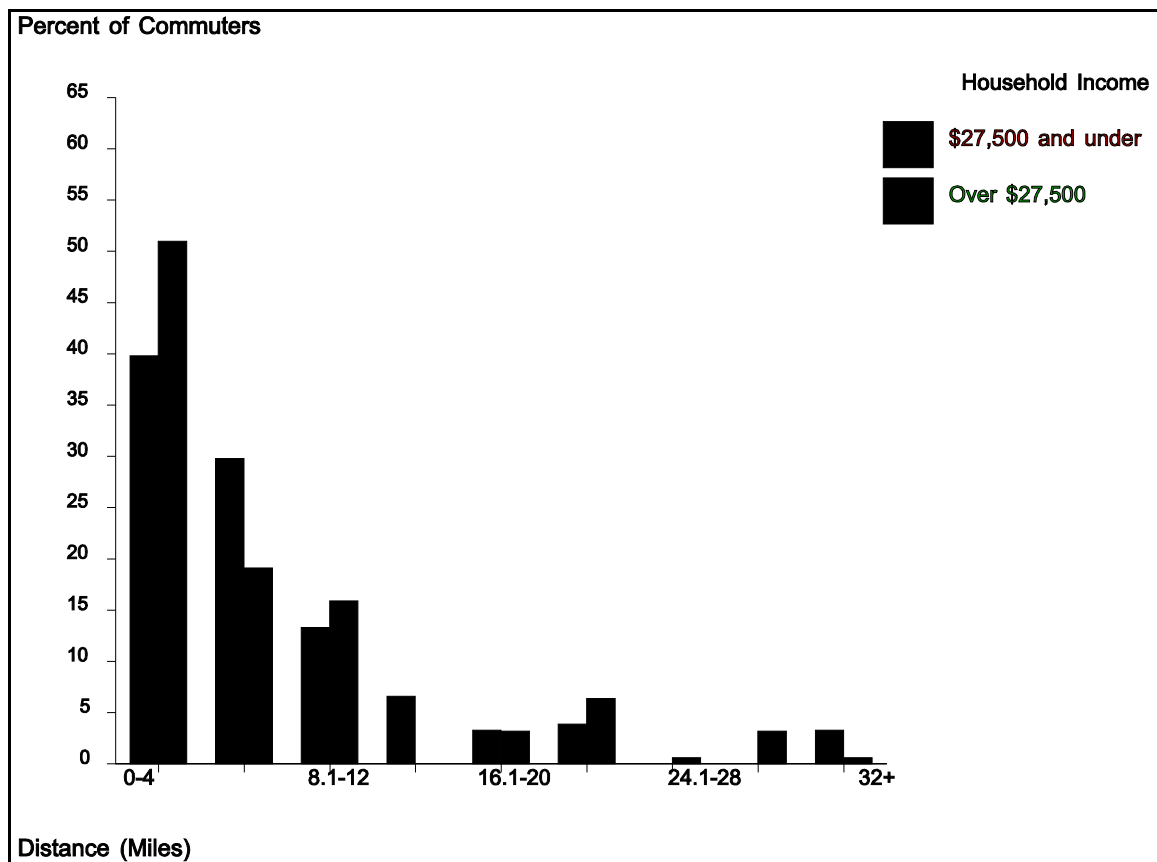
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varies more widely in suburban and exurban areas. First, a positive relationship between commute and income (i.e., higher income workers journeying farther to work) appears at the edges of the area as well as the center; eastern Alameda County, eastern Solano County and northern Sonoma County all exhibit a center-city like positive association between commute and income. This appears to be related to a more rural than suburban pattern wherein upper income workers commute to jobs at the urban fringe from well developed suburbs that offer high levels of urban amenities. Lower paid workers may tend to live and work in the smaller towns at the metropolitan periphery (6).

Within the Bay Area's inner ring, most suburban superdistricts exhibited independence between household incomes and commute distances. Exceptions to this were found in the same areas that exhibited longer than typical suburban commutes: Richmond area ( $r=0.27$ ), northern San Mateo County ( $r=0.25$ ), and northern Santa Clara County ( $r=0.09$ ). As discussed in Chapter III, the latter two match the "high density center" typology; hence, the positive correlations would be in accord with predictions. Employment and housing stock densities in Richmond are lower; it does not match the "high density center" typology

as well as San Mateo or Santa Clara Counties. The reason for the positive association between commute distance and income found among its workers may be found partly in the extent of environmental externalities associated with refining and other heavy industry in Richmond; these environmental effects would spur some upper income households to longer commutes (Guest and Cluett 1976).

In contrast, in two of the Bay Area's suburban superdistricts, higher income workers lived closer to their workplaces than those from lower income households. These areas included the 680 corridor communities of Walnut Creek and Lafayette ( $r=-0.18$ ) and Danville and San Ramon



**Figure 26: Commute Distance Distribution by Household Income Group, Walnut Creek-Lafayette and San Ramon-Danville Superdistricts, 1981**

( $r=-0.29$ ). Notwithstanding the low explanatory power of household income as a predictor of commute distance, a frequency distribution of the 66 households surveyed in those two superdistricts reveals a distinct pattern of commutes by income (26); the higher income group lives with a much greater frequency within four miles of work than the lower income group (51 versus 39.8 percent). The 680 corridor appears to be a promising locale for further investigation of emerging suburban commute patterns in which lower salaried workers may journey far in search of

affordable housing. Nonetheless, the positive relationship between income and commute distance in the northern end of the corridor does not support the hypothesis of independence or positive association between commute distances and income in areas with high multifamily housing stock.

The second assumption of the advocates of large scale employment suburbanization -- that of a beneficial effect for all income classes -- is not confirmed for the Bay Area as a whole. A positive relationship between income and commutes held weakly in 1981 for all workers in all three Bay Area central cities, as well as its industrial suburbs, including the "Silicon Valley." Most other suburbs exhibit no significant relationship, with the notable exception of the 680 corridor communities of Walnut Creek, Lafayette, San Ramon and Danville to which lower income workers journeyed farther to work than higher paid workers. Further investigation of this area is required to determine if the patterns detected there for 1981 remain.

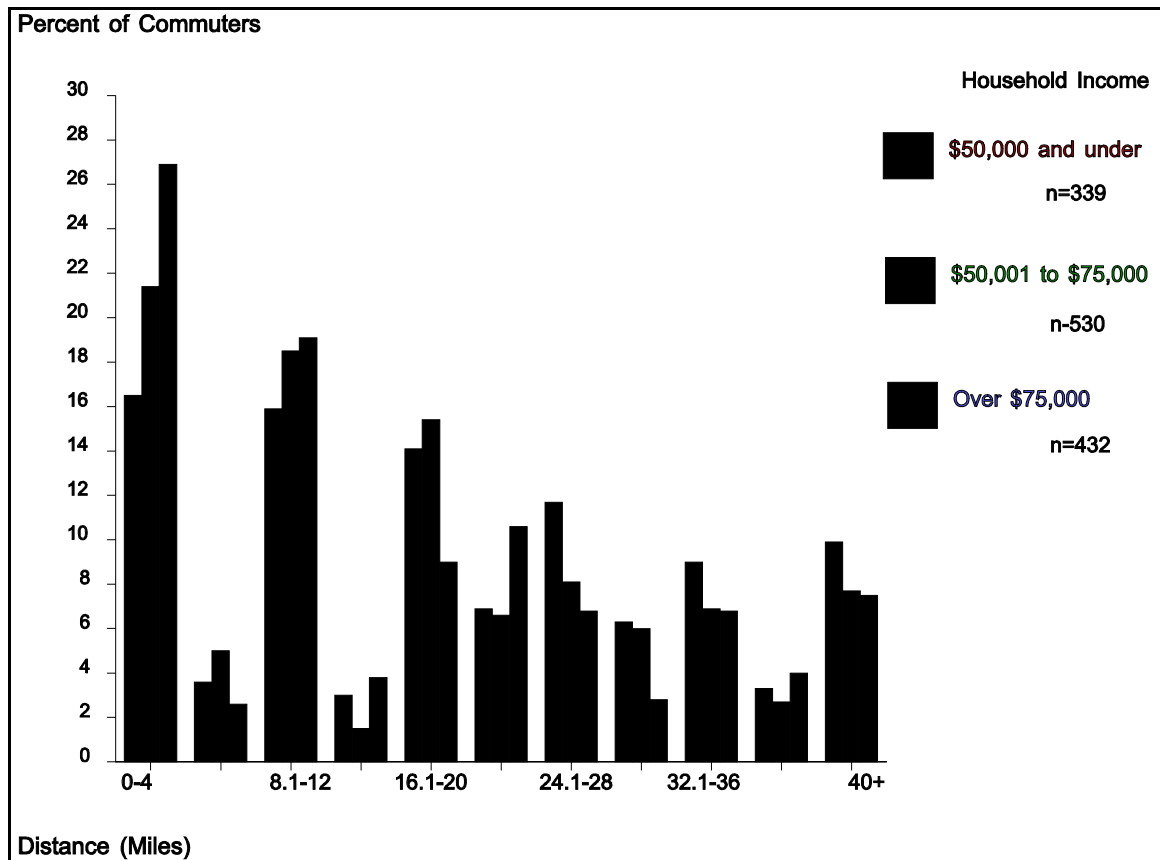
#### **Commute Patterns by Location: 1989**

No direct comparisons are possible between data emanating from the 1981 BATS data and the 1989 workplace survey. The first reason is geographic coverage; whereas the 1981 study included data from all Bay Area counties, the

1989 data is from six communities only. In addition, the 1989 data were generated from workplace surveys of selected employers, in contrast to the more inclusive 1981 home-based survey methodology. On the other hand, the larger sample size within communities surveyed in 1989 allows a more detailed analysis of commute patterns by income.

#### Income and Commute Distance

Despite the incompatibilities of the sources, data from 1989 revealed similar patterns to those found for 1981. The correlation between income and commute remained positive and significant for the San Ramon workers, though once again without much explanatory power ( $r=0.11$ ) due to a high variance of commute times at all income levels.



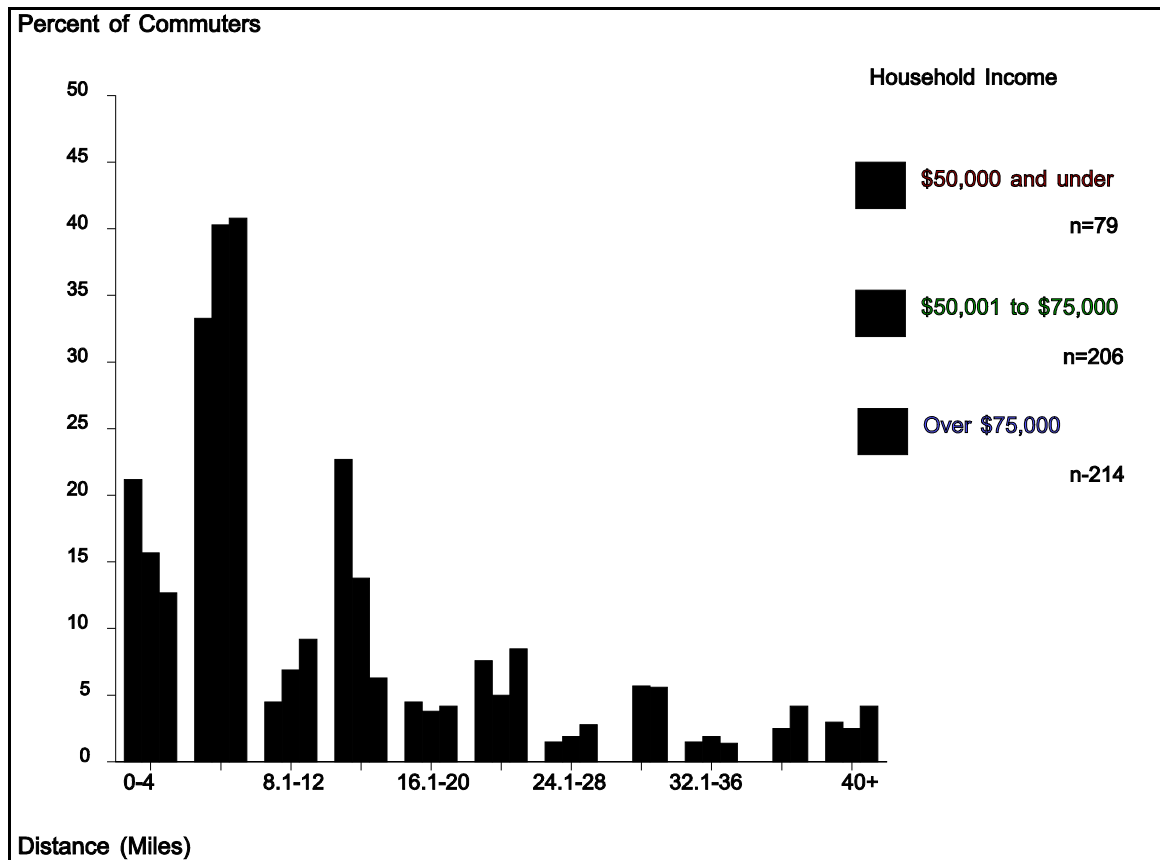
**Figure 27: Commute Distance Distribution by Household Income Group, San Ramon Workers, 1989**

Despite the low explanatory power of income on commute distance, a commute distribution histogram (27) reveals a clear pattern of commutes by income. Among the highest earning households (above \$75,000 in annual household income), 26.9 percent lived within four miles of their San Ramon workplace, while only 16.5 percent of those households earning up to \$50,000 lived within so close a commuting range. The opposite pattern emerges when one considers the longest commutes of 40 miles or more; 9.9 percent of the lower income households commuted this distance, while only

7.5 percent of their higher income counterparts accepted such a long commute to San Ramon. In fact for all the distance categories up to 24 miles from San Ramon, the lower income households were outnumbered (in percentage terms) by their middle income or higher income counterparts. In each of the distance categories beyond 24 miles from San Ramon, the lower income households proportionately outnumbered both those in the middle income and upper income categories.

Commute patterns broken down by income group are less regular for workers at the sites studied in northern Santa Clara County. No significant correlations were found at any of the sites between income and distance commuted. Neither was any significant correlation found for workers from all the sites pooled. The lack of relationship may also be seen in the distribution of commutes by income (28). While the lowest income category appears to locate within four miles of work with greater frequency than others, the pattern at greater distances appears much more random, with no particular trend emerging throughout the entire commute shed. The expectation of independence between household income and commute distance for areas of dense housing appears to be supported for the Santa Clara County sample.





**Figure 28: Commute Distance Distribution by Household Income Groups, Santa Clara County Workers, 1989**

The commutes to the two San Francisco sites retained the classic center city pattern, with lower income residents tending to live closer to work than higher salaried employees. The relationship was weak, with a positive correlation of 0.09 between distance and income, significant with 85 percent confidence only.

### Relocation and Commute Distance

Regardless of income, commute distances differed markedly between the San Ramon workers and those in northern

**Table 7:** Median Commute Distance by Subgroups, San Ramon and Northern Santa Clara County, 1989

<u>Subgroup:</u>	<u>San Ramon</u>	<u>Northern Santa Clara County</u>
Overall	17.3 mi.	6.8 mi.
Household Income up to \$50,000	17.3 mi. n=339	6.8 mi. n=79
Household Income \$50,001 to \$75,000	17.3 mi. n=530	6.6 mi. n=206
Household Income above \$75,000	12.6 mi. n=432	6.8 mi. n=214
Last move 1986 or later	10.1 mi. n=599	6.8 mi n=160
Last move 1985 or earlier	17.3 mi. n=493	6.3 mi n=204

Santa Clara County. For the sample as a whole and for all subgroups analyzed, San Ramon commutes were nearly double the distance of Santa Clara County commutes, or even greater in some cases (6). This is due to a great degree to the newness of the San Ramon employment centers and the fact that they recently relocated; many employees continue to

live in more central Bay Area locations. This can be seen by the sharp difference between the commute distance of those San Ramon commuters who changed addresses in 1986 or later versus those who have remained in place since 1985; the movers save approximately 7.2 miles compared to households staying in place. If the trend towards moving closer to San Ramon continues, the unusually long commute distances reported in 6 will surely decline. Yet even among those households relocating since 1986 the median commute distance of 10.1 miles remains long for a suburban commute.

**Table 8:** Median Commute Distance of San Ramon Workers by Income Group and Housing Tenure

<u>Subgroup:</u>	Households in Place Since <u>1985</u>	Households Moving Since <u>1986</u>
Household Income up to \$50,000	23.1 mi. n=98	16.7 mi. n=113
Household Income \$50,001 to \$75,000	17.3 mi. n=197	9.6 mi. n=212
Household Income above \$75,000	17.3 mi. n=191	10.1 mi. n=183

The option of relocating closer to San Ramon appears to offer the lower income households scant opportunity to equalize their commutes with upper income households. Quite the opposite is true; the difference in commute distance between those earning above \$75,000 and those earning up to

\$50,000 is greater among households moving since 1986 than for the sample as a whole (8).

#### **Summary of Chapter IV**

The hypothesis that employment suburbanization benefits overall metropolitan accessibility is based on two premises:

1) Commutes to suburban workplaces are shorter than those to center city; 2) Employment suburbanization benefits all income classes. The first premise is supported by the 1981 data set, though commutes of near center-city lengths were observed in some suburban areas.

The premise of commute benefits accruing to all income classes seems to be valid in some areas and incorrect in others. Some industrial suburbs (including the Silicon Valley) exhibited a weak positive relationship between income and commute distance in 1981. Communities in the 680 corridor exhibited the opposite relationship, with lower income workers commuting farther to work than their higher income counterparts.

Similar analyses were performed on results from the 1989 survey, though a demonstrated bias toward upper income households in this survey requires that the results be interpreted with caution. Among the sample respondents, commute distances of San Ramon employees were negatively

associated with household income (similarly to the finding for 1981). No significant relationship between income and commute distance was found for workers in northern Santa Clara County. San Ramon commute distances were unusually long, though much of this was attributed to the newness of the employment center and the fact that the two firms had relocated there. Nevertheless, even commute distances of San Ramon workers who had changed addresses within the past several years remained much longer than those in northern Santa Clara County. Moreover, the relative inequality of commutes between higher and lower paid San Ramon workers was greater when only the recent movers were considered.

The expectation of a negative relationship between income and commute in employment centers with low residential density appears to be supported for San Ramon. The expectation of independence between income and commute distance for high residential density employment centers appears to be supported for northern Santa Clara County communities studied. Commute patterns in some areas did not match expectations; for example, household incomes and commute distances were negatively related for Walnut Creek area employees, despite a high proportion of multifamily housing within the City of Walnut Creek. Further analysis of the hypotheses regarding the influence of housing stock

on commute patterns require the construction of models to separate the impact of housing stock characteristics on residential location decisions.

## **Chapter V:**

### Modeling Framework and Results

This chapter describes methods used in and results of the nested multinomial logit modeling for workers in San Ramon and Santa Clara County. The models are designed to test the hypothesis that the availability of multifamily housing in a suburban community increases the chances of a low to moderate income household selecting that community. By extension, the models can also shed light on the hypotheses of multifamily housing in a suburban employment center being associated with shorter commutes by low to moderate income households.

It should be emphasized that the starting point for the modeling is the place of work; thus the "San Ramon model" refers not to a model of San Ramon residents but San Ramon workers who may live virtually anywhere in the San Francisco Bay Area and beyond. These models take workplace as a given, and as such represent just one part of a three-sided system: the mutually influencing processes of employment location, job change and residential location.

Issues that need to be addressed in order to transform the discrete choice theory discussed in Chapter II to a workable empirical model include the definition of relevant

commute sheds; reduction of choice sets to achieve computational feasibility; grouping of communities into community types for nested multinomial logit analysis; and sampling and weighting. After a discussion of these issues, modeling results for San Ramon and Santa Clara County will be presented, together with initial interpretation of the results; more formal analysis of the models is presented in the following chapter. Finally the validity of the independence from irrelevant alternatives (IIA) assumption is tested for both models.

## **Methods and Procedures**

### Identification of Choice Set Communities

The capacity of the multinomial logit model to analyze both characteristics of the individual and the community requires an explicit delineation of the set of communities from which the individual chooses. The feasible set of communities for all households in the sample was assumed to be those communities within a 60 minute driving radius of the workplace. Communities falling farther than 60 minutes away were not excluded for lack of observations; 6.7 percent of the San Ramon sample and 7.6 percent of the Santa Clara County sample lived in communities over 60 minutes'



driving distance from their workplace. Rather, the 60 minute radius was drawn in an attempt to include in the choice sets those communities that were the most relevant choices for the bulk of the sample. The number of excluded commuters was not great, and the 60 minute boundary was able to capture even most of the long distance commutes. This approach still defined a large number of communities within the choice sets for both the San Ramon and Santa Clara County workers. Several potential pitfalls are apparent when the number of communities in the choice set are so large. The first is the sheer size of the data set required. For example, the San Ramon data set includes 69 communities and 1475 individuals; generating a record for each accepted and rejected community for each individual would have yielded a data set of 101,775 records.

McFadden (1978) has shown that in those cases where the multinomial logit form is a valid model specification, unbiased parameter estimates may be obtained using a randomly selected subset of choice set elements, provided that if a rejected element is placed in a particular subset, it could logically have been the selected choice. This principle was utilized in order to reduce the choice sets to manageable proportions. For each individual, a random sample of thirty-five communities was selected from the

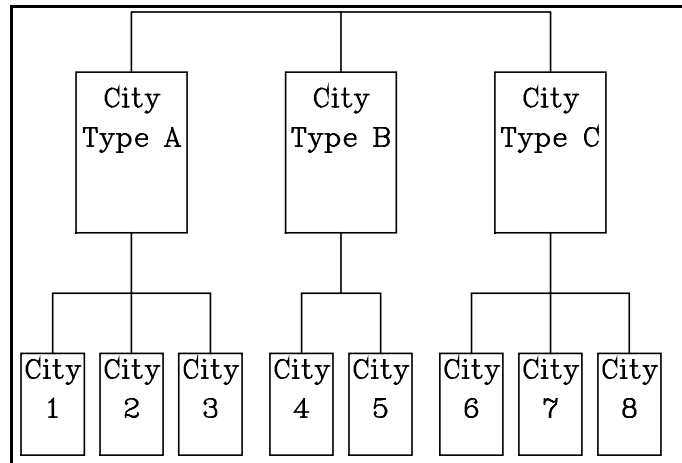
total choice set. The sample of communities faced by each individual was independent of those faced by others, and over all individuals the entire choice set was included. After the sampling of thirty five communities, the community actually chosen was added to the sample, and any duplicates were eliminated. Finally, communities beyond the 60 minute boundary were excluded from the choice sets, as well as individuals selecting these communities. The communities remaining after these eliminations were the ones from which utilities were estimated; the number of communities faced by any individual ranged from 12 to 28 in the San Ramon model ( $\mu=20.4$ ,  $\sigma=2.2$ ) and from 17 to 28 for the Santa Clara County workers ( $\mu=23.4$ ,  $\sigma=2.2$ ).

The second potential disadvantage of presuming a choice between such a large number of communities is that the independence from irrelevant alternatives assumption is likely to be violated; given the large number of communities involved, it is likely to assume that there exists a structure of perceived similarities in the unobserved attributes between communities that would have violated a central assumption of multinomial logit and biased parameter estimates. This problem was dealt with in both cases using the nested logit structure. A nested (as opposed to joint) structure was shown to be necessary given

the sets of communities involved, and tests for the validity of the IIA assumption on the nested models appeared to indicate that the nesting had in fact allowed the assumption to be fulfilled.

Development of Community  
Types for Primary Level  
Choice      Nested

structures are  
appropriate for  
controlling for the IIA  
assumption but have been  
little used due to



**Figure 29:** Diagram of Nested Structure of Communities within Community Clusters

practical difficulties in their estimation (Daly 1987).

This study employs a nested structure in which an initial selection of a general type of community is made, within which the individual community selection occurs (29). In that is models choice of a fine-grained geographic unit within a coarser aggregations of such units, it is similar in structure to Quigley's (1985) modeling of neighborhood choice within a selection of communities. Most other previous studies have not opted for this kind of structure.

For the most part this is because nested multinomial logit models in land use and transportation have concerned

themselves with a number of aspects in addition to location: mode choice, vehicle ownership, or characteristics of the housing unit being selected. As this study is concerned with the residential locational decision alone, it is able to focus more on the locational choice and test the validity of modeling locational decisions in a joint versus nested structure. As will be demonstrated by the empirical results for both the San Ramon and the Santa Clara County models, a nested model is in fact necessary to account for the structure of similarities between communities.

A model based on a behavioral interpretation should define the most fundamental decision as the top level nest.

A household's preferences regarding commute distance, safety or school quality must necessarily be expressed within the group of affordable communities, for all but the wealthiest households in the region. Thus a scheme was sought by which the primary level nest centered on affordability, with the lower level nest centering on preference issues was sought<sup>12</sup>.

Clearly a component of affordability is housing price.

As discussed in Chapter III, the two measures considered as

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<sup>12</sup>Communities are clustered in order to satisfy the assumptions of the multinomial logit model, not to match the classification of suburban employment centers discussed in Chapter I.

a measure of housing price were median price per home and median price per square foot. Of the two, median price per home was used in the primary level decision, because it was assumed that for the household purchasing a home, the total price constitutes the primary constraint. Within the group of communities that offer houses of a given price, the household may then choose between communities that offer smaller homes at a higher cost per square foot (presumably offering greater access or community amenities) or larger homes at a lower cost per square foot. This latter aspect of the decision was deemed to be primarily an expression of the household's preference for house size versus other locational attributes, and as such belonged in a lower level of the decision tree. Thus median price per house served as a stratifying variable for the upper level nest, whereas price per square foot remained as a right hand side variable in the lower level nest.

Price alone does not adequately measure affordability.

For example, under the classic monocentric model of urban areas the lowest income residents live on the highest priced land in the center of the metropolitan area. Affordability in these instances is achieved through high density of residential development. Thus if the goal of the stratification in the upper level nest is to capture the

concept of affordability, it must operate on the dimensions of price and density simultaneously. Accordingly, communities within the San Ramon choice set were stratified into six groups based on: 1) three groups of median home price designed to divide the choice set into thirds (\$227,000 and under, \$227,001 to \$307,000, and over \$307,000); and 2) two groups of multifamily housing stock, designed to divide the choice set into halves (33 percent and under, and over 33 percent). For the San Ramon model, groups were defined as described in Table 9.

**Table 9:** Grouping of Communities for Nested Analysis,  
Choice Set for San Ramon Workers

Median Home Price	Percent of Housing Stock in Multifamily	
	<u>33 percent and under</u>	<u>Over 33 percent</u>
\$227000 and under	Antioch	Concord
	Benecia	Fairfield
	Brentwood	Hayward
	El Sobrante	Pleasant Hill
	Livermore	Richmond
	Manteca	San Leandro
	Martinez	San Pablo
	Newark	SJ: Alum Rock
	Oakley	SJ: Downtown
	Petaluma	Union City
	Pinole	
	Pittsburg	
	San Lorenzo	
	Suisun	
	Tracy	
	Vacaville	
	Vallejo	
	Median Price=\$154000	Med. Price=\$182000
	Median percent	Median Percent
	multifamily=26.5	multifamily=39.0
\$227,001- \$307,000	Castro Valley	Alameda
	Dublin	Albany
	El Cerrito	Berkeley
	Fremont	Campbell
	Half Moon Bay	Colma
	Kensington	Daly City
	Milpitas	Hercules
	Pleasanton	Oakland
	San Ramon	Santa Clara
	SJ: Berryessa	SJ: Evergreen
	SJ: Cambrian/Blossom Hl.	S San Francisco
	SJ: Zipcode 95125	Walnut Creek
	Median price=\$251000	Med. Price=\$253000
	Median percent	Median percent

Table 9, continued

Median Home Price	Percent of Housing Stock in Multifamily	
	<u>33 percent and under</u>	<u>Over 33 percent</u>
Over \$307,000	Alamo Danville Lafayette Los Altos Orinda Piedmont San Carlos Saratoga	Belmont Cupertino Foster City Los Gatos Moraga Mountain View San Francisco San Mateo SJ: Westgate Sunnyvale
	Median Price=\$417000 Median Percent multifamily=12.0	Median Price=\$340000 Median Percent multifamily=50.0

Communities within the choice set for the Santa Clara County workers were grouped in a similar fashion. However communities falling within a 60 minute drive of Cupertino, Sunnyvale, Santa Clara, Mountain View or the northern part of San Jose are generally more expensive and denser than those within San Ramon's commute shed. Accordingly the boundaries between groups were adjusted upward in both dimensions in order to produce six community clusters of approximately equal size. The choice set for the Santa Clara County workers is described in 10.



### Sample Weighting

Because of the nature of the employee survey (Chapter III) Sun Microsystems of Mountain View, Tandem Computers of Cupertino, and Pacific Bell of San Ramon were over-sampled

**Table 10:** Grouping of Communities for Nested Analysis, Choice Set for Santa Clara Workers

Median Home Price	Percent of Housing Stock in Multifamily	
<u>Price</u>	<u>36 percent and under</u>	<u>Over 36 percent</u>
\$235,000 and under	Dublin Livermore Newark San Lorenzo SJ: Alum Rock SJ: Evergreen Median price=\$213000 Median percent multifamily: 24.5	Gilroy Hayward San Leandro Santa Cruz SJ: Downtown Union City Med. price=\$193000 Median percent multifamily=41.0
\$235,000 to \$315,000	Castro Valley Colma Fremont Half Moon Bay Milpitas Pacifica Pleasanton San Ramon SJ: Berryessa SJ: Cambrian/Blossom Hill SJ: Zip Code 95125 Median price=\$255000 Median percent	Campbell Daly City Oakland Redwood City San Bruno Santa Clara SJ: Westgate S San Francisco Med. price=\$270000 Median percent
Over \$315000	Alamo Danville Hillsborough Los Altos Millbrae Piedmont San Carlos Saratoga SJ: Almaden 138 Median price=\$438000 Median percent	Belmont Burlingame Cupertino Foster City Los Gatos Menlo Park Morgan Hill Mountain View Palo Alto San Francisco San Mateo Sunnyvale Med. price=\$368000 Median percent

relative to other firms in the areas under study. For samples such as these, the weighted exogenous sample maximum likelihood (WEMSL) estimator may be used to derive consistent parameter estimates (Ben Akiva and Lerman 1985).

The estimator is derived by assigning each observation a weight equal to the ratio of its group's proportion in the population of all employees of sampled firms to the group's proportion in the sample. Weights were computed as in 10.

#### Variable Definition

This section defines variables used in the nested multinomial logit models. Some of the variables are used in both models, others in one alone. Variables that were tested but not included in the models for lack of

**Table 11:** Derivation of Sample Weights by Firm, 1989  
Sample

##### 1. San Ramon Sample

	<u>Firm</u>	
	Pacific Bell	Chevron
Population Proportion	0.64	0.36
Sample Proportion	0.75	0.25
Weighting Factor	0.86	1.40

##### 2. Santa Clara County Sample

	General Electric	Sun	Tandem Cupertino	Tandem Sunnyvale	Tandem Santa Clara
Population proportion	0.19	0.39	0.37	0.02	0.03
Sample proportion	0.33	0.34	0.22	0.05	0.06
Weighting Factor	0.56	1.39	1.68	0.41	0.59

statistical significance are also presented here. With the exception of a dummy variable representing a center city location, no alternative specific variables were used.

#### Access Variables

HTIME      Peak hour automobile travel time from accepted or rejected place of residence to place of work of the highest wage earner in the household. (In case of ties the household member responding to the survey was assigned the HTIME position).

LTIME      Peak hour automobile travel time from accepted or rejected place of residence to place of work of the second wage earner in the household.

#### Affordability Variables

\$SQFT/INC      Median 1989 price per square foot of single family homes in a community divided by total annual household salary (in thousands).

\$MED/INC      Median home price for all communities within a cluster divided by household income.

%MULT      Proportion of housing stock in a community in non-

single family homes. This includes duplexes, apartment, condominiums and mobile homes.

%MULT:LO Equal to %MULT for households with total income up to \$50,000, 0 for other households. This variable is designed to measure the utility of multifamily housing for lowest segment<sup>13</sup> of the sample in terms of income.

%MULT:MED Equal to %MULT for households between \$50,000 and \$74,999, 0 for other households. This variable is designed to measure the utility of multifamily housing for middle segment of the sample in terms of income.

%MULT:HI Equal to %MULT for households with total income of \$75,000 or more, 0 for other households. This variable is designed to measure the utility of multifamily housing for highest segment of the sample in terms of income.

TENURE/\$ For homeowners, equal to the number of years of residence at their current address divided by

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<sup>13</sup>The boundaries between low, medium and high income groups were set principally to ensure sufficient sample sizes in the low income group.

community median home price. The variable is equal to 0 for renters.

#### Community Service and Amenity Variables

SCHOOL Aggregated test results from California Assessment Program standardized testing for 1989. SCHOOL was the median of six scores: statewide percentile rankings for third, eighth and twelfth grades in reading and mathematics.

CRIME Residential and commercial burglaries per capita, 1989.

MFCHILD Equal to %MULT for households with children present, 0 for other households. This variable is designed to measure any disutility of multifamily housing in a community to household with children.

CENTER- A center-city dummy variable, equalling 1 for San  
DUMMY Francisco and Oakland and 0 for all other cases.

#### Variable Specific to Nested Logit

LOGSUM A variable used in the nested logit model, equal to:

n

$$\log \sum_{i=1} \text{EXP} ( \beta' x_{ij} )$$

where  $i$  is an index of communities within each lower level nest and  $\beta'$  is the vector of estimated parameters, and  $x_{ij}$  are the observed characteristics of the communities (or the interaction of the individual and the communities, as in the case of house price divided by income).

### **Predicted Relationships**

Most of the independent variables are expected to affect the model in a straightforward fashion. One can expect the utility of HTIME to be negative; communities falling a longer commute away from work are, all else being equal, less desirable than closer in communities. A significant negative sign on HTIME would tend to support the importance of workplace access in the residential decision.

SCHOOL is expected to have a positive coefficient for households with children; for these households school quality is a attractor. SCHOOL also may be positive for households with grown children. Those households may have originally chosen a community based in part on school quality; to the extent that school districts' relative

rankings are constant over time, the positive utility of SCHOOL would still be perceptible. In addition, SCHOOL may capture an element of the social environment of the community that can attract or repel even childless households.

The other measure of municipal service quality, CRIME, may be expected to carry a negative utility.

MED\$/INC, the ratio of price to total salary, is expected to have a negative utility. Controlling for other aspects such as municipal service quality and accessibility, households are expected to prefer communities that require a smaller portion of their annual income over those that require a larger share.

Because Bay Area housing prices increased rapidly in real terms over the late 1970's and the 1980's, many current Bay Area homeowners find themselves living in homes they would be hard pressed to purchase at current prices. TENURE/\$ is designed to capture this effect, and is expected to carry a positive utility. In an inflating housing market, length of tenure is expected to be associated with residence in communities of higher current value.

Two variables may enter the model in a somewhat less straightforward fashion. CENTERDUMMY, the central city dummy variable, is designed to account for the problem that

the majority of communities in the choice set are suburban to a greater or lesser extent. It is assumed that living in a central city, one encounters opportunities and incurs costs that may not be adequately captured by the variables representing distance, municipal service quality, density and access. Certainly the concept of accessibility is ill-captured by HTIME for center city residents, since their urban residence affords them accessibility to many nonwork travel opportunities. As Lerman (1975) pointed out in a locational choice model for the Washington D.C. area, upper income residents of the District of Columbia tend to send their children to private schools; public school quality would not be a factor influencing residential choice of these people. Urban disamenities exist as well: a fear of crime that may well exceed that which is capturable in the CRIME variable, deteriorated housing or overcrowding. Thus it is difficult to predict the direction of the CENTERDUMMY variable a priori, only that it may be needed to account for urban uniqueness in a largely suburban commuter shed.

The second variable whose effect needs to be carefully interpreted is LDIST, the accessibility variable for the secondary wage earner in the household. The difficulty arises due to the direction of causation between the location of the secondary wage earner and the household's



residential location. For example consider a household residing in a community a half hour's commute from one worker's place of work, but only 5 minutes away from the other. Assume further that the closer job is considerably lower paid than the more remote employment. Did the household locate close to the job, or did the secondary worker seek a workplace close to home?

At first gloss the question may seem answerable by analyzing the dates of the last move and the starting dates at work for each of the workers of the household. But in fact the analysis may be even more complex. If the primary worker changes jobs to an even more remote location, all else being equal, the household may prefer to move. But the secondary worker's job (initially chosen for its proximity to home) may have become a sufficient draw to prevent the household from moving and thus may have lead to a new locational decision -- a decision not to move -- that generates an even longer commute for the primary worker.

Lerman (1975) details four alternative causal mechanisms in the locational decisions of multiworker households;

- "1. Complete primary worker dominance;
2. A primary worker with the remaining workers secondary (i.e. without fixed workplace) in the location decision;

3. Some or all workers with fixed workplaces but each with different weights;
4. Complete equality in the perception of work trip attributes."

The initial working assumption of this study was that the geographic "draw" of the secondary worker was proportional to the ratio of the salaries of the two household workers. Thus when the salaries of both workers in a household were equal, the variables LTIME and HTIME would enter the equation with equal weights, and when LSALARY was half HSALARY, LTIME would enter with a weight of 0.5. The assumption behind this hypothesis is that higher income employment represents more specialized and hence less interchangeable employment; thus the higher the income of the secondary worker, the less able that worker would be to change workplaces in response to a household move. This hypothesis will be explored later in this chapter.

%MULT:LO, %MULT:MED and %MULT:HI test the utility of multifamily housing in a community to the lowest, middle and highest segments of the sample in terms of income. %MULT:LO is expected to carry a positive utility, as the presence of multifamily housing may render a high priced community affordable. To the extent that higher income families prefer and can afford less dense communities, the coefficient of %MULT:HI is expected to be negative; %MULT:MED should be somewhere in the middle.

**Table 12:** Expected Signs of Variable Coefficients

	<u>Variable</u>	<u>Expected Sign</u>
MFCHILD, the proportion of multifamily housing in a community for households with children, is designed to test the hypothesis that non-single family housing carries a negative utility for these households, and would be expected to be nonpositive.	HTIME	-
	LTIME	-
	SCHOOL	+
	CRIME	-
	MED\$/INC	-
	TENURE/\$	+
	CENTERDUMMY	?
	%MULT:LO	+
	%MULT:MED	?
	%MULT:HI	-
	MFCHILD	0 OR -

### Alternative Models

Nested multinomial logit models were estimated using the LIMDEP statistical package compiled on the

Berkeley Cray X-MP/14 under unconstrained maximum likelihood sequential estimation. For each model the following

statistics are presented:

1. Asymptotic t-statistics for each estimated parameter. As in multiple regression, the t-statistics represent equal the value of the estimated parameter divided by its standard error and provide a test of  $H_0: \beta=0$ .

2.  $L^*(0)$ , the value of the log likelihood function when all parameters are initially set at zero. Under this base case, all residential communities are equally likely choices; this is a "no information" model. This provides a base case from which improvements from parameter estimation may be measured.

3.  $L^*(\beta)$ , the value of the log likelihood function when parameters are set at their maximum likelihood value. The closer this negative number is to zero (relative to the  $L^*(0)$  starting point) the more explanatory value in the model.

4.  $\rho^2$ , equal to  $1-[L^*(\beta')/L^*(0)]$ . This measure, analogous to  $R^2$  in multiple regression, measures the degree of increase in the likelihood function when estimated parameters are used (and hence the explanatory power of the model) and varies between 0 (no explanatory power) and 1 (complete explanatory power).

5.  $\rho(\text{bar})^2$ , equal to  $1-[(L^*(\beta')-K)/L^*(0)]$  where K equals the number of independent variables. This measure of explanatory power is designed to compensate for the loss of degrees of freedom caused by the inclusion of additional variables; unlike  $\rho^2$  it can decline with the addition of a variable if the additional explanatory power is low.

The initial specification for both the San Ramon and northern Santa Clara County workers utilized the full set of variables listed above (Table 13). The majority of the variables in these full specifications (San Ramon Model 1,

Santa Clara Model 1) emerged with statistical significance and the predicted sign. Several exceptions are noteworthy, however.

**Table 13:** Alternative Nested Logit Model Specifications

Variable	S a n Model 1	R a m o n Model 2	S a n t a Model 1	C l a r a Model 2
<u>Lower level nest (community choice) variables (t-statistics)</u>				
HTIME	-0.0672 (-13.8)	-0.0754 (-17.0)	-0.0687 (-12.5)	-0.0725 (-14.3)
LTIME	-0.0631 (-13.3)		-0.0497 (-7.95)	
\$SQFT/INC	-0.6847 (-5.68)	-0.524 (-5.1)	-0.5073 (-2.88)	-.5605 (-3.59)
%MULT:LO	3.38540 (3.230)	2.9235 (2.93)	4.2524 (2.089)	
%MULT:MED	not es- timable		-0.6612 (-0.46)	
%MULT:HI	2.0393 (1.80)		-0.5383 (-0.39)	
CENTERDUMMY	2.0813 (7.31)	2.1344 (8.55)	3.7664 (5.623)	4.1276 (8.07)
SCHOOL	0.0102 (2.34)	0.0100 (2.71)	0.02547 (4.255)	0.0266 (4.69)
MFCHILD	0.5729 (0.44)		-4.5821 (-2.70)	-4.941 (-3.7)
TENURE/\$	-0.253 (-0.3)		2.5153 (0.528)	
CRIME	-13.73 (-1.2)		-1.069 (-0.05)	
<u>Model statistics: Lower level nest</u>				
L*(0):	-1494.1	-1494.1	-570.6	-570.6
L*( $\beta'$ ):	-898.26	-1024.5	-364.5	-406.6
rho <sup>2</sup> :	0.3988	0.3143	0.3612	0.2874
rho(bar) <sup>2</sup> :	0.3914	0.3110	0.3520	0.2787
<u>Upper level nest (choice of community clusters) variables</u>				
\$MED/INC	-0.100 (-3.9)		0.0840 (3.13)	
LOGSUM	0.5988 (17.2)	0.8417 (16.9)	0.3258 (7.38)	0.3398 (7.16)
<u>Model Statistics: Upper level nest</u>				
L*(0):	-1167.0	-1167.0	-536.0	-536.0
L*( $\beta'$ ):	-939.81	-965.98	-495.3	-505.7
rho <sup>2</sup> :	0.1947	0.1723	0.0759	0.0565
rho(bar) <sup>2</sup> :	0.1927	0.1714	0.0722	0.0547
<u>Summary statistics for both levels</u>				
L*(0):	-2661.1	-2661.1	-1106.6	-1106.6
L*( $\beta'$ ):	-1838.1	-1990.5	-859.79	-912.3

rho <sup>2</sup> :	0.3093	0.2520	0.2230	0.1756
rho(bar) <sup>2</sup> :	0.3044	0.2497	0.2113	0.1702
No. of Observ.	1,475	1,475	480	480

Of the two variables measuring local service quality, only one -- SCHOOL -- emerged as statistically significant.

CRIME carried the expected negative sign but was not significant and was hence dropped from the equation. Two possible explanations may exist for CRIME's lack of explanatory power. First, perhaps the definition of the variable -- residential and commercial burglaries per capita -- inadequately captured people's perceptions of criminal activity. It may be that higher visibility crimes of violence are more of a repelling factor than less traumatic, if commoner crimes such as burglary.

The second reason that CRIME failed to emerge statistically significant may be that there is little perception of difference in crime rates between communities in the largely suburban choice set. To be sure those differences exist, but may be below the threshold of effect on residential location decisions (Harvey 1988 found this for Santa Clara County). Sharper differences are likely perceived between city and suburb, but the CENTERDUMMY variable would have accounted for much of these.

The coefficient TENURE/\$, or years of tenure in current home (for owners) divided by current median housing prices, was not statistically discernable from zero in either the Santa Clara or the San Ramon case. This may be due to the

fact that tenure is being called upon to serve as a proxy for equity, a task it fulfills only incompletely<sup>14</sup>.

Households having recently moved after a long period of residence in a previous home would have a low value for tenure, yet may have amassed sufficient equity in their prior residence to purchase housing apparently beyond that which their current income would support. The insignificant negative coefficient of TENURE/\$ for the San Ramon residents is probably due to the relative newness of the San Ramon firms; the large number of households relocating to a high priced community such as San Ramon may have masked the expected effect of tenure on residential choice.

MFCHILD carried the expected negative sign for the Santa Clara County model, but was insignificantly positive for the San Ramon workers, and was dropped in later model versions. Possible explanations for the lack of significance of the variable in the San Ramon model are discussed later in this chapter.

The coefficient of %MULT:HI was negative as expected in the Santa Clara model, though without statistical significance. Contrary to expectations, the coefficient was positive in the San Ramon model and was dropped in later

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<sup>14</sup>Harvey (1988) used data on income, housing cost and tenure together in a single variable estimating current income remaining after housing costs, based on tenure.



models. The San Ramon model was not estimable when the %MULT:MED variable was included.

San Ramon Model 2 and Santa Clara Model 2 were designed to determine how LTIME was to enter the final models. The initial hypothesis of a geographic draw of the secondary worker proportional to the ratio of the two salaries was tested as follows: A subsample including only those families with more than one full time wage earner was generated, and divided into four groups (three for Santa Clara County because of a smaller sample) based on the ratio of the salaries of the two wage earners. In order to determine the relative influence of the secondary wage earner, models were estimated for these groups according to the specification of San Ramon Model 2 and Santa Clara Model 2, purposely excluding the commute of the lower wage earner.

If the hypothesis of a relative influence proportional to the ratio of the salaries were true, the ability of the models to explain residential choices should decline as the ratio approaches unity. That is, the absence of the information that has been deliberately excluded from the analysis -- the commute time of the secondary worker -- should be felt more and more acutely as the salary of the secondary wage earner increases.

**Table 14:** Rho-squared Statistics for Models Calibrated on Multiworker Subsamples, by LSALARY to HSALARY Ratio

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1. San Ramon Workers		
<u>LSALARY To HSALARY Ratio</u> <u>Statistic</u>	<u>Rho-Squared</u>	<u>n</u>
0.90 - 1.00	0.251	183
0.75 - 0.89	0.276	139
0.50 - 0.74	0.170	172
Under 0.50	0.182	191
2. Santa Clara County Workers		
<u>LSALARY To HSALARY Ratio</u> <u>Statistic</u>	<u>Rho-Squared</u>	<u>n</u>
0.90 - 1.00	0.204	35
0.60 - 0.89	0.201	94
Under 0.60	0.279	105

---

The foregoing hypothesis does not appear to be confirmed by the results of these exploratory analyses, presented in 14. While a slight trend towards decreasing values of rho-squared (the multinomial logit analog of  $R^2$ ) may be evident among the Santa Clara County workers, the pattern in the San Ramon case appears to be opposite. In neither case does the relative influence of the secondary

wage earner on the household locational decision appear to be a clear function of the ratio of the salaries<sup>15</sup>.

The lack of a clear pattern relationship between either the ratio of the two household salaries and the influence of LTIME led to the variable being used in an untransformed fashion. Importantly, in neither model did the introduction of LTIME interfere with the direction or statistical significance of HTIME. This may serve as further evidence of the independent effect of LTIME on residential location decisions (as opposed to the alternative explanation of secondary workers' locations being primarily determined by their household location).

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<sup>15</sup>There may be several explanations for this. First, the secondary worker in a higher income household may have easier access to a better quality automobile and may thus be more mobile, and have a lower disutility of travel, than counterparts in lower income household. Second, it may be that the availability, quality and hours of childcare is a major determinant of a working parent's mobility. Thus a working parent who has reliable, high quality childcare with adequate hours may be more mobile for commuting purposes than the parent who is concerned about the reliability, quality or hours of childcare available. The latter parent might tend to restrict commuting ranges in order to be within easier reach of young children.

Finally, the assumption that lower paying jobs are more interchangeable than higher paying positions may be less true than in the past. Highly salaried and trained workers in technical fields may be in demand in many areas, whereas a lower paid service worker may be hard pressed to make a move without taking a salary cut. Thus it may actually be the more highly paid secondary workers who are able to adjust their job locations in response to changing family circumstances. The less fixed a job location is, the less one would expect it to exert a pull on residential locational decisions.

## Final Model Results

### San Ramon Workers

The first stage of the San Ramon model was the modeling of the lower level nest; i.e., modeling community choice within the six community clusters. Results are presented in 15.

**Table 15:** Results of Lower Level Nest Modeling for San Ramon Workers: Choice of Community as a Function of Community Characteristics and Travel to Work

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<u>Variable</u>	<u>Coefficient</u>	<u>Standard Error</u>	<u>t-Ratio</u>	<u>p-Value</u>
HTIME	-0.0677	0.0047	-14.277	0.000
LTIME	-0.0618	0.0046	-13.422	0.000
\$SQFT/INC	-0.6513	0.1111	-5.863	0.000
%MULT:LO	3.4334	1.0184	3.372	0.000
CENTERDUMMY	2.0287	0.2721	7.455	0.000
SCHOOL	0.0122	0.0040	3.048	0.002
L*(0):	-1494.1			
L*(β'):	-901.96			
rho <sup>2</sup> :	0.3963			
rho(bar) <sup>2</sup> :	0.3923 (K=6)			
No. of Observations	1378			

---

The log of the denominator of the equation stemming from this estimation level was saved as a variable and utilized in the estimation of the higher level nest, as described in 15.

The initial hypothesis of a nested structure with community clusters forming the higher level nest and individual communities forming the lower level was validated

**Table 16:** Results of Higher Level Nest Modeling for San Ramon Workers: Choice of Community Type and Summary Statistics for Both Levels

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Variable	<u>Coefficient</u>	<u>Standard Error</u>	<u>t-Ratio</u>	<u>p-Value</u>
\$MED/INCOME	-0.1390	0.0258	-5.389	0.000
LOGSUM	0.5979	0.0345	11.655*	0.000

\*The t-statistic of LOGSUM tests  $H_0: \beta = 1$ , rather than  $H_0: \beta = 0$ .

$L^*(0):$  -1167.0  
 $L^*(\beta'):$  -934.18  
 $\rho^2:$  0.1995  
 $\rho(\bar{\rho})^2:$  0.1977 (K=2)  
 No. of Observations 1475

#### Summary Statistics for Both Model Levels

$L^*(0):$  -2661.1  
 $L^*(\beta'):$  -1836.14  
 $\rho^2:$  0.3100  
 $\rho(\bar{\rho})^2:$  0.3071 (K=8)  
 No. of Observations 1475

---

by these results. The coefficient of the LOGSUM variable was equal to 0.5979, and was statistically discernable from unity. Thus in the case of the San Ramon workers, a joint (i.e., non-nested) model of locational choice would have

violated the crucial IIA assumption of the logit model and would thus have biased parameter estimates.

The coefficients of HTIME and LTIME are both negative and significant. Among sample members workplace access appears to be a critical factor in residential location decisions. The other half of the accessibility-price tradeoff is captured in \$SQFT/INC, the price per square foot divided by income in thousands. As predicted, the coefficient of this variable is negative and significant. It should be noted that this significance occurs within community clusters that are partly defined on the basis of the median price of their housing to begin with.

The statistical significance of LTIME together with the fact that it perturbs neither the direction of HTIME nor its statistical significance indicates the importance of secondary workers' job locations as independent factors in households' residential decision making. Undoubtedly many decision making patterns exist in households, including the pattern that sets the location of the secondary worker's job according to a previously determined household location. But results of these models appear to indicate that for a large number if not the majority of dual worker households, residential location is determined with reference to both work places.

The positive coefficient of the CENTERDUMMY variable can be interpreted in two ways. First, it appears that the center city (i.e., Oakland and San Francisco) on balance constitutes a draw given the variables measured here. A major part of the apparent "draw" may be accounted for by the fact that low standardized school test scores (SCHOOL) for Oakland and San Francisco are irrelevant to many of the well paid workers in this survey because upper middle class members of these communities commonly send their children to private elementary and secondary schools. The other reason for CENTERDUMMY's significant positive coefficient is the fact that both Pacific Bell and Chevron, the two San Ramon firms surveyed, relocated to San Ramon from central locations in 1984. There may be a number of people unable or unwilling to move that still reside close to their former workplaces in the central Bay Area (Cervero and Landis 1990).

The remaining local service variable, SCHOOL, was tested against an alternative variable representing school quality only for those families with children. Interestingly, SCHOOL carried more explanatory power (in terms of its contribution to  $\rho^2$ ) and a higher t-statistic.

SCHOOL may thus be picking up aspect of a community's socioeconomic makeup that are not measured by other

variables, as well as accounting for families whose children have left home but made earlier locational decision in part based on school quality.

The most important policy variable in the model is %MULT:LO, equal to percent of a community's housing stock in multifamily housing for households with up to \$50,000 income (and 0 otherwise).

Finally, the significant and positive sign of %MULT:LO is interpreted as indicating the importance of multifamily housing in a suburban community to low to moderate income households. While these results should be viewed with caution due to sample biases, these results appear to imply that increasing multifamily housing levels in a suburban community increases the likelihood of that community's selection by low to moderate income households. If the community is a job center, changes in the housing stock may also reduce commutes by low to moderate income households. These effects are modeled in Chapter VI.

#### Santa Clara County Workers

Overall, the modeling results for the Santa Clara workers were similar to those for San Ramon. First, the nested logit structure was validated for both models.

Second, the coefficients of the access related variables



(HTIME and LTIME) were negative and highly significant in the Santa Clara model as they were in San Ramon. Third, most estimated coefficients were fairly similar between the models (19).

**Table 17:** Results of Lower Level Nest Modeling for Santa Clara County Workers: Choice of Community as a Function of Community Characteristics and Travel to Work

---

<u>Variable</u>	<u>Coefficient</u>	<u>Standard Error</u>	<u>t-Ratio</u>	<u>p-Value</u>
HTIME	-0.0680	0.0053	-12.710	0.000
LTIME	-0.0494	0.0061	-8.065	0.000
\$SQFT/INC	-0.5399	0.1618	-3.336	0.000
%MULT:LO	4.4481	2.0055	2.234	0.025
CENTERDUMMY	3.6321	0.5574	6.515	0.000
SCHOOL	0.0256	0.0059	4.312	0.000
MFCHILD	-4.981	1.4635	-3.408	0.001

$L^*(0):$  -570.62  
 $L^*(\beta'):$  -364.82  
 $\rho^2:$  0.3606  
 $\rho(\bar{\rho})^2:$  0.3484 (K=7)  
 No. of Observations 480

**Table 18:** Results of Higher Level Nest Modeling for Santa Clara County Workers: Choice of Community Type and Summary Statistics for Both Levels

---

<u>Variable</u>	<u>Coefficient</u>	<u>Standard Error</u>	<u>t-Ratio</u>	<u>p-Value</u>
LOGSUM	0.3089	0.0422	16.377*	0.000

\*The t-statistic of LOGSUM tests  $H_0:\beta=1$ , rather than  $H_0:\beta=0$ .

$L^*(0):$  -535.97  
 $L^*(\beta'):$  -504.41  
 $\rho^2:$  0.0589  
 $\rho(\bar{\rho})^2:$  0.0570 (K=1)  
 No. of Observations 480

Summary Statistics for Both Model Levels

$L^*(0):$  -1106.59  
 $L^*(\beta'):$  -869.23  
 $\rho^2:$  0.2145  
 $\rho(\bar{\rho})^2:$  0.2064 (K=8)

---

The models differed in two important ways, however. The explanatory power of the Santa Clara County model was noticeably lower than that of the San Ramon model. The loss of explanatory power occurred mostly at the upper level of the nested structure; i.e., at the point of selection of community clusters. Part of the reason is that the San Ramon model included median home price as a variable at this level, whereas in the Santa Clara model the variable carried an incorrect sign and was dropped. In addition, it may be that the Santa Clara choice set is in general more homogenous and hence more difficult to model.

The second important difference between the models is the significance and negative coefficient of the variable MFCHILD (equal to percent multifamily housing for households with children) in the Santa Clara model. The implication is that while the presence of multifamily housing may draw lower income households to a community, it may in some circumstances repel households with children. The fact that the variable was significant in the Santa Clara case but not in San Ramon may indicate the existence of a threshold level of multifamily housing. Increasing density beyond this threshold may begin to repel households with children. The communities nearby the five Santa Clara job sites all have much higher levels of multifamily housing than those in the

San Ramon area. Possibly for some households with children, these communities are in fact at that threshold.

**Table 19:** Comparison of Estimated Coefficients for San Ramon and Santa Clara County Workers

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	Estimated San Ramon <u>Coefficient</u>	Estimated Santa Clara County <u>Coefficient</u>
HTIME	-0.0677	-0.0680
LTIME	-0.0618	-0.0494
\$SQFT/INC	-0.6513	-0.5399
%MULT:LO	3.4335	4.4481
CENTERDUMMY	2.0287	3.6321
SCHOOL	0.0122	0.0256
MFCHILD	N/A	-4.98

---

Overall, 19 reveals a similarity between the two models. The coefficient of \$SQFT/INC was more negative in the San Ramon model than in the Santa Clara model. One might expect the opposite, given the higher prices for communities with the Santa Clara County choice set. This may reflect the higher presence of multifamily housing in the Santa Clara choice set, which causes prices for single family housing to be less crucial than they are among the San Ramon workers. This is supported by the fact that the utility of %MULT:LO is higher for the Santa Clara workers

than it is for the San Ramon sample.

The difference in utilities between the SCHOOL variable of the two models is the largest proportional difference in the models. This may be due in part to the nature of the school districts near San Ramon and the Santa Clara County workplaces. Those near San Ramon tend to be of near uniform high quality, while Santa Clara County school districts are more of a patchwork. Some districts are highly ranked, such as Cupertino and the Westgate and Almaden areas of San Jose, but nearby schools, principally in other San Jose neighborhoods such as Alum Rock and Downtown, score significantly worse on standardized scores (California Department of Education 1989). A perception of relative constancy in school district quality in the San Ramon choice set may tend to lessen the importance of school quality relative to other community attributes in determining residential location.

#### Independence from Irrelevant Alternatives

The fact that both the San Ramon and the Santa Clara County models were nested (i.e., the LOGSUM coefficient significantly lower than 1) indicates that nonnested

multinomial logit models calibrated on the same data would have violated the IIA assumption. Still, the nesting itself does not necessarily satisfy the IIA assumption, for within clusters of the lower level nest, the model is in fact a simple multinomial logit model.

If the IIA assumption is fulfilled, consistent parameter estimates should be deriveable from a reduced choice set as well as from the full set. Hausman and McFadden (1984) developed a test statistic to test the null hypothesis that  $\beta_u = \beta_r$ , where  $\beta_u$  is the vector of population parameters for the unrestricted choice set and  $\beta_r$  is the corresponding choice set with some alternatives missing. Denoting  $V_u$  and  $V_r$  as the corresponding variance-covariance matrices, the test statistic

$$(\beta'_r - \beta'_u)'(V_r - V_u)^{-1}(\beta'_r - \beta'_u)$$

is asymptotically  $\chi^2$  distributed with  $K_r$  degrees of freedom, where  $K_r$  equals the number of coefficients estimated in the reduced model. Frequently this number is smaller than that of the full model due to alternative specific constants and variables; in this case the number of estimated parameters are equal.

In order to carry out this test, five communities selected at random were temporarily eliminated from each of the choice sets. Eliminated from the San Ramon choice set

were the communities of Alameda, Oakland, Campbell, San Lorenzo and Vacaville. Eliminated from the Santa Clara County choice set were Menlo Park, the Almaden, Alum Rock, Westgate areas of San Jose and Union City. In addition, households selecting these communities were excluded, and a models with identical specification as the full model were calibrated on the restricted choice sets.

For the San Ramon model, the test statistic was calculated to be 5.46, well under the  $X^2$  critical point (95% confidence, 6 degrees of freedom) of 12.6. Thus for the San Ramon model the null hypothesis of equal population parameters between the reduced and the full model is not rejected. In the case of the Santa Clara County model, the similar test produced a  $X^2$  test statistic of 12.79, still under but uncomfortably close to the critical point (95% confidence, 7 degrees of freedom) of 14.1. The null hypothesis of equal population parameters (and hence satisfaction of the IIA assumption) is thus not rejected for the Santa Clara model as well. The relatively high  $X^2$  statistic may be cause for concern, however; it may be that a structure of perceived similarities between communities exists within current clusters and is not captured by the specific nesting structure developed.

## **Summary of Chapter V**

Chapter V described the methods and procedures used in developing the nested multinomial logit models. Choice sets were constructed of all communities lying within a 60 minute automobile commute of the two employment centers, San Ramon and Santa Clara County. Communities were clustered for a nested multinomial logit analysis on the basis of median home price and the percent of the housing stock in multifamily units, and a weighting procedure was applied to correct for differential sampling.

Modeling results for both San Ramon and Santa Clara County indicated a nested structure with the primary level nest being aggregations of communities. Model results were as expected with access and affordability variables carrying the expected negative signs, and school quality emerging as positive and significant. The variable representing crime levels in a community carried the expected negative sign but was not significant. In Santa Clara County (but not in San Ramon), the presence of multifamily housing appeared to have a deterring effect on households with children. But for both areas modeled a significant and positive utility was associated with multifamily housing for households earning up to \$50,000 (representing approximately the lowest third of the sample in income terms). Thus the hypothesis that



the presence of multifamily housing increases the likelihood of a low to moderate income household selecting a particular community appears to be confirmed for the sample. This result can lend support to the hypothesis that suburban employment centers with a large multifamily or high density housing stock can stem long distance commuting by lower income households. Conversely, based on these results, lower income households employed at a suburban employment center with low density housing in the vicinity would be less likely than upper income counterparts to select nearby housing.

## **Chapter VI:**

### **Model Interpretation and Policy Implications**

The final chapter of this dissertation analyzes results of the models presented in the preceding chapter. The analysis centers on several issues: what the models may demonstrate for households' locational decision making processes, how these processes may affect commuting behavior, and potential policy and theoretical lessons that may be deriveable from the study.

#### **Model Evaluation**

In Chapter V, the significance, direction and magnitude of estimated utilities were evaluated, and a comparison was made of utilities between the San Ramon and Santa Clara models. Here, the derivation of implied or hedonic prices for attributes of the residential location decision is explored briefly. Then, for policy purposes, the models are used to forecast land use and transportation responses to policy changes.

#### **Derivation of Implied Values**

The derivation of implied values in this section provides a check on the reasonableness of the models'

estimated utilities -- a sort of "reality check" for the statistical procedures. However, certain estimates presented in this section may have policy relevance, such as the estimated increase in multifamily stock that would be necessary to "overcome" real housing price increases.

Utilities in multinomial logit models are unitless and make sense only in comparison with each other. However, the ratio of utilities can be used to infer price, when one of the variables is dollar-denominated. In the models described in Chapter V this variable would be  $\$SQFT/INC$ , or the ratio of price per square foot to total income in thousands.

#### School Quality

For example, the implied per square foot value of an additional point in school quality may be estimated as follows:

$$|u(SCHOOL)/u(\$SQFT/INC)| \times Y$$

where         $u$  = estimated utility  
                $Y$  = household income in thousands

For the San Ramon households, this value is estimated at  $0.0122/0.6513 \times$  household income. For example, for a household earning \$60,000 annually, the per square foot value of an additional percentile point in school quality is

\$1.12, or for a 1,400 square foot house, \$1,568. An improvement in school quality from the 75th to the 90th percentile, then should raise the amount this household would be willing to pay for this house by \$23,520. The corresponding figure for the Santa Clara workers would be  $0.0256/0.5399 \times$  household income, or \$2.84 per point per square foot, or \$3,982 per point per 1400 square foot house.

The fifteen point jump above is predicted to be associated with a \$59,724 rise in price. The discrepancy may be partly explained by higher home prices in the vicinity of the Santa Clara County worksites, as well as by a greater variability in school quality as explained by the previous chapter. With home values in the \$250,000 to \$350,000 range, neither figure seems inordinately high.

#### Multifamily Housing

Similarly, it is possible to calculate the value of the availability of multifamily housing to low to moderate income households, using the %MULT:LO variable. The question that this number would attempt to answer would be "how large a percentage increase in multifamily housing stock would be needed in particular community to offset a rise in median home prices, thus leaving the community equally affordable to households earning under \$50,000

annually?" The implicit assumption in this question is that multifamily housing in a community tends to be a lower cost alternative to the single family home. Increasing the density of a community can keep the cost of the median dwelling constant even as prices of single family homes rise. This value may be computed using:

$$\frac{u(\%MULTI:LO)/100}{u(\$SQFT/INC)} \quad x \quad Y$$

Thus for a household earning \$40,000 and working in San Ramon, the value would equal  $3.43334/0.6513 \times$  household income, or \$2.11 per square foot per percent multifamily housing in the community. For example, consider a community with median home prices of \$250,000, median home sizes of 1400 square feet, and 20 percent of the 25,000 housing units in multifamily housing. Now allow real home prices to rise to \$275,000. The amount of new multifamily housing that would need to be constructed to offset the price rise and render the community as affordable as before to this household would be:

$$\frac{[0.01(\$275,000-\$250,000)]}{\$2.11 \times 1400} \times 25,000 = 2,116 \text{ units}$$

The comparable per square foot figure for the Santa Clara would be  $4.4481/0.5399 \times$  household income, or \$3.29. Thus based on the Santa Clara County model, the community

described above would need to add 1,357 multifamily units to render it equally affordable to the household earning \$40,000, after the price rise.

Multifamily housing has its costs as well, particularly for households with children. According to the Santa Clara model, the per square foot value of a percentage point drop in multifamily housing equals:

$$\frac{u(\text{MFCHILD})/100}{u(\$SQFT/INC)} \times Y$$

or \$5.53 per square foot for a household earning \$60,000 annually. If this is a household with children, then, the value of a 1400 square foot home in a community with 30 percent of the housing stock in multifamily housing would be \$77,420 greater than the same house in a community with 40 percent multifamily housing. This number seems unreasonably high, and is probably the result of an unreasonably high negative coefficient of MFCHILD.

The reason that the disutility of MFCHILD might be overstated is because it may be capturing two effects. The first is as described above; i.e., the desire of many households to raise children in a single family home situated in a low density environment. The second effect the variable is capturing is the desire of these households to occupy single family homes, regardless of whether their environment is of a lower or higher density. For example,

for some households, a single family home in a dense community such as Mountain View may have no lower utility than the same home in a sparser community such as San Jose; for these families the negative coefficient of MFCHILD is simply due to the relative unavailability of single family homes in cities with predominantly multifamily housing stocks.

Nevertheless, there may be an important policy implication in the results as they pertain to the utility or disutility of multifamily housing for households with children. The fact that the utility of MFCHILD was negative and significant for the Santa Clara County workers but not for those in San Ramon may indicate a certain threshold level beyond which residential density may tend to repel larger households.

It may be that density per se is not the sole factor in repelling larger households. The San Ramon housing stock tends to be newer than that in Santa Clara County. Many of the multifamily units that do exist are within attractive landscaped complexes adequately planned for open space. In contrast, much of the Santa Clara County multifamily housing stock is in units of poorer quality and amenities. If density repels some households with children, this factor may partly overcome through the provision of open space and

other amenities together with the dense housing.

Examination of this question is beyond the scope of this study. Adequately addressing such a question would require housing type choice model that would facilitate an analysis of the tradeoffs between accessibility, density and housing quality.

#### Workplace Access

Finally, it is possible to calculate the implied price of access to a job site. However, these numbers must be treated with similar caution. The principal reason is that the network data from which peak hour highway travel times were derived was from 1980 Metropolitan Transportation Commission skim trees. Peak hour travel times in many parts of the Bay Area have increased markedly since then (Chapter III), such that what was a 20 minute commute in 1980 may easily have been a 30 minute commute in 1989. If this is the case, the coefficients of the access variables are too high, and the estimates presented below are overstated.

With that caution, per square foot estimates of the value of one minute of travel time may be calculated as follows: Value of a minute of accessibility to the primary

worker's job site, per square foot of house =  
$$\frac{u(\text{HTIME})}{u(\$ \text{SQFT}/\text{INC})} \times Y$$



For a household earning \$60,000 dollars annually, this amount equals  $0.0677/0.6513 \times 60 = \$6.23$  for the San Ramon worker and  $-0.0680/0.5399 \times 60 = \$7.55$  for the Santa Clara worker. The corresponding per home values for a 1,400 square foot home are \$8,722 and \$10,570. Thus a home located 30 minutes from the job site would be worth \$87,220 less to the San Ramon worker than a home 20 minutes away; the corresponding figure for the Santa Clara worker would be \$105,700. As anticipated, these numbers appear to overstate the case. However, if one assumes an underestimation of commute time by 33 percent, the amounts would be approximately \$58,000 and \$70,000 respectively. These latter figures appear to be within the plausible range.

#### Changes in Commutes in Response to Housing Stock Changes

One of the most important uses of the multinomial logit model in land use and transportation modeling is its potential as a forecasting tool. Using already calibrated coefficients, attributes of the choice sets (or the households themselves) may be manipulated to predict roughly the range of potential land use and transportation system responses to policy stimula. What variables may be considered as the relevant policy variables in a model will vary with the purpose of the study. As this study has been structured, the critical policy variable is the amount of

multifamily housing in the vicinity of suburban employment concentrations, but other variables included in these models may be considered policy variables in other contexts. For example, in a study attempting to assess the residential patterns arising from the construction of a new high speed link, this group would include the accessibility variables HTIME and LTIME. Studies attempting to assess the implications of home price increases stemming from land use regulation might focus on the housing cost variables; whereas public service studies might view SCHOOL (or the excluded variable, CRIME) as central.

#### San Ramon Case

As this study has been structured, the critical policy variable is the amount of multifamily housing in the vicinity of suburban employment concentrations. Two options are tested for San Ramon. The first is raising the levels of multifamily housing in San Ramon and neighboring Dublin 10 percentage points, to the point that multifamily housing represents 36.7 percent and 38.6 percent of the housing stock, respectively (no addition to the single family housing stock is assumed). This is equivalent to adding 1,815 multifamily units in San Ramon and 1,095 units in Dublin, based on California Department of Finance (1989) figures. The question the model seeks to answer is as

follows: Under these revised conditions, how many more households may be expected to locate in San Ramon or Dublin than under current conditions? Which communities would be expected to house a lower proportion of San Ramon workers if the San Ramon housing stock were changed? The second policy experiment entails boosting the multifamily proportion of these communities' housing stocks to 50 percent, a figure typical of the communities studied in Santa Clara County.

Partial results of the simulation are presented in 20, which summarizes results for all those communities forecast to gain or to lose San Ramon workers under the alternative housing stock scenarios described above. The first column represents the forecast when San Ramon's multifamily housing stock equals 36.7 percent and Dublin's 38.6 percent of the total. The figures in column 1 represent that percent of the sample forecast to live in that community that did not reside there before; thus 1.7 percent of the sample (over and above those currently living there) would be forecast to opt for living in San Ramon under the new housing stock conditions. Similarly, one half of one percent of the sample of San Ramon workers is forecast to opt against living in Benecia in response to the housing stock change.

The second column represents the forecast locational response when both San Ramon and Dublin include 50 percent

multifamily housing in their housing stock. The final two columns represent approximate automobile travel time and travel distance from each community to San Ramon.

With the exception of Walnut Creek, all communities forecast to lose San Ramon workers are at least 10 miles removed from San Ramon. In general, the development of multifamily housing nearby the employment concentration in San Ramon is forecast to divert households from relatively low cost, more remote communities. This indicates considerable potential for a commute reduction policy based on local affordable housing.

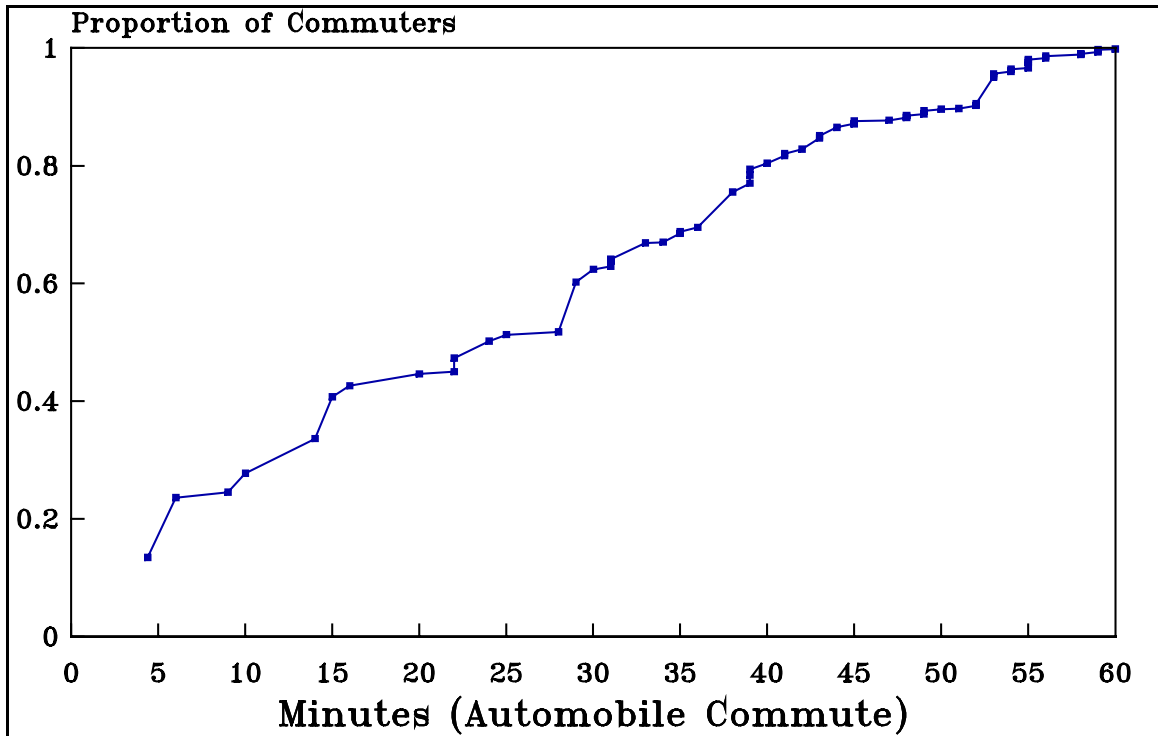
Even the exception to this rule -- Walnut Creek -- presents an interesting case. Walnut Creek is relatively near San Ramon and offers expensive housing (the median price for a single family home is \$300,000) but offers a high proportion of multifamily housing as well; 59 percent of Walnut Creek's housing stock is in multifamily housing. Thus it represents a relatively affordable community from which moderate income households would be drawn were more affordable housing to be constructed in San Ramon and Dublin.

To check the reasonableness of these results it is possible to calculate the proportion of new multifamily housing in San Ramon that would be occupied by San Ramon

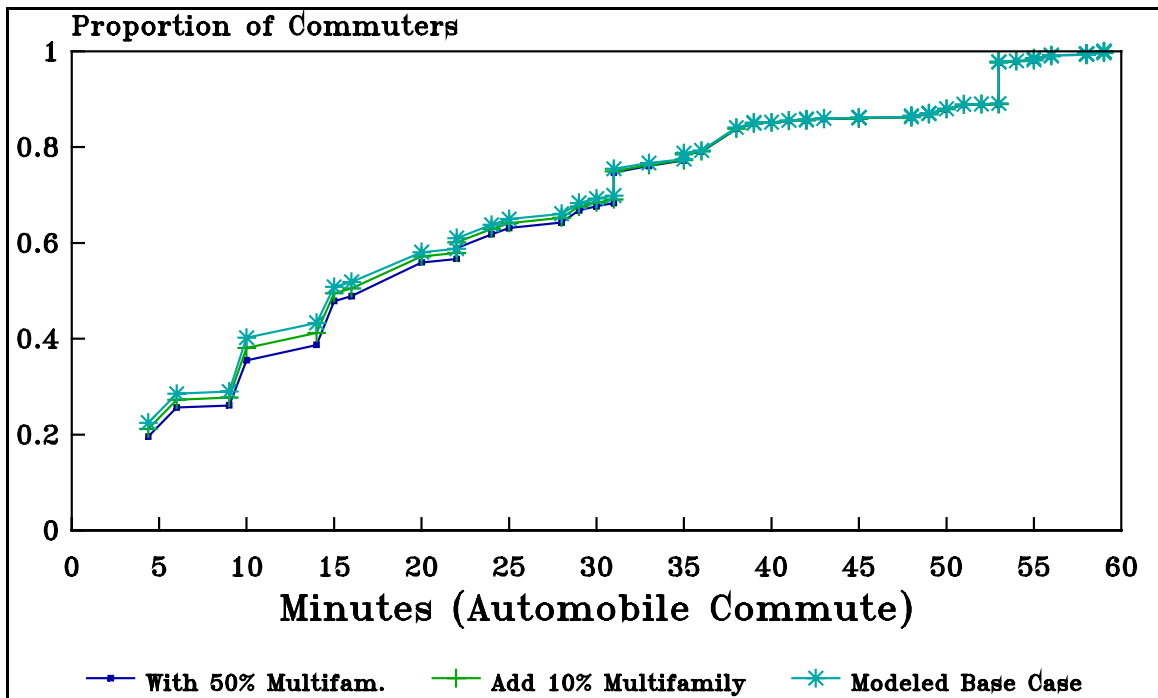
workers, if these results held. The Association of Bay Area Governments (1989) projects San Ramon 1990 employment at 24,109 jobs. The first scenario would have increased housing units in San Ramon and Dublin by 2,910 units; extrapolating the sample results to the San Ramon employee population would imply an additional  $1.7\% + 1.03\% = 2.73\%$  of San Ramon workers residing locally, or 658 workers. Under these assumptions, the percent of new multifamily units that would be occupied by San Ramon workers would be 22.6 percent.

Another approach to analyzing the potential results of altering the housing stock is presented in 29 and 29, representing the cumulative distribution of commutes (up to 1 hour) to San Ramon, under current and modeled conditions.

29 represents actual data from the workplace survey, whereas 29 represents modeling results for a base case with current conditions assumed, as well as the two alternate scenarios described. First it should be noted that the modeling result (29) matches the survey-based data well, if not exactly. The model appears to do a adequate job of simulating current conditions.



**Figure 30:** Cumulative Commute Time Distribution, from Survey Data, San Ramon Workers, 1989



**Figure 31:** Cumulative Commute Time Distribution, Forecast for San Ramon Workers Under Alternative Multifamily Housing Scenarios

The model's prediction of the distribution of commutes is shown in 29. The picture is one of reduced commutes overall, with the greatest differences occurring in the middle of the range. For example, the difference between the 40th percentile commute under the base case and the same commute under the 50 percent multifamily scenario is nearly five minutes.

The result tends to confirm the jobs-housing balance approach to transportation planning that presumes that people would select housing that reduces their commutes if it were available at affordable prices. It should be noted, however, that both workers in a dual worker household may not work in San Ramon; a move to the area could conceivably entail an increase in the commute of the non-San Ramon worker. However, those households that would be most susceptible to diversion to nearby living would be those for whom the move shortens both commutes.

The results presented above may underestimate the commute reducing potential of multifamily construction in these communities, for three reasons. First, as described above, communities falling beyond 60 minute drive from San Ramon were excluded from the analysis in order not to perturb the results of the model with potential commutes that represented relevant options for only a tiny minority

of San Ramon commuters. Commuters from these communities were excluded from the forecasting as well in order not to impute characteristics on untested data. An explicit forecast as to the behavior of these groups when faced with increased supplies of multifamily housing would require a housing type model in order to capture explicitly the tradeoff between affordable but dense housing nearby and larger remote single family homes. But to the extent that these long distance commuters come from moderate income households, they may be amenable to living in potential multifamily housing nearby their workplaces.

Second, the results presented below are for the household's primary worker only. Those multiworker households that would be most amenable to nearby higher density living would be the ones for whom the move to Dublin or San Ramon reduces both commutes, not just one.

Finally, the models understate the commute reducing potential of multifamily development because they include only those primary wage earners actually working in San Ramon. A new condominium unit in San Ramon occupied by, for example, a Dublin worker in all likelihood represents a shortened commute compared to alternative residential locations; the same may be true for Pleasanton, Livermore or other workers residing in San Ramon. The model simulates



the behavior of San Ramon workers only, and thus fails to capture these potential effects.

**Table 20:** Cities Forecast to Gain or Lose San Ramon Workers under Increased Multifamily Housing Scenarios

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Travel City	Percent Change, Multifam.	Percent Change, Multifam.	Auto Travel Minutes	Dis Miles
San Ramon	1.70%	3.08%	4	2
Dublin	1.03%	1.95%	10	6
Hayward	-0.06%	-0.06%	30	12
Antioch	-0.07%	-0.20%	39	29
Pleasanton	-0.09%	-0.08%	14	10
Pittsburg	-0.13%	-0.28%	35	26
San Leandro	-0.13%	-0.13%	25	18
Martinez	-0.14%	-0.28%	33	21
Livermore	-0.14%	-0.15%	24	17
Concord	-0.20%	-0.19%	29	17
Pleasant Hill	-0.39%	-0.86%	20	13
Benecia	-0.50%	-0.80%	31	23
Walnut Creek	-0.90%	-1.73%	15	9

**Table 21:** Cities Forecast to Gain or Lose Santa Clara County Workers under Increased Multifamily Housing Scenario

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<u>City</u>	Percent Change, Add 10% <u>Multifamily</u>
Los Altos	7.48%
SJ: Berryessa	4.54%
Saratoga	3.21%
SJ: Zipcode 95125	2.03%
San Ramon	1.50%
Palo Alto	1.27%
Milpitas	1.27%
Danville	1.20%
Santa Clara	-1.10%
Los Gatos	-1.27%
Campbell	-1.85%
SJ: Almaden	-2.55%
SJ: Cambrian/Blossom Hill	-2.73%
Cupertino	-3.11%
SJ: Westgate	-3.35%
Mountain View	-5.92%

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## Santa Clara County Case

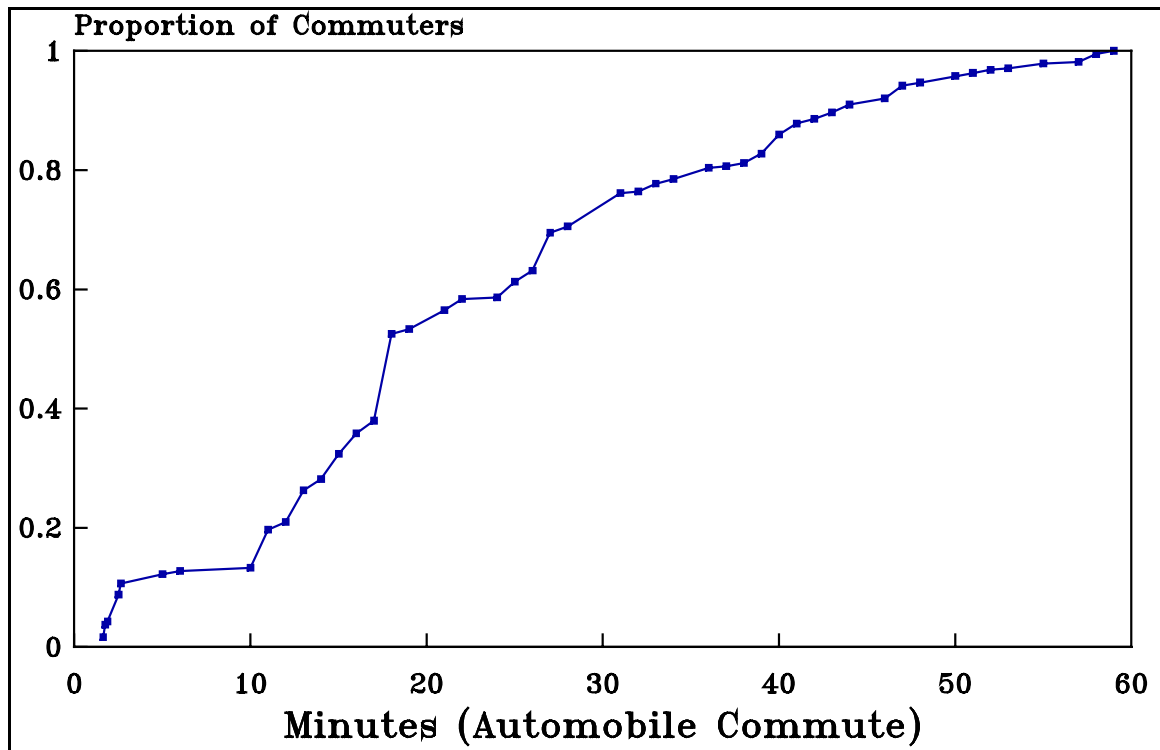
The case of the Santa Clara County workers is considerably less clear, for two major reasons. The first is the lower explanatory power of the Santa Clara model. More important is the significant negative utility accompanying MFCHILD, the percentage of multifamily housing in a community appearing in the utility function for households with children present. On the one hand, simulating growth in the multifamily housing stock in these communities does tend to attract low to moderate income households to local living, but at the same time it pushes away larger households with children. The net result of these forces varies (21).

Only one policy option was tested for Santa Clara County because of already high levels of multifamily housing in Santa Clara County. The scenario increased the multifamily housing stock in these communities 10 percentage points over the current: to 81% in Mountain View, 64% in Sunnyvale, 62% in Santa Clara, 51% in Cupertino and 41% in the 95125 area of San Jose. Of these communities, only one -- the 95125 district of San Jose -- was positively affected by these changes, gaining an estimated 2 percent of Santa Clara County workers. Significantly, this is the community with by far the lowest supply of multifamily

housing in the area; at 31 percent multifamily its density is closer to San Ramon than to the rest of industrial Santa Clara County. The draw of additional multifamily housing in this community appeared to overcome its repellant aspect.

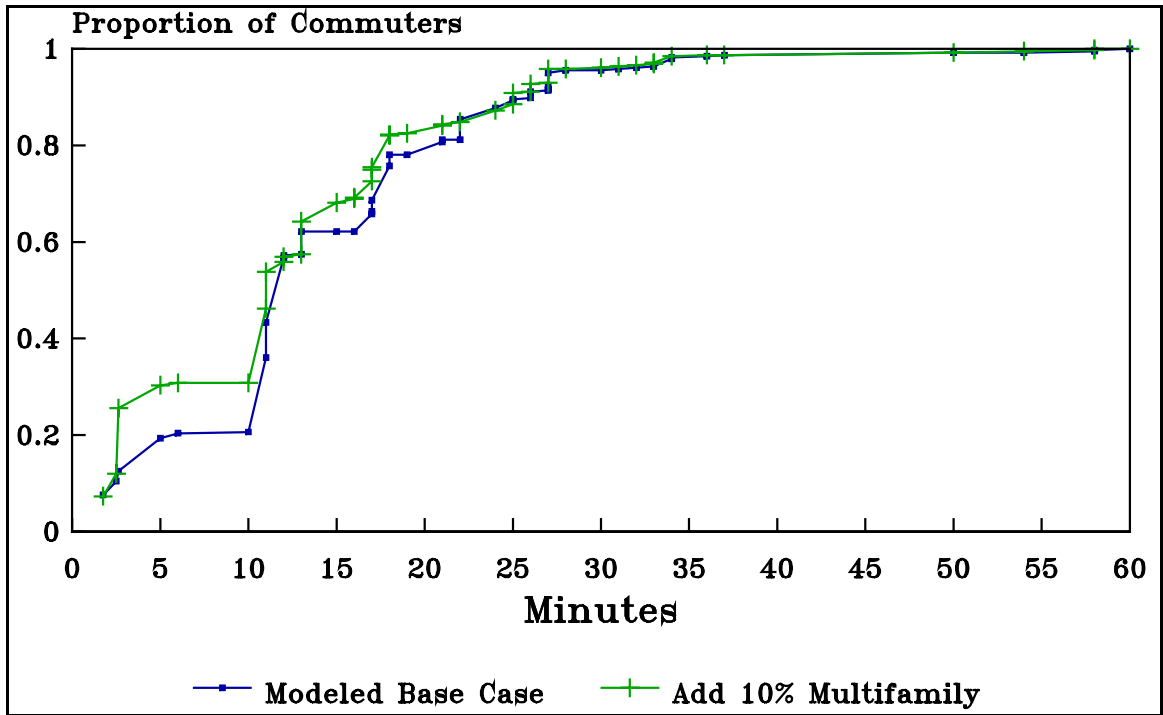
Other communities gaining Santa Clara County workers from the change in the housing stock were often less dense closeby communities. These would presumably be attractive to households avoiding the higher density environments of Mountain View, Cupertino and Santa Clara.

The ambiguity of the results for Santa Clara County is reflected in travel time distributions as well. The cumulative distribution based on survey data is depicted in



**Figure 32:** Cumulative Commute Time Distribution, from Survey Data, Santa Clara County Workers, 1989

32; its slope is considerably steeper than that of the San Ramon workers, indicating the generally shorter commutes in Santa Clara County.



**Figure 33:** Cumulative Commute Time Distribution, Forecast for Santa Clara County Workers Under Alternative Multifamily Housing Scenario

Modeled results are presented in 33. The base case may be compared to the actual data presented in 32. The model appears to capture the steepness of the slope of the actual, but perhaps in excess. Over most of the range the modeled base case results are steeper than those from the survey data, with shorter commutes than actually occur.

The effect of the addition of multifamily housing varies. At the low end of the distribution the addition of multifamily housing appears to be successful in shortening commutes overall, but the distributions cross later on, yielding ambiguous results. The overall effect does appear to be one of shortening commutes, however. Where the two distributions are not overlapping, the distribution representing the increased multifamily scenario lies above that of the base case, and thus indicates shortened commutes. Although results for Santa Clara County are more ambiguous than those for the San Ramon workers, the direction of the effect of multifamily development on commutes appears to be similar.

The limitations of this forecasting exercise must be emphasized. Samples were not representative of the general employee populations of the areas studied, but exhibited systematic biases towards higher income populations. In general, the imputing of utilities based on current

conditions to the future is speculative and fraught with uncertainty. The multinomial logit model as specified in this study in particular should be viewed as strictly a short term forecasting tool. The model envisages households selecting from communities that are static in their characteristics (save any policy variables that are altered); it is not designed to anticipate the ways the communities themselves may develop in response to new patterns of development. For example, what were sleepy Bay Area fringe communities two decades ago have been transformed into prosperous suburbs with a reputation for high costs, services and amenities. This transformation would not have been predicted by an analysis similar to this study's, which treats attributes of the choice sets essentially as fixed.

Thus estimates developed in this section should thus be viewed cautiously as indicating potential directions and orders of magnitudes of effects rather than precise predictions. All this notwithstanding, these results are referred to as "forecasts" and not merely "projections," not because of a great faith in their accuracy, but because they represent more than a mere extrapolation of current trends.



## **Policy Implications of Findings**

Cervero (1989) asserts that "(t)he principal reason for jobs-housing mismatches is that ad hoc market forces have generally shaped suburban growth in most U.S. metropolitan areas." He hypothesizes five forces leading to the imbalance, two of which are demographic trends (two wage earner households and job turnover) and three of which are the product of planning and public decision making rather than the market: fiscal and exclusionary zoning, growth moratoria and worker earnings/housing cost mismatches generated by fiscal zoning and growth ceilings. The problem does not appear to be not enough planning, but rather a planning style that seeks a localized kind of environmental quality (defined as large lot single family development) without full regard for more regional concerns. The problem may in fact be too little reign given to the market rather than too much. General plans and zoning ordinances typically do not define minimum densities but rather maxima.

The policy expressed in the San Ramon Housing Element (City of San Ramon 1990) of restricting high density housing to just one of the City's eight planning subareas may be seen as one example of this phenomenon. It may be that allowing developers to build more densely near suburban job centers is all the incentive needed to produce significant

residential densification near many suburban employment centers.

Results of this study are in accord with the jobs-housing balance approach to metropolitan transportation planning; when concentrations of suburban employment are matched with sufficient affordable housing, households seek to reduce commutes. Importantly, this approach is strictly a voluntary, incentive based system; it is based on harnessing individuals' own desire to reduce commutes, rather than imposing travel or mode restrictions that would be politically unpopular and intrusive on individuals' lives.

Still, there are many sides to the jobs-housing balance complex. As evidenced by modeling results from Santa Clara County, a policy of increasing housing density may eventually suffer from decreasing or even negative marginal returns in its commute reducing potential. Replicating urban levels of multifamily housing in suburban employment centers may eventually incur the costs of central-city style development in congestion and in-commuting by larger households without the crucial transportation advantages of a central location. Results of this study in this regard are speculative due to income biases in the sample; further research on the potential deterring effect of suburban

density is needed.

Yet the potential of denser development to repel some households seeking lower density environments may be mitigated through the adequate planning and zoning of multifamily housing. Such planning will ensure open space for residents, as well as privacy sufficient to afford them some of the amenities of the more remote single family house they may now be foregoing.

The potential repelling effect of denser housing in the suburbs should not be overstated. In virtually all suburban Bay Area housing markets housing affordability remains the central issue to most households. Results of this study suggest that policies to enhance that affordability through housing density overall will have the desired effect in commute reduction. Model results appear to indicate that even the communities studied in Santa Clara County, the densest of the Bay Area's suburban subregions, stand to gain from multifamily development.

Affordable housing's commute reducing potential is of course dependent on its occupancy by employees of nearby job sites. Results discussed above indicate that less than one quarter of new housing in the San Ramon vicinity may actually be occupied by San Ramon workers. Policies to generate acceptance of nearby housing on the part of local

workers can hold significant benefits in commute reducing potential. When a developer builds housing in a community he or she is indifferent to its occupancy by local workers or by commuters. In contrast, to the extent that commute reduction seen as a public goal, it is in the community's interest that the housing be occupied by local workers rather than out-commuters. It is not difficult to envisage community-developer agreements that would stipulate the nature and extent of locally targeted marketing for newly constructed housing in order to attempt to boost the proportion of housing occupied by local workers.

#### Equity and Efficiency

The benefits accruing from a policy to achieve a spatial match between affordable housing with suburban job centers have ramifications at the juncture of equity and efficiency, the often competing goals of urban land use and transportation planning. When a higher income household opts to commute some distance to work rather than living closeby, there are effective limits on this household's commuting range. The high value of travel time of workers from this household places a fairly tight boundary on the residential communities acceptable to this upper income household.

But when municipal policies send low to moderate income households out of town in search of affordable housing, they run the risk that the commute thus generated will be considerably longer than that bargained for. The household's lower valuation of travel time, combined with a search for the elusive affordable single family home, can precipitate overlong commutes, generating excess pollution and congestion all along the way. The rationale that "somebody is going to commute to these suburban job centers, and it doesn't matter if it is the rich or the poor" is probably fallacious. Rather, given the multiplicity of forces acting on locating households, the surest policy to minimize commutes would be a policy to give households of all income groups viable housing options in a variety of locations.

There may be an even deeper reason for planners to be concerned about the implications of spatial mismatches between suburban job centers and affordable housing. Planners' analytical models, as well as their style of operation, presume individual actors making unfettered choices among land use and transportation alternatives. When planning restricts those alternatives by locking in the single family house as the exclusive or dominant suburban model, it precludes the kinds of individual decision making

that can serve public environmental quality goals. A planning style that seeks to enhance those alternatives -- alternatives to the single family home, or alternatives to long distance automobile commuting -- allows the system to work by allowing individuals to choose commute-minimizing options. Results of this study indicate that when provided these options individuals will tend to take them.

Transportation planners point out the externalities of highway congestion; the individual embarking on a trip considers the congestion he or she is liable to suffer, but not the congestion the trip would impose on other travellers in the system. The planners' interpretation is evident, but the fact remains that a great share if not the majority of congestion costs are internal. By removing barriers to commute-minimizing behavior, an effective policy of affordable housing in the vicinity of suburban job centers can harness the private interest in reducing travel time to attack social problems of excess congestion and pollution.

### **Theoretical Implications**

At the beginning of this study, three typologies of employment suburbanization and the land use and transportation system response to it were delineated: 1) The sparse employment suburb in which noncentral employment

is relatively dispersed and does not significantly affect the pattern of concentric rings of decreasing density and increasing income radiating out from the center of a metropolitan area; 2) The low residential density suburban job center in which important suburban employment concentrations exist but local land use policy resists the development of concentrated residential development; 3) The high density center in which important suburban employment concentrations lead to significantly increased residential density nearby.

The major question this study has attempted to address is that of the effect of employment and housing stock conditions on commutes by income. Of the two detailed study areas, San Ramon with its nearly three-quarters single family housing stock best matches the low density center typology. As predicted, for workers employed in that community, a negative relationship exists between commute time and household income; the commute distribution of lower income households was markedly longer than that for upper income households. The power of income alone to explain commute time is not great, largely because suburban commutes are an artifact of the choices available to locating households. The selection among these choices was analyzed within a discrete choice framework, which further

illustrated both the overarching importance of access to work and the relevance of dense alternatives to the single family home for households in the lower end of the income spectrum.

With their largely multifamily housing stock, the industrial communities of Santa Clara County match the high density center typology quite closely. The original expectation for such communities was that residential density could overcome high land costs, thus enabling low to moderate income households to reside close by suburban employment centers. This may be the case in northern Santa Clara County, where commute distances appear independent of household income, at least within the income ranges studied.

This occurs despite a surplus of jobs over housing units over large regions in the Silicon Valley, and the massive in-commuting that situation necessitates (Chapter III).

The phenomenon of a negative relationship between commute and income (such as that found for San Ramon) may be seen as a contradiction of the monocentric model's expectation of increased commutes with increasing incomes. Such is not the case. Where residential densification is allowed to take place the negative relationship is reduced or eliminated. Monocentric models of location may in fact be useful tools in describing polycentric urban areas, by



treating subregional centers as centers in their own right.

But strict suburban land use controls can impede the monocentric logic from operating. When this restriction on density is viewed as a variable, the old driving forces of the monocentric urban model -- affordability and access -- still emerge as powerful shapers of urban form.

### **Questions for Further Research**

This study was of a single metropolitan area; the San Francisco Bay Area. A more universal theory of the effects of employment suburbanization on the commutes of different income groups will depend on empirical study of a variety of metropolitan areas, including those in lower priced areas of the country. Research in this subject should avoid blanket generalizations on the effect of employment suburbanization, focusing rather on the impact of local land use conditions on the transportation response to decentralizing employment.

Progress in identifying emerging suburban commute patterns will emanate from disaggregate studies of particular metropolitan areas.

Aggregate nationwide studies will continue to suffer from the ecological fallacy of imputing to individuals the characteristics of the groups within which they are analyzed. They will continue an unproductive disregard for

local land use conditions and policies, potentially the most important policy variables for charting a course in a rapidly suburbanizing environment.

Thus this study of the San Francisco Bay Area needs to be complemented with similar studies of major metropolitan areas around the country and abroad. Within the San Francisco metropolitan area, the present study was based upon data from relatively circumscribed employment centers.

Housing stock changes in a given community can affect commutes not only to that community but to its neighbors as well. Similar studies employing more comprehensive data sets will better forecast the overall effect of policy changes on commutes. This is particularly crucial in regard to the representativeness of the samples; the fact that the current study sampled a relatively high income segment of suburban employees renders many of its conclusions tentative.

The methodological problem of how to incorporate both workers in the locational decision making process of dual worker households has vexed transportation planners for years. This study attempted to understand the relative influence of the secondary worker by temporarily excluding that person from the analysis and seeking evidence of greater or lesser explanatory power under alternate

stratification schemes. While conclusive results on the influence of both workers in multiworker households were not reached, that approach may be further explored to test hypotheses on the appropriate way to incorporate this information into future models.

The present study indicated a potential deterrent effect of suburban density on households with children. This is a question that deserves further research to ascertain if there is a point in the course of a community's densification this phenomenon becomes important. If a deterrent effect exists, is it related more to density per se or to the amenities or lack of amenities offered by denser housing?

Questions surrounding the tradeoff between commute distance and housing quality or size are best addressed within the framework of a model that includes a housing choice model, either jointly with the community selection model, or as a separate level in a nested structure. Such a model should allow for a different decision structure between various income groups. For example, it may be that the housing type/community choice decision of upper income households is best modeled in a nested structure in which household first select a housing type (e.g., single family home) and then select community. In contrast, the decision

process of low-to-moderate income households may be more of a joint nature in which a tradeoff is made between close by dense living and more remote larger housing types.

Models estimated in this study excluded the longest distance commutes, due to the effect of these commutes on the validity of the IIA assumption. There is no compelling reason why the nested multinomial logit<sup>16</sup> model should not be able to account for this and include very remote communities within an employment center's commute shed. The only requirement would be to develop clusters of communities within which the IIA assumption is satisfied. This study

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<sup>16</sup>A more widespread use of nested multinomial logit analysis will hinge important software advances. LIMDEP, while adequate and perhaps the best commercially available software for calibrating multinomial logit models, nevertheless has several features that needlessly slow the modeling process and hamper rapid refinement of models. First, its FORTRAN code is not readily compilable on a number of mainframes without modification requiring significant programming expertise. Second, it lacks an error trapping routine, frequently presenting the user with compiler or operating system errors that are nearly useless in helping to identify and repair problems with the data or the commands. Finally LIMDEP's nested multinomial logit routines are incapable of determining which choices belong to which nest (and consequently which nests are accepted and which rejected) without a set of counting variables generated by the user. The difficulty is that while eliminating an observation from the data set is simple enough, eliminating or adding an alternative requires reworking of the entire data set. Nested logit software should be able to identify membership in a particular nest by means of a single identifying variable, and acceptance or rejection of that nest the independent variable within the nest. In this fashion modifying the choice set would be as straightforward as selecting the observations, the crucial iterative process of model refinement would be facilitated and models consequently improved.

attempted to limit the number of community types by classifying communities in the two dimensions of housing price and multifamily housing stock only. Adding a third dimension of distance may allow nested multinomial logit models to analyze simultaneously the selection of both nearby and remote residential communities.

This study focused on emerging commute patterns by income for suburban employment centers. Center city patterns may be changing as well, as indicated by the weakness of the still positive relationship between income and commute distance for the San Francisco-employed workers in the 1989 survey. It may be that in many metropolitan areas, lower income households will be forced to commute long distances whether they are employed in the center city or in the suburbs. This issue will require detailed, disaggregate study of center city workers over time to determine such large scale commuting trends.

## **Conclusion**

The conditions modeled in this study represent a single point in time, a snapshot in a continuum of development patterns that are constantly evolving. Many of those communities that appear to be lacking in alternatives to the single family home today have already added considerable

amounts of multifamily housing over the past decade, and may in fact be on a path towards development patterns that will afford households the kind of choices referred to in this chapter.

The future course of these communities is still open. The challenge of planning research is to achieve a marriage of analytical tools and a clear policy focus to chart potential outcomes of alternative futures. It is becoming increasingly clear that decision makers in suburban communities must recognize tradeoffs between high employment levels, low density residential environments and uncongested highways; these three traditional goals may not be achievable simultaneously. When communities offer a range of dwelling and commuting choices, individuals and households will respond in ways that can meaningfully improve the quality of living in metropolitan areas.

**Appendix B: 1989 Workplace Survey Instrument  
Bibliography**

Alonso, William. (1960) A Theory of the Urban Land Market. *Papers and Proceedings of the Regional Science Association* 6:156.

Alonso, William. (1964) *Location and Land Use*. Cambridge, MA: Harvard University Press.

Anas, Alex and Chaushie Chu. (1982a) Discrete Choice Models and the Housing Price and Travel to Work Elasticities of Location Demand. Manuscript, Northwestern University.

Anas, Alex (1982b) *Residential Location Markets and Urban Transportation: Economic Theory, Econometrics and Policy Analysis with Discrete Choice Models*. New York: Academic Press.

Association of Bay Area Governments. (1989) Projections '90. Oakland, CA.

Association of Bay Area Governments. (1986) Projections '87. Berkeley, CA.

Beckmann, Martin J. (1976) Spatial Equilibrium in the Dispersed City. In George Papageorgiou (ed.) *Mathematical Land Use Theory*. Lexington, MA: D.C. Heath and Company.

Belliveau, Michael, Michael Kent and Grant Rosenblum. (1989) Richmond at Risk: Community Demographics and Toxic Hazards from Industrial Polluters: A Report. San Francisco: Citizens for a Better Environment.

Ben-Akiva, Moshe and Steven R. Lerman. (1985) *Discrete Choice Analysis: Theory and Application to Travel Demand*. Cambridge, MA: The MIT Press.

Bay Area Council (1989a). *Housing and Development Report* 2(5).

Bay Area Council (1989b). *Housing and Development Report* 2(6).

Boyce, David E. and Tschangho John Kim. (1987) The Role of

Congestion of Transportation Networks in Urban Location and Travel Choices. *Transportation* 14:53-62.

Brown, Barbara. (1986) Modal Choice, Location Demand and Income. *Journal of Urban Economics* 20(5):128-139.

Brown, H. James. (1975) Changes in Workplace and Residential Location. *Journal of the American Institute of Planners* 41(1):32-39.

California Department of Finance. (1989) Municipal Housing Data Base (magnetic disk).

California Department of Finance (1990). California Statistical Abstract.

California Department of Transportation, Highway Operations Branch. (1981 through 1990) Information Memorandum: Traffic Performance of Bay Area Freeway System. San Francisco.

California Department of Education. (1990) California Assessment Program - 1988-89 Four Year School and District Summary. Computer printout. Sacramento.

Cervero, Robert. (1989a) Jobs-Housing Balancing and Regional Mobility." *Journal of the American Planning Association* 55(2) 136-150.

Cervero, Robert. (1989b) *America's Suburban Centers: The Land Use Transportation Link*. Boston: Unwin Hyman.

Cervero, Robert and John Landis. (1990) Suburbanization of Jobs and the Journey to Work. Manuscript, Department of City and Regional Planning, University of California at Berkeley.

Cervero, Robert. (1986) *Suburban Gridlock*. New Brunswick: Center for Urban Policy Research, Rutgers University.

City of San Ramon, Community Development Department, Planning Services Division. (1990) 1990 Housing Element Update (Draft).

Cremer, Helmuth. (1990) Residential Choice and the Supply of Local Public Goods. *Journal of Urban Economics* 27:168-187.

Daly, Andrew. (1987) Estimating 'Tree' Logit Models.



*Transportation Research Part B: Methodological*. 21B(4):251-267.

Daniels, P. W. (1972a) Transport Changes Generated by Decentralized Offices. *Regional Studies* 6:273-289.

Daniels, P.W. (1972b) *Office Location and the Journey to Work: A Comparative Study of Five Urban Areas*. Kettering, UK: Gower.

Daniels, P.W. (1981) Transport Changes Generated by Decentralized Offices: A Second Survey. *Regional Studies* 15(6):507-520.

Danielson, Michael N. (1976) *The Politics of Exclusion*. New York: Columbia University Press.

De La Barra, Tomás. (1989) *Integrated Land Use and Transportation Modeling: Decision Chains and Hierarchies*. Cambridge, UK: Cambridge University Press.

Department of Commerce, Bureau of the Census (1980). 1980 Census of Population: Characteristics of the Population, United States Summary.

Department of Commerce, Bureau of the Census (1960). 1960 Census of the Population: Volume 1, Characteristics of the Population, Part 1, United States Summary.

Domencich, T. and D. McFadden. (1975) *Urban Travel Demand: A Behavioral Analysis*. Amsterdam: North Holland.

Federal Home Loan Bank Board of San Francisco. (1986, 1987) "Housing Vacancy Survey." various PMSAs.

Federal Highway Administration. (1984) Personal Travel in the United States: 1983-1984 Nationwide Personal Transportation Study.

Feldman, Marshall. (1981) The Political Economy of Class and the Journey to Work. Ph.D. Dissertation, Department of Urban Planning, University of California, Los Angeles.

Fujita, Masahisa. (1986) Urban Land Use Theory. In Gabszewicz, Jean Jaskold, et al., eds. *Location Theory*. Chur, Switzerland: Harwood Academic Publishers.

Fujita, Masahisa. (1985) Towards General Equilibrium Models

of Urban Land Use. *Revue Economique* 36(1):135-167.

Gordon, Peter, Ajay Kumar and Harry W. Richardson. (1987a) Some Urban Travel Surprises. Presented to the 29th Annual Conference of the Association of Collegiate Schools of Planning. Los Angeles, November 1987.

Gordon, Peter and Harry W. Richardson (1987b) "Why Urban Transportation Plans Fail." Manuscript, School of Urban and Regional Planning, University of Southern California.

Gordon, Peter, Ajay Kumar and Harry W. Richardson. (1989) Congestion, Changing Metropolitan Structure and City Size in the United States. *International Regional Science Review* 12(1):45-56.

Gordon, Peter, Ajay Kumar and Harry W. Richardson. (1988) Beyond the Journey to Work. *Transportation Research Part A* 22a(6)419-426.

Guest, Avery M. and Christopher Cluett. (1976) Workplace and Residential Location: A Push-Pull Model. *Journal of Regional Science* 16(3):399-410.

Greenbelt Alliance (1989) Reviving the Sustainable Metropolis: Guiding Bay Area Conservation and Development into the 21st Century. San Francisco.

Gross, David J., C. F. Sirmans and John D. Benjamin (1990) An Empirical Evaluation of the Probabilistic Bid-Rent Model. *Regional Science and Urban Economics* 20(1)103-109.

Halvorson, Peter Leon. (1970) Residential Location and the Journey-to-Work: Charleston, West Virginia. Ph.D. Dissertation, University of Cincinnati.

Harvey, Greig. (1985) Using the Bay Area 1981 Home Interview Survey for Travel and Activity Analysis. Manuscript.

Harvey, Greig. (1988) Residential Location and the Journey to work in Suburban Households. Manuscript, Department of Civil Engineering, Stanford University.

Hausman, J. and D. McFadden. (1984) Specification Tests for the Multinomial Logit Model. *Econometrica* 52:1219-1240.

Hecht, A. (1974) "The Journey-to-Work Distance in Relation to the Socio-Economic Characteristics of Workers." *Canadian*

*Geographer* 18(4):367-378.

Hotelling, Harold (1929) Stability in Competition. *The Economic Journal*, March. pp. 41-57.

Izraeli, Oded and Thomas R. McCarthy. (1985) Variations in Travel Distance, Travel Time and Modal Choice among SMSAs. *Journal of Transport Economics and Policy* 19(2):139-161.

Kain, John. (1962) The Journey to Work as a Determinant of Residential Location. *Papers and Proceedings of the Regional Science Association* Volume 9.

Kroll, Cynthia A. and Elizabeth Morris. (1988) Bay Area Spillover and Other Forces Shaping San Joaquin County. *Quarterly Report 4* (Center for Real Estate and Urban Economics, University of California, Berkeley).

Lerman, Steven R. (1975) A Disaggregate Behavioral Model of Urban Mobility Decisions. Ph.D. Dissertation, Department of Civil Engineering, Massachusetts Institute of Technology.

LeRoy, Stephen F. and Sonstelie, John. (1983) Paradise Lost and Regained: Transportation Innovation, Income and Residential Location. *Journal of Urban Economics* 13:67-89.

Ley, David. (1985) Work-Residence Relations for Head Office Employees in an Inflating Housing Market. *Urban Studies* 22:21-38.

Maddala, G. S. (1983) *Limited-Dependent and Qualitative Variables in Econometrics*. Cambridge, UK: Cambridge University Press.

McFadden, Daniel. (1978) Modelling the Choice of Residential Location. In Anders Karlqvist, et al., eds. *Spatial Interaction Theory and Planning Models*. Amsterdam: North Holland.

Metropolitan Transportation Commission (1981) "1981 Bay Area Travel Survey." Prepared by Crain & Associates, Menlo Park, California.

Muth, Richard F. (1985) Models of Land Use, Housing and Rent: An Evaluation. *Journal of Regional Science* 25(4): 593-606.

Muth, Richard F. (1969) *Cities and Housing*. Chicago: University of Chicago Press.

Nelson, Kristin. (1986) Labor Demand, Labor Supply and the Suburbanization of Low-Wage Office Work. In Scott, Allen J. and Michael Storper, eds. *Production, Work, Territory: The Geographical Anatomy of Industrial Capitalism*. Winchester, MA: Allen & Unwin.

Office of the Attorney General, Department of Justice, Division of Law Enforcement, Identification and Information Branch, Bureau of Criminal Statistics and Special Services (1989). 1988 Criminal Justice Profile: A Supplement to Crime and Delinquency in California. Sacramento.

Ogawa, Hideaki and Masahisa Fujita. (1980) Equilibrium Land Use Patterns in a Nonmonocentric City. *Journal of Regional Science* 20(4):455-475.

Palumbo, George, Seymour Sacks and Michael Wasylenko. (1990) Population Decentralization within Metropolitan Areas: 1970-1980. *Journal of Urban Economics* 27:151-167.

Persky, Joseph. (1990) Suburban Income Inequality: Three Theories and a Few Facts. *Regional Science and Urban Economics*. 20(1)125-137.

Pisarski, Alan E. (1987) Commuting in America: A National Report on Commuting Patterns and Trends. Westport, CT: Eno Foundation for Transportation, Inc.

Pivo, Gary Elliott. (1988) The Urban Form and Journey to Work Impacts of Office Suburbanization in the San Francisco Bay Area. Unpublished Ph.D. dissertation, Department of City and Regional Planning, University of California at Berkeley.

Quigley, John M. (1985) Consumer Choice of Dwelling, Neighborhood and Public Services. *Regional Science and Urban Economics* 15:41-63.

Rosen, Sherwin. (1974) Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy* 82(1):34-55.

Rossi, Peter. (1955) *Why Families Move*. Glencoe, Illinois: The Press, quoted in Peter Leon Halvorson (1970). Residential Location and the Journey-to-Work: Charleston, West Virginia. Ph.D. Dissertation, University of Cincinnati.

Shin, Jung-Chuel. (1985) Residential Location Choice : A Nested Logit Model with Transportation and Housing Characteristics. Ph. D. Dissertation, Department of Civil Engineering, Stanford University.

Stegman, Michael A. (1969) Accessibility Models and Residential Location. *Journal of the American Institute of Planners* 35:22-29.

Straszheim, Mahlon R. (1975) *An Econometric Analysis of the Urban Housing Market*. New York: Columbia University Press.

Sunset Development Company. (1989?) Bishop Ranch. San Ramon, CA.

Tiebout, Charles. (1956) A Pure Theory of Local Expenditures. *Journal of Political Economy* 54:416-424.

Varady, David P. (1990) Influences on the City-Suburban Choice. *Journal of the American Planning Association* 56(1):22-40.

Von Thunen, J. H. (1826) *Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie*, Hamburg. English translation by C. M. Wartenburg (1966), in P. Hall, ed. *Von Thunen's Isolated State*. London: Pergamon Press.

Weiland, Kenneth F. (1987) An Extension of the Monocentric Urban Spatial Equilibrium Model to a Multicenter Setting: The Case of the Two-Center City. *Journal of Urban Economics* 21:259-271.

Weisbrod, Glen E., Steven R. Lerman and Moshe Ben-Akiva (1980). Tradeoffs in Residential Location Decisions: Transportation Versus Other Factors. *Transport Policy and Decision Making: An International Journal* 1(1):13-26.

Wheaton, William. (1979) Monocentric Models of Urban Land Use: Contributions and Criticisms. In Peter Mieszkowski and Mahlon Straszheim, eds. *Current Issues in Urban Economics*. Baltimore: Johns Hopkins University Press.

White, Michelle J. (1988) Location Choice and Commuting Behavior in Cities with Decentralized Employment. *Journal of Urban Economics* 24:129-152.