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Suburban Non-Motorized Access to Transit: A Framework for Evaluation

by

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B.A., Political Science
University of Wisconsin-Madison, 1989

Submitted to the Department of Urban Studies and Planning
in Partial Fulfillment of the Requirements for the Degree of

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ABSTRACT

In recent years, transportation planners and others in the US have focused increasing attention on the potential for non-motorized transport to play a larger role in providing access to suburban high capacity transit (HCT) services. Much of what accounts for this interest has been a change in professional attitudes regarding the relationship between transportation and land uses. Planners, transit officials, developers and others have started to realize that creating compact, mixed-use, traffic-calmed, and pedestrian/bicycle-friendly developed environments in close proximity to HCT services is more conducive to suburban "livability" than previously understood. Moreover, even in transit-served areas where substantially increasing development densities, changing land use mixes, or moderating traffic flows is not possible, planners and others have become interested in how incremental path network restructuring, site re-design, and amenity enhancements can improve non-motorized travel conditions. This, together with the availability of federal funds to develop non-motorized transport infrastructure and to undertake transportation-related environmental "enhancements," has prompted initiation of numerous pedestrian, bicycle and transit-friendly planning, design and development projects in cities across the US.

The ostensible goal of most of these projects is to improve walking and cycling conditions in small geographic areas. The degree to which realization of this goal occurs, however, is often difficult to assess. Planners, urban designers and others simply don't possess the tools required to evaluate non-motorized travel conditions in a clear, consistent and comprehensive fashion. Such tools could potentially improve non-motorized planning, design and investment decisions by identifying non-motorized strengths and weaknesses. This, in turn, could enable discovery of areas that are most in need of improvement, and help draw resources away from areas where they could not be spent effectively.

Given the substantial attention and resources that cities are now devoting to improving non-motorized transit access, a formal framework for evaluating current pedestrian and bicycle travel conditions would be a welcome addition to the stock of available land-use planning and urban design tools. The purpose of this thesis is to develop such a framework.

The design of the framework permits systematic and highly detailed evaluation of current non-motorized travel conditions in small geographic areas. The means by which this is achieved involves application of a set of evaluation criteria. The overall function of these criteria is to describe and analyze how well or poorly physical and institutional characteristics of the areas meet a wide range of complex pedestrian and cyclist needs. Description and analysis of such needs contributes to an improved process for identifying non-motorized improvement options.

Thesis Supervisor: Nigel H.M. Wilson

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CHAPTER ONE: Introduction

1.1 SUBURBAN NON-MOTORIZED TRANSIT ACCESS

In recent years, transportation planners and others in the US have focused increasing attention on the potential for non-motorized transport to play a larger role in providing access to suburban high capacity transit (HCT) services. This new-found interest in walking and cycling represents an important shift in thinking about how transit systems should function in the developed environment.

Traditionally, planners tended to disregard walking and cycling as serious modes of suburban access. Instead, they emphasized access by automobiles and buses. This emphasis was encouraged by federal transportation policy, which for many years provided substantial subsidies to park-and-ride and transit, but not to pedestrian and bicycle improvements (Replogle and Parcells, 1992; Weiner, 1992). As a consequence, pedestrian access tended to receive serious attention only in downtown and some pre-1940 suburban areas. Even in these places, however, planners sometimes expected that shuttles or other forms of motorized access (e.g., personal rapid transit) could someday replace much of the need for walking. Bicycling was rarely, if ever, even considered for access to HCT systems.

Today, however, planners are taking a more balanced approach to suburban HCT access. Park-and-ride and feeder buses are no longer considered the only appropriate forms of interface between HCT services and suburban areas. Walking and cycling are now also coming to be considered more seriously.

Much of what accounts for the shift in thinking toward non-motorized access has been a change in professional attitudes regarding the relationship between transportation and land uses. Planners, transit officials, developers and others have started to realize that creating compact, mixed-use, traffic-calmed, and pedestrian/bicycle-friendly developed environments in close proximity to HCT services is more conducive to suburban “livability” than previously understood (APTA, 1989; Local Government Commission, 1992; Oregon Chapter APA, 1993; Federal Transit Administration, circa 1995; USDOT, 1996; APA, 1996; Project for Public Spaces, 1997). Moreover, even in transit-served areas where substantially increasing development densities, changing land use mixes, or moderating traffic flows is not possible, planners and others have become interested in how incremental path network restructuring, site re-design, and amenity enhancements can improve pedestrian and bicycle travel conditions (Untermann, 1984; Moudon, 1987; Snohomish County Transportation Authority, 1989, 1993). The result has been a substantial increase in pedestrian, bicycle and transit-friendly planning, design and development projects in cities across the US.

The primary goal of most of these projects is to improve walking and cycling conditions in small geographic areas. The degree to which realization of this goal occurs, however, is often difficult to assess. Planners, urban designers and others simply don't possess the tools required to evaluate non-motorized travel conditions in a clear, consistent, and comprehensive fashion. Moreover, aesthetic considerations and issues related to implementability seem to be the primary criteria by which the success of many projects are judged. While both factors are undoubtedly important to project success, other project aspects are important as well.

Clearly, evaluation of existing non-motorized travel conditions should consider as wide a range of travel influences as possible. Lack of wide-ranging consideration of influences could result in failure to satisfy important pedestrian and cyclist needs. Failure to satisfy pedestrian and

cyclist needs, in turn, could result in lower rates of non-motorized travel than under alternative circumstances. This suggests that any framework for evaluating the quality of walking and cycling should be as comprehensive and systematic as possible. In spite of the recent renaissance of interest in non-motorized travel, such a framework has yet to be developed. Given the substantial time, resources, and effort that planners and others are now devoting to improving pedestrian and bicycle travel conditions, some attention should be paid to correcting this deficiency.

1.2 THE RECENT RENAISSANCE OF INTEREST IN NON-MOTORIZED TRAVEL: BACKGROUND AND ISSUES

The difficulties that pedestrians and cyclists have traditionally faced in gaining access to suburban transit reflect a more general non-motorized access problem that has characterized suburban environments since the second world war. Over the past half-century, suburbs have become increasingly oriented towards travel by automobile. This orientation has manifested itself through a variety of physical, institutional, and cultural channels.

Physically, orientation to autos has both encouraged and been encouraged by (1) the development of inwardly focused, hierarchical street networks designed to concentrate through traffic on a relatively small number of arterials; (2) construction of freeways, fences and other barriers to short-distance movement by non-motorized means; (3) the emergence of stand-alone architecture, low development densities, segregated land uses, and vast expanses of surface parking; and (4) the decline in attention to the needs of pedestrians and cyclists in the design of both public and private outdoor spaces.

Institutionally and culturally, orientation to automobiles has both encouraged and been encouraged by (a) zoning ordinances and site-review processes that not only facilitate, but very often require automobile-oriented physical development; (b) traffic ordinances and roadway management practices that tend to neglect or even ignore the needs of users of non-motorized

transportation; (c) organizational cultures in public works and other municipal planning agencies that are focused on meeting the needs of motorists regardless of the consequences to travel by other modes or to neighborhood or site-level “quality of life”; and (d) suburban social cultures that tend to view non-recreational use of streets and other outdoor public spaces with suspicion, fear or disdain.

In recent years, however, a movement to reverse the trend toward suburban automobile primacy has emerged. This movement has grown from public and professional concern over the environmental, fiscal, and social impacts of growing automobile use and dependence. The concern has galvanized support for measures intended to encourage shifts away from autos and toward the pedestrian and bicycle modes for short-distance trips. Creating urban environments that support these modes promises to

- improve local and regional air quality
- reduce land-consumptive sprawl development
- reduce demand for environmentally harmful, socially disruptive, and fiscally burdensome roadway development projects
- help control growth of traffic noise
- improve employment access and overall mobility for persons of limited income
- reduce health care costs (to employers and others) by improving popular health and fitness levels.

Among the more notable achievements of the new movement have been the passage of the federal Americans with Disabilities Act in 1990, the passage of the Intermodal Surface Transportation and Efficiency Act (“ISTEA”) in 1991, and the popularization of the New Urbanist design paradigm. Other achievements include substantial growth in the number of transportation demand management (TDM) programs, pedestrian and bicycle-friendly streetscape and site improvements, traffic-calming projects, and bikeways and trails system development. ISTEA and the New Urbanism, in particular, have offered much promise to those who advocate changing

infrastructure and site development patterns away from strict orientation to automobiles. Also driving these changes, however, has been the growing interest of Americans in health and fitness.

1.2.1 The Americans with Disabilities Act

The Americans with Disabilities Act (ADA) has profoundly affected the way in which cities and developers plan, design, and build outdoor pedestrian infrastructure. Whereas before passage of the act, new facilities could be built without regard to ease of use by the elderly and handicapped, today all new projects must accommodate the special needs of these travelers. Such needs include generous vertical and horizontal pathway clearances, moderation of ramp gradients, curb cuts, special signage, etc. These features make travel by foot easier not only for the elderly and handicapped, but also for everyone.

1.2.2 The ISTEA Legislation

The ISTEA legislation has required transportation planners to consider means of improving integration between urban passenger transportation modes, and to better coordinate transportation and land use planning processes. ISTEA has also made funds available to develop non-traditional alternatives to traffic congestion, improve air quality, and make transportation projects more conducive to improving local quality of life. Both the multimodal and the funding provisions of ISTEA have been of particular importance to the pedestrian and bicycle modes. The multimodal provisions have elevated the status of walking and cycling vis-à-vis the motorized modes, and have galvanized interest in the important land use changes necessary for their success. The funding provisions, in turn, have promoted and sustained walking and cycling by giving cities resources to undertake the infrastructure and amenity improvements required for their support.

1.2.3 The New Urbanism

Proponents of the New Urbanism seek to correct certain aspects of contemporary suburban planning and design that they regard as deficient. These include placelessness, lack of community, poor aesthetic quality, high rates of land consumption, and automobile dependence (Baldassare, 1988; Hough, 1990; Duany & Plater-Zyberk, 1991; Hiss, 1991; Calthorpe, 1993; Katz, 1994; Kunstler, 1994; Langdon, 1994; Adler, 1995). The New Urbanism applies neo-traditional planning and design principles to change the way developers build suburban environments. This encompasses a variety of project types, ranging from infill to greenfield development. Projects which focus explicitly on improving access to public transportation are known as transit villages or transit-oriented developments (TODs).

Transit villages are compact, mixed-use communities built in close proximity to high-capacity transit stations. By design, such villages are intended to invite residents, workers, and shoppers to reduce automobile use and increase transit ridership (Cervero, 1996). This goal is achieved primarily through co-location and concentration of residential, employment and shopping activities within easy walking distance (i.e., no more than approximately 1200 feet) of village core areas. The core areas serve dual roles as community centers and primary transit access points.

Closely related to the concept of the transit village is Peter Calthorpe's concept of the transit-oriented development (TOD). TODs are essentially transit villages surrounded by lower-density peripheral zones (Girling, 1993; Calthorpe, 1993; Christoforidis, 1994; Ryan and McNally, 1995).

Like all neo-traditional developments, transit villages and TODs rely heavily on high levels of outdoor amenity to compensate for high density levels, and to increase the attractiveness of walking and cycling. Potential advantages of such development include (a) reduced reliance on automobiles for short and long distance travel, (b) land conservation, (c) greater sense of

community among residents and workers, and (d) the creation of affordable housing opportunities (Cervero, 1996).

The neo-traditional concept is generally characterized by a strong focus on the importance of streets and other public spaces, human scale, and diversity of land uses in urbanized places. In short, the overarching goal of the New Urbanism is to present historic town-making concepts, appropriately modernized to fit contemporary circumstances, as an ideal form of suburban development. As Calthorpe has noted,

[c]ontemporary suburbs have failed because they lack, as do many of the so-called “modern” new towns and edge cities, the fundamental qualities of real towns: pedestrian scale, an identifiable center and edge, integrated diversity of use and population and defined public space. They may have diversity in use and user, but these diverse elements are segregated by the car. They have none of the places for casual and spontaneous interaction which create vital neighborhoods, quarters or towns. Unless urban infill sites, suburban new development areas and satellite towns embody the qualities of the New Urbanism, they will fail too. In every context, therefore, the quality of new development in a region should follow town-like principles-- housing for a diverse population, a full mix of uses, walkable streets, positive public space, integrated civic and commercial centers, transit orientation and accessible open space. (Calthorpe, 1994)

1.2.4 Transportation Demand Management (TDM) Programs

Transportation demand management programs are employer-managed efforts to reduce single-occupant automobile use. They include providing bicycle parking facilities, showering and changing rooms, various types of traveler information, and incentives to use alternative travel modes.

1.2.5 Pedestrian and Bicycle-Friendly Streetscape and Site Improvements

Pedestrian and bicycle-friendly streetscape and site improvements are intended to enhance the safety, convenience, attractiveness and comfort of non-motorized travel in publicly accessible areas, or along public street segments. Specific project elements may include sidewalk reconstruction and widening, removing property-to-property barriers to non-motorized circulation,

street tree planting, installation of glare-free outdoor lighting, sidewalk furniture placement, and building facade renewal.

1.2.6 Traffic-Calming Projects

Traffic calming is intended primarily to reduce motor vehicle speeds on local streets in order to improve the safety and attractiveness of walking and cycling (Smith, *et al.*, 1980). Other traffic calming goals include reducing vehicle noise and accidents, clarifying the equality of status between different road users (i.e., pedestrians, cyclists, and motorists), and increasing opportunities for landscaping and children's play space on public rights of way. Specific traffic-calming measures include installation of stop and yield signs; reductions in intersection curve radii; and construction of speed humps, speed tables, traffic circles, chicanes, partial or total traffic diverters, and flared curbs (Pinsof & Musser, 1995).

1.2.7 Bikeways and Trails System Development Projects

Bikeways and trails systems consist of stand-alone paths, bicycle lanes and clearly-marked bicycle routes extending continuously in network fashion, often over a distance of many miles. A well-designed bikeway and trail system can potentially improve non-motorized access to HCT services from developed areas located as far as three, four or even five miles from a station.

1.2.8 Health and Fitness

Expression of strong public interest in health and fitness has both enabled political support for development of non-motorized infrastructure, and provided a market for high-quality walking and cycling environments.

1.3 NON-MOTORIZED PLANNING AND DESIGN: THE NEED FOR AN EVALUATION FRAMEWORK

In spite of the recent flurry of activity surrounding the non-motorized modes, there has been surprisingly little interest in developing tools for evaluating the quality of pedestrian and cyclist travel conditions. Such tools could potentially improve non-motorized planning, design and investment decisions by identifying non-motorized strengths and weaknesses in suburban developed environments. Insights derived from such identification could then be used to pinpoint areas within these environments that are most in need of improvement, and draw resources away from areas where they could not be spent as effectively.

The absence of evaluative tools becomes particularly apparent when municipalities or other governmental entities seek to meet the ADA requirements, or spend resources as a result of ISTEA mandates or incentives. Neither ADA nor ISTEA requires that actions taken to improve pedestrian and cyclist travel conditions must be effective at increasing rates of non-motorized travel. Thus, when cities or other entities use federal dollars to improve streetscapes and site conditions, implement traffic-calming measures, or develop bikeways and trail systems, they do not necessarily encourage more walking and cycling. Moreover, partly because of the lack of an evaluative framework, even the use of other forms of public or private funds (e.g., funds from developer exactions) for these purposes does not always produce better results.

Theoretically at least, the New Urbanism promises to solve this problem by avoiding the need for an evaluative framework altogether. The movement offers a kind of “pre-packaged” set of design and development solutions that (ostensibly at least) explicitly recognize the relationship between actions taken to improve walking and cycling conditions (i.e., streetscaping, traffic calming, etc.), and creation of cohesive living and working environments that support alternative forms of travel.

Yet the New Urbanism is not without its own set of problems. First, New Urbanist projects tend to require substantial up-front expenditure on infrastructure. Such expenditure poses substantial financial risk to developers and lenders. Second, the market demand for neo-traditional projects is limited. Many home buyers, home renters, office tenants, and other real estate consumers simply prefer conventional suburban developed environments to New Urbanist neighborhoods. Third, retrofitting existing developed areas along New Urbanist lines can be difficult. The process requires very high levels of cooperation between multiple land owners. Finally, even if New Urbanist projects are brought to completion, they may not, in the end, satisfy important needs of non-motorized travelers.

For example, among the few New Urbanist projects that have actually been brought to completion are Laguna West, California and Kentlands, Maryland. As Southworth (1997) has shown, these projects -- which have received widespread attention as models of good non-motorized planning and design -- fail to satisfy pedestrian needs in many important respects. While both neighborhoods “have a stronger sense of public structure [and]...offer more interesting and cohesive streetscapes” than conventional suburbs, neither

achieves the ease of access to retail and office uses, mix of housing types, pedestrian access to daily needs, and overall connectedness found in many small towns or in the early-twentieth-century streetcar suburbs that the neotraditional models emulate. In many instances, the designers were forced to compromise their conceptions to satisfy existing codes, environmental requirements, and developers’ demands. At minimum, they represent modest improvements over most conventional suburban, planned-unit developments.

Southworth also criticizes the neo-traditional approaches embodied in Laguna West and Kentlands for their superficiality and formulary character. These neo-traditional models, he argues, “are essentially anti-urban, sanitized versions of the small town, and...exclude much of what it takes to make a metropolitan region work.” In practical terms, there is little real population and land use diversity in these places. Moreover, little opportunity exists for evolutionary

development reflecting individual needs and tastes. For many people, such diversity and opportunity may contribute to walking and cycling comfort levels.

In spite of these problems, planning professionals and others may be tempted to look toward the New Urbanist approach as a kind of “universal” standard by which to judge non-motorized travel conditions in existing developed environments. This would pose a problem because areas not likely to be re-developed according to strict New Urbanist planning and design principles would be ignored.

One means of avoiding this problem is to rely on a more paradigm-neutral framework for evaluating the quality of non-motorized travel. This framework should be based on a solid and comprehensive understanding of pedestrian and cyclist needs.

1.4 REQUIREMENTS OF A SUCCESSFUL EVALUATION FRAMEWORK

Development of a successful framework for evaluating current non-motorized travel conditions in small geographic areas has two primary requirements. First, a clear theoretical and empirical understanding of the many factors that influence willingness to travel by foot and bicycle is required. These factors include indirect influences such as street network structure, travel barriers, population and employment densities, and land use mix, as well as more direct influences such as age, income, vehicle ownership, climate, etc. Given a solid understanding of behavioral influences, it becomes possible to structure the evaluation framework to consider fully how different aspects of a developed environment may affect travel choices.

The second requirement involves recognizing the critical role played by travel distance in influencing pedestrian and cyclist behavior. While ostensibly obvious, this point is overlooked surprisingly often in planning and design processes. As discussed previously in the context of the Laguna West and Kentlands developments, projects designed to be pedestrian and bicycle-friendly

often do not actually end up being so. Travel distances in these cases are simply too great to make walking and cycling a reasonable option for most people. A good evaluation framework would provide a means of correcting this problem.

1.5 DEVELOPMENT OF AN EVALUATION FRAMEWORK: THE PURPOSE OF THE THESIS

Given the substantial attention and resources that cities are now devoting to improving non-motorized transit access, a formal framework for evaluating current pedestrian and bicycle travel conditions would be a welcome addition to the stock of available land-use planning and urban design tools. The purpose of this thesis is to develop such a framework.

The design of the framework permits systematic, comprehensive, and highly detailed evaluation of current non-motorized conditions in small geographic areas. Systematization ensures that the evaluation will be internally consistent. Comprehensiveness ensures that all possible factors that might influence individual decisions to travel by foot or bicycle are considered. Finally, high levels of detail are necessary to understand how physical characteristics affect pedestrian and cyclist needs. This is because low travel speeds, the physical burden of non-motorized travel, and potential threats of exposure to the elements, speeding cars, and crime make pedestrians and cyclists very sensitive to small variations in their travel environment.

In sum, the overall function of the evaluation framework is to describe and analyze how well or poorly physical and institutional characteristics of an area meet a wide range of complex pedestrian and cyclist needs. In this respect, the framework departs substantially from current planning and design practice, which tends to consider these needs in a piecemeal and less explicit manner.

1.6 THESIS STRUCTURE

The structure of the thesis is as follows. Chapter Two reviews theoretical and empirical research on relationships between willingness to use a non-motorized mode and three indirect classes of influence: (1) path network structure and travel distance, (2) population and employment densities, and (3) land use mixing. The purpose of this review is threefold. First, the review introduces the reader to important concepts and terms necessary to understand and discuss pedestrian and cyclist planning and design issues. Second, it provides a theoretical and empirical foundation upon which assertions made in Chapters Five and Six will rest. Finally, the review places the thesis in the context of existing research.

Chapter Three accomplishes two tasks. The first task is to review empirical literature that investigates more direct influences on walking and cycling. The second task is to hypothesize associations between non-motorized behavior and the potential direct influences that are not considered in the empirical literature. These tasks accomplish the same purposes as those of Chapter Two.

Chapter Four develops efficiency measures for pedestrian and bicycle path networks. Here, efficiency is defined in terms of the divergence of airline and shortest-path distances between origin-destination pairs. The purpose of these measures is to support the evaluation process by providing a means of assessing how well or poorly network conditions satisfy pedestrian and cyclist needs for the shortest possible travel distances.

Chapter Five represents the heart of the thesis. It focuses on development of a systematic approach to evaluating current pedestrian and bicycle travel conditions in employment-oriented suburban HCT station areas. Purposes of the approach include (1) characterizing the overall potential for the pedestrian and bicycle modes to satisfy the commuting, shopping and other travel needs of residents, employees and visitors in high-capacity transit station areas; (2) identifying

specific problem areas; and (3) outlining potential problem solutions. The theoretical and empirical foundations of the approach are derived from the material of Chapters Two and Three. At the heart of the approach lies a set of structured evaluation criteria. Support tools for the application of these criteria include (a) network efficiency measures described and developed in Chapter Four; (b) systems for mapping, coding and classifying pedestrian paths, bicycle paths and crosswalks contained in Appendices C, D, and E; and (c) a system for mapping and coding travel barriers contained in Appendix F.

Chapter Six demonstrates the evaluation approach with a case study of a station area located on the Santa Clara County (San Jose) light rail system. This case study includes detailed background on the station area's salient features, as well as profiles of indirect and direct influences. These are used as a foundation for application of the evaluation criteria. The evaluation criteria are used to identify possible changes to pedestrian and bicycle path network configurations, urban environmental conditions, and traveler support features in the study area that hold potential for improving non-motorized travel.

Finally, Chapter Seven concludes the thesis by reviewing its purpose and scope; considering the utility of the evaluation approach based on the experience of the case study; considering the resource demands of the evaluation process; discussing the generalizable findings of the case study; and suggesting ways in which the evaluation approach might be improved.

CHAPTER TWO: Indirect Influences on Non-Motorized Mode Use: A Literature Review

Pedestrians and cyclists face numerous difficulties traveling in suburban areas. These difficulties can be generally attributed to three environmental characteristics: (1) inadequate pedestrian and bicycle path infrastructure, (2) low development densities, and (3) coarse-grained land use mixes. In recent years, researchers have focused much attention on relationships between these characteristics and travel behavior. The result has been a substantial body of theoretical and empirical literature. This literature is reviewed in this chapter.

The purpose of this review is threefold. First, the review introduces the reader to important concepts and terms necessary to understand and discuss pedestrian and cyclist planning and design issues. Second, it provides a theoretical and empirical foundation upon which assertions made in Chapters Five and Six will rest. Finally, the review places the thesis in the context of existing research.

The chapter's organization is as follows. Section 2.1 examines issues related to the relationship between travel distance and the willingness to travel by foot and bicycle. These issues include, in particular, the effects of path network configuration and physical barriers to non-motorized travel on travel behavior. Sections 2.2 and 2.3 discuss the roles of suburban density and land use mix, respectively.

2.1 SUBURBAN PEDESTRIAN AND BICYCLE ACCESSIBILITY

Poor pedestrian and bicycle accessibility represents an important factor accounting for the low rates of foot and bicycle travel in the suburbs. When used to describe a geographic area, accessibility refers to the ease with which people may travel by a particular mode (auto, transit, foot, bicycle, etc.) between different points in space relative to the distribution of residential, employment, retail, educational, or other activity sites (Manheim, 1979; Pooler, 1995). For empirical research and analysis, accessibility can be defined precisely. Over the past several decades researchers have used a variety of accessibility measures for many different purposes.

The importance of accessibility in understanding individual pedestrian and bicycle travel choices relates to the high sensitivity of these modes to distance. The literature reviewed in this section suggests that pedestrian travel rates decline sharply with small changes in distance between travel origins and destinations. What little data exists on bicycle travel behavior indicates that most trips by this mode probably fall within the 2000-to-6000-foot distance range. Trips as long as two or three miles may be common as well, however.

In addition to the relative locations of trip origins and destinations in space, pedestrian and bicycle travel distances are determined by (1) the configuration of street and path networks; and (2) the location and character of physical barriers (i.e., busy streets, fences, hedgerows, etc.) to non-motorized travel. Thus, a full understanding of the linkages between pedestrian/ bicycle accessibility and suburban non-motorized travel behavior also requires understanding the potential influences of these two factors.

In general, researchers have found that street and path network configuration can affect accessibility through the degree to which

- streets and paths (for pedestrians or cyclists) offer direct rather than circuitous routes between origin-destination pairs
- important streets and paths focus on major activity sites
- path systems are continuous

- access into the network from external locations is possible
- the number and configuration of street and path intersections provide travelers with route choices
- closed loops and cul-de-sacs are present
- blocks created by streets and paths are minimized in size.

Physical barriers, in turn, can affect accessibility by

- increasing the circuitry of travel between origin-destination pairs
- prohibiting travel by certain groups (e.g., the elderly and handicapped)
- prohibiting or complicating casual development of short cuts or other informal paths by pedestrians and cyclists.

2.1.1 The Effects of Distance on Pedestrian Trip-Making

The empirical literature on relationships between distance and pedestrian travel for access to transit is surprisingly large. Less extensive is the literature on relationships between distance and pedestrian travel for general purposes.

Trip-Making for General Purposes. In an investigation of the influence of demographic and land-use variables on mode choice, Kockelman (1997) found that accessibility, measured in terms of the number of sales and service jobs within a 30-minute radius of travel origins and destinations, can exert a powerful influence on the choice to walk or ride a bicycle for general purposes. At the median value of an accessibility index computed for points in the San Francisco Bay Area, elasticity with respect to a binary walk/bike mode-choice variable (i.e., a variable in which a value of 1 signified a trip made by foot or bicycle) equaled 0.22. For this analysis, Kockelman relied on an exponential time function with coefficients estimated by Levinson & Kumar (1994).

A well-known work in the area of pedestrian travel for general purposes is Untermann's (1984) frequently-cited book on adapting towns and neighborhoods to non-motorized transport. His central claim is that, while Americans will generally walk no more than 2300 feet for any

purpose, pedestrian travel distances can be increased through better design of pathways and other public spaces.

Trip-Making for Transit Access. This 2300-foot distance is approximately what other researchers have found to be a maximum walking distance for access to bus transit. For access to rail systems, maximum walking distance appears to be somewhat longer.

Lam & Morrall's (1982) examination of bus-rider behavior in Calgary, Alberta used survey data to determine, among other things, how far riders walked to and from a bus stop, how fast riders walked, and the degree to which riders' actual travel routes deviated from the airline distance between the bus stop and the origin or destination. For walking distance, they found an overall summertime average of 1056 feet. The summertime overall median walking distance was 922 feet, while the 25th, 75th, and 95th percentiles were approximately 605, 1385, and 2250 feet, respectively. Average summertime walking distance in suburban residential areas (where buses ran at headways of between five and eight minutes) was approximately 1225 feet, while average summertime walking distance in industrial areas (where buses ran at 30-minute headways) was approximately 565 feet. For walking speed, Lam & Morrall found that people walked an average of about 262 feet per minute. Finally, for travel-route deviation, they found the following summertime "detour factors" (equivalent to ratios between actual walking distances and airline distances): 1.18 (city-wide), 1.24 (suburban residential), 1.15 (central business district), and 1.06 (industrial areas). Their explanation for the strong difference between average detour factors in residential and industrial areas is that "pedestrian trips in residential areas are confined to streets, sidewalk, and back lanes, while pedestrian trips in industrial areas are made directly across parking lots and fields."

In a recent follow-up to the Lam & Morrall study reviewed in the preceding paragraph, O'Sullivan & Morrall (1996) investigated the pedestrian behavior of Calgary's light rail users. Overall, they found an average walking distance to LRT stations of about 1385 feet. In the CBD this figure averaged about 1070 feet, while in the suburbs it averaged about 2135 feet. The suburban median walking distance was approximately 1770 feet, while the 25th, 75th, and 95th percentiles were approximately 900, 2705, and 4600 feet, respectively. There were no statistically significant differences between men's and women's walking distances. The average detour (i.e., circuitry) factor for all stations was found to be 1.24. Citing Vuchic & Kikuchi (1982), the authors recommend as a pedestrian planning guideline that the detour factor for walkways leading to and from LRT stations not exceed 1.2. By comparison, in pure orthogonal street environments, the maximum detour factor is 1.414. O'Sullivan and Morrall note that 13-percent of walking trips to and from suburban stations exceeded this maximum level; while in the CBD only 6-percent of trips did.

Studies conducted by JHK & Associates (1987, 1989) of the Washington Metrorail system found that transit (bus and rail) use rates declined about 0.65 percentage points for every 100-foot increase in the distance between a Metrorail station entrance and a residential site. For close-in sites, most access was by foot. Stringham (1982) found that, for distances up to about 3200 feet, walking constituted the dominant mode of access to Toronto subway and Edmonton light rail lines for people living near stations on these systems. He found the maximum walking distance to be approximately 4000 feet.

In a study of medium to high-density suburban housing located near stations on five rail systems in California, Cervero (1994a) found that, on average, rail mode share declined by approximately 0.85 percentage points for every 100-foot increase in the distance between a station and a site. Eighty-eight percent of respondents to the survey conducted for this study said they

used walking as the mode of access from home to station. In a related study, Cervero (1994b) found similar results for access to rail-oriented suburban and non-suburban office complexes in California. All other things being equal, the likelihood of workers commuting by rail decreased with the distance between an office and the nearest station. This relationship followed a hyperbolic form in which rail share fell by about eight percent for every 10-percent increase in distance. The overwhelming majority of workers walked between station and office.

One of the most ambitious investigations of pedestrian access to rail transit was undertaken by researchers for a Transit Cooperative Research Program (TCRP) report on relationships between transit and urban form (Parsons Brinckerhoff, 1996). Part of this study involved examination of access to the BART system in the San Francisco Bay Area. For BART stations serving suburban activity centers and having large park-and-ride lots, they found that walking is the dominant mode of home-to-station access for distances up to about 2700 feet. At a distance of 660 feet, approximately 68-percent of BART users walked to a station; while at distances of 1320, 1980, 2640, 3300, 3960 and 4620 feet approximately 63, 51, 33, 20, 10, and 5 percent, respectively, of users walked. For the same stations, the researchers found that walking is the dominant mode of station-to-work travel for distances up to about 3000 feet. Beyond this distance, more travelers used connecting transit services than walked. At a distance of 660 feet, approximately 93-percent of BART users walked from a station to work; while at distances of 1320, 1980, 2640, 3300, 3960 and 4620 feet, approximately 92, 93, 80, 48, 17, and 12 percent, respectively, of users walked. All of these distances, however, are straight-line distances. This implies that actual travel distances (via streets and pathways) may be somewhat longer than suggested.

2.1.2 The Effects of Distance on Bicycle Trip-Making

One of the few studies that has considered bicycle access to rail transit is the TCRP study (Parsons Brinckerhoff, 1996) cited in the preceding section. Researchers working on this project found that, for BART stations serving suburban activity centers, bicycling accounts for approximately two-to-three percent of home-to-station access trips for distances of about 2000-to-5280 feet. Bicycling's share of access trips for other distances is negligible, with the possible exception of trips in the two to three mile range. In this case, however, bicycling's share does not exceed about two percent. For station-to-work travel, bicycling seems to account for about three to five percent of trips over very short distances (i.e., less than 700 feet), and a similar percentage for distances of about a mile.

2.1.3 The Role of Street and Path Network Configuration

In recent years, researchers in the planning and architecture fields have focused increasing attention on relationships between accessibility and suburban street and path network configuration. In a study of suburban evolution, Southworth & Owens (1993) applied a comparative case study framework to investigate patterns of growth, land uses, and street layout in the San Francisco Bay Area. Of particular interest was the role that network configuration plays in enabling non-motorized travel and multiple uses for streets in primarily residential environments. Among the contributions of their research is a set of organizing principles and spatial/ street typologies for suburban development at three scales: community, neighborhood and street/ house lot.

At the community scale, Southworth & Owens identified five street network types (speculative grid, interrupted parallels, incremental infill, loops and lollipops, and a hybrid). the

evolution of which, they argued, corresponds to increasing self-containment in suburban planning and design. They claimed that this self-containment has “eroded the integrity of the public street framework and severed connections between neighborhoods.”

At the neighborhood scale, Southworth & Owens again noted the importance of street network configuration, and identified several aspects of street patterns that “contribute to the quality and character of a neighborhood.” These include length of street segments; the number of intersections, cul-de-sacs, and loops per unit area of land; and the degree of interconnectedness between neighborhoods. They observed that, over time, neighborhood street patterns have tended to become “increasingly disconnected (more cul-de-sacs and loops, fewer through streets), curvilinear, and organized in self-contained units with few points of access.” Similar to their community-scale analysis, they identified five pattern types (the gridiron, fragmented parallels, warped parallels, loops and lollipops, and lollipops on a stick), the evolution of which represents a “transition from open and interconnected street patterns to more closed and discontinuous ones.”

Finally, at the scale of individual streets, lots and houses, Southworth & Owens noted several trends injurious to pedestrians and cyclists:

- road widths have increased over time, resulting in faster automobile travel speeds and less sense of street enclosure;
- street amenities, such as street trees, have generally disappeared;
- lot widths have generally increased over time and lots have become more uniform in size, resulting in a diluted sense of street enclosure and “much lower levels of spatial variety and visual interest”; and
- the “long” edges of houses have been built parallel rather than perpendicular to streets, resulting in “further dissolution” of a sense of street enclosure.

In an on-going investigation of associations between pedestrian travel frequency and street and path network configuration in the Seattle area, Moudon, *et al.* (1997) are comparing residential neighborhoods on the basis of general street network type, general qualities of the pedestrian environment, the extent and completeness of pedestrian facilities, and pedestrian route

directness. So far, the study has focused on two specific neighborhoods: Wallingford and Crossroads. Wallingford is a pre-World War Two rectilinear grid neighborhood characterized by small block sizes, relatively narrow roads, abundant sidewalks, and strong separation of pedestrians from moving traffic (provided by street trees, planting strips, and on-street parking). Crossroads, by contrast, is a curvilinear neighborhood with qualities nearly the opposite of Wallingford.

To compare inter-neighborhood differences in “extent” of pedestrian facilities, Moudon, *et al.* are measuring total miles of public sidewalks in each neighborhood. To compare differences in “completeness” of facilities, they are using two measures: (1) the ratio of total sidewalk length to total block frontage (where a 1:1 ratio is generally considered optimal); and (2) an indicator of path “fragmentation” (still under development as of January 1997) that considers the number and length of sidewalk segments per block front. Finally, to compare inter-neighborhood differences in pedestrian route “directness”, they are computing detour factors (i.e., ratios of actual to straight-line distances) between the commercial centers of each neighborhood and a sample of points in the surrounding residential areas. Citing an earlier finding by one of the co-authors, Hess (1994), Moudon, *et al.* note that path network configuration can significantly affect the “pedestrian market” of a neighborhood commercial center. For example, in an examination of paths leading from the commercial center to a sample of 32 points in the residential area of the Wallingford (grid) neighborhood, Hess found an average detour factor of 1.18. By comparison, the average detour factor in the Crossroads (curvilinear) neighborhood was 1.65. Furthermore, of the points sampled in Wallingford, almost 94-percent corresponded with residential uses, and half were associated with the optimal 1.00 detour factor. In Crossroads only 63-percent of points sampled were residential, the rest being parking lots, open space or other commercial locations.

Hess also plotted half-mile walk-distance contours for the two study neighborhoods. In Wallingford, he found that 67-percent of the land area was within a half-mile of the neighborhood commercial center. In Crossroads, by contrast, only 45-percent of land area was within this distance. Moreover, the very symmetric and uniform street pattern of Wallingford meant that the neighborhood's walk-distance contour was also very symmetric and uniform (the contour assumed the diamond-shaped pattern characteristic of rectilinear grid networks). In the Crossroads case, irregular block sizes produced a very unevenly distributed contour in which some residential areas clearly had better access to the commercial center than others, even where straight-line distances to the center were equal.

2.1.4 The Role of Physical Barriers to Non-Motorized Travel

As noted earlier in this chapter, physical barriers such as busy streets, fences, hedgerows, etc. can affect accessibility by increasing the circuitry of travel between origin-destination pairs; prohibiting travel by certain groups (e.g., the elderly and handicapped); and preventing casual development of short cuts and other informal paths by pedestrians and cyclists. In spite of this potential for influencing rates of walking and bicycling, few -- if any -- researchers have ever investigated the effects of barriers in a systematic manner.

2.2 SUBURBAN DENSITY

The effect of population and employment density on travel behavior has long been a subject of interest to transportation researchers. Twenty years ago, Pushkarev & Zupan (1977) argued that density plays an important role in generating high rates of transit use. Newman & Kenworthy (1989) focused on the relationship between density and urban energy consumption, arguing that the negative association between the two is due primarily to different rates of

automobile, transit, and non-motorized mode use between cities analyzed. Finally, Holtzclaw (1990) found that rates of transit-riding and non-motorized mode use rise with neighborhood density.

While each of these studies represents an important contribution to the literature on suburban travel behavior, they are open to substantial criticism on a number of grounds, including: (1) failure to analyze relationships between density and travel behavior at a disaggregate level; (2) failure to consider spatial relationships between different land uses in a systematic manner; and (3) failure to control adequately for the effects of the socioeconomic and demographic characteristics of travelers (Steiner, 1994). Moreover, as Kockelman (1997) has pointed out, the statistical significance of density found in many studies “may be almost entirely due to its strengths as a *proxy* variable for many difficult-to-observe variables that affect travel behavior.” Such variables include accessibility, parking costs and availability, traffic congestion, and transit service levels. In most recent studies researchers have generally sought to avoid the problems noted by Steiner, and to move away from the simplistic uses of density as an explanatory variable.

In an investigation of travel behavior in the Seattle area, Frank & Pivo (1994) hypothesized that:

- statistically significant relationships exist between urban form (i.e., land use density and mix) and travel behavior;
- statistically significant relationships exist between urban form variables and mode choice when non-urban form factors are controlled;
- a stronger relationship exists between mode choice and urban-form characteristics when they are measured at both trip ends than at one trip end; and
- the relationship between population density, employment density, and mode choice is non-linear.

To test the first hypothesis, they examined simple linear correlation coefficients at the census tract level, finding statistically significant relationships between employment density (i.e., employees per unit area) and rates of SOV use, transit riding, and walking for both work and

shopping trips. While no statistically significant relationships existed between population density and SOV use for either work or shopping trips, such relationships did exist for transit riding and walking.

To test the second hypothesis they used multivariate regression, entering non-urban form factors (e.g., age of traveler, vehicle ownership level, etc.) into the analysis before entering urban-form variables in a step-wise fashion. In general, they found a consistent association between tract-level urban form variables and rates of transit riding and walking. For transit riding, a strong positive relationship appeared to exist with employment density for both work and shopping trips. Walking appeared to be strongly and positively related to employment density for work trips, and to population density for both work and shopping trips. Rates of SOV use were found to be negatively related to employment density. The strongest link between an urban-form and mode-choice variable related to employment density and transit riding for work trips. The greatest effect of population density was on rates of walking trips for both work and shopping.

In testing the third hypothesis, Frank & Pivo provided some confirmation that mode choice and urban-form variables are more strongly related when measured at both rather than only one trip end. This applied only in certain instances, however. Average origin-destination employment density was found to provide the most explanatory power over variation in (a) transit riding for work and shopping trips; (b) walking for work and shopping trips; and (c) SOV use for work trips.

Finally, to test their fourth hypothesis, Frank & Pivo sought to identify thresholds where shifts from SOV use to transit riding and walking occur as a function of employment and population density. Their findings suggest that significant shifts away from SOV use and towards both transit riding and walking occur at two employment-density thresholds: 20-to-75 employees per acre, and more-than-125 employees per acre. Over the 0-to-20 and 75-to-125 employees per acre ranges, transit and walking mode shares are relatively constant. For shopping trips, Frank &

Pivo's analysis suggests that population densities must exceed approximately 13 residents, or seven to nine dwelling units, per gross acre before significant shifts will occur away from SOV commuting.

Cervero & Gorham's (1995) study of travel behavior in California transit and automobile-oriented residential neighborhoods also suggests an influence of density on travel behavior. In this study, which was designed to test the joint effect of density and street pattern on travel behavior, the researchers compared higher-density, rectilinear grid (or transit-oriented) neighborhoods to lower-density neighborhoods with automobile-oriented street patterns. Matching seven neighborhood pairs in the San Francisco Bay Area on the basis of four control criteria (median household income, transit service types and intensities, topography, and relative location), they found lower drive-alone and higher pedestrian/ bicycle work-trip modal shares and trip generation rates in the transit than in the automobile neighborhoods. Pair-wise differences in the drive-alone mode shares ranged from 4 to 17.5 percentage points. For transit and pedestrian work trips, the differences ranged from 0.7 to 5.3 and from 1.2 to 13.4 percentage points, respectively. The pair-wise differences for trip generation rates ranged from 37 to 483 trips per thousand housing units in the case of drive-alone commuting, from 5 to 129 trips per thousand housing units in the case of transit commuting, and from 23 to 142 trips per thousand housing units in the case of pedestrian commuting. On average, the Bay Area transit-oriented neighborhoods generated about 70-percent more transit trips and 120-percent more pedestrian/bicycle trips than the nearby automobile-oriented neighborhoods.

For matched neighborhoods in the Los Angeles area, Cervero & Gorham found pair-wise differences in drive-alone mode shares ranging from 0.6 to 14.3 percentage points. For transit and pedestrian work trips, the differences ranged from 1.2 to 7.8 and from 1.7 to 24.6 percentage points, respectively. The pair-wise differences for trip generation rates ranged from 42 to 279 trips

per thousand housing units in the case of drive-alone commuting, from 15 to 191 trips per thousand housing units in the case of transit commuting, and from 1 to 179 trips per thousand housing units in the case of pedestrian commuting.

Controlling for household size and income levels, Ewing, *et al.* (1994) examined differences in travel-behavior patterns between traditional and automobile-oriented communities in Palm Beach County, Florida. The two community types were contrasted on the basis of attributes such as density, street patterns, and accessibility to local and regional travel destinations. While inter-community differences in rates of walking/ bicycling, transit riding, and automobile use were found to exist, Ewing, *et al.* argue that these differences are of no real significance. Of the six communities studied, the most traditional was characterized by very low transit and walking/bicycling mode shares (of only about 2-percent each). SOV mode share, by contrast, was about 50-percent, with carpooling accounting for the remaining 46-or-so percent. In the most automobile-oriented of the communities, transit and walking/bicycling mode shares were nearly zero and the SOV share was 56-percent. More significant than the differences in mode shares, they found, are inter-community differences in automobile trip-generation rates, trip purposes, and travel times. Such differences relate to differential levels of regional access to retail, employment and other activities. Because access to such activities is generally good in the more-traditional communities, individual trips by car in those places can be shorter and serve relatively more purposes than trips in the access-poor, auto-oriented areas. Thus, as Ewing (1995) argued in a follow-up study to Ewing, *et al.*, accessibility “has much more effect on household travel patterns than...density or land use mix in the immediate area.”

2.3 LAND USE MIX

The tendency over the course of this century toward the segregation of land uses has been well studied and documented. Accompanying this segregation has been a reorientation of building design towards access by automobile, the consolidation of neighborhood-scale land uses (e.g., grocery stores) into increasingly larger individual units, and a general increase in travel distances between land uses of both the same and different types. One result has been substantial diminution in personal ability to travel by foot or bicycle for commuting and general purposes.

In most contemporary suburban environments, residential neighborhoods are located too far from work sites, shopping locations, services, and other activities for walking and bicycling to be feasible. Around work sites, employees often experience difficulty walking or bicycling to restaurants, banks, drug stores or other mid-day trip destinations; given the limited time available during lunch or other breaks, these uses are simply too distant to make non-motorized transport a practical option. Moreover, in both residential and employment areas, the relative locations of different uses often complicate pedestrian and bicycle trip chaining, or make it virtually impossible.

For access to rail transit, the ability to chain trips may be of particular importance to an individual's choice to travel by foot and bicycle. In general, where a person has the ability to stop off at a cafe, dry cleaning establishment, day care center, health club or other intermediate destination on the way to or from a station, he or she may be more willing to use a transit service. If a station is located within walking or bicycling distance of home or work, and if visiting intermediate destinations does not require substantial deviation from the otherwise shortest path to the station, then he or she may be more willing to gain access to the transit service by non-motorized means.

Since at least the 1980s, researchers have focused much attention on relationships between land-use mix and travel behavior. In a study of trip-chaining behavior in Brentwood, Tennessee (a suburban employment center near Nashville), Davidson (1991) found evidence that providing various services at or near employer sites could replace the need for employees to make stopovers on the way to or from work, thus facilitating ride-sharing and other forms of non-SOV transportation. The services include postal, banking, restaurant, general retail, convenience shopping, dry cleaning, child-care, doctor, dental, and exercise.

Cervero (1989) hypothesized that land use mix plays a particularly important role in influencing travel behavior in large suburban employment centers. Using an areal entropy measure, he found a generally negative association between mix and rates of SOV travel.

Frank & Pivo (1994) used the same entropy measure to examine the effects of mix on travel behavior in the Seattle region. Looking at simple linear correlation coefficients at the census tract level, they found that the degree to which mixing occurred among seven land use categories was significantly related to SOV use, transit riding and walking for work trips. For shopping trips, however, they found no correlation. Using linear regression Frank & Pivo found that, with the exception of walking for work trips, mix had a weak effect on mode choice.

Kockelman (1997) analyzed the effects of land use mix using three different measures: (1) tract-confined entropy; (2) “mean” entropy; and (3) a dissimilarity index. Tract-confined entropy was simply the measure Cervero used in his analysis of suburban employment centers. Mean entropy, by contrast, was an average of “neighborhood” entropies computed for all developed hectares within each census tract (where a neighborhood was defined to include the developed area within a half-mile radius of each hectare). Finally, the dissimilarity index was calculated by awarding points to each actively developed hectare on the basis of dissimilarity between its land use and the land uses of the eight adjacent hectares, and summing the points awarded over all

hectares. The dissimilarity index assumed two forms: “general mix” and “detailed mix”. The general mix index considered four distinct land use types: residential, commercial (including industrial and office), educational, and outdoor recreational. The detailed mix index included eleven distinct types: residential, educational, commercial outdoor recreational (e.g., stadiums and golf courses), religious, general and retail commercial, travel (e.g., hotels and convention centers), offices and research park, industrial, airport, and military.

When used as variables in linear regression models, Kockelman found

- negative association between VMT per household and the mean entropy and general mix measures;
- negative association between non-work home-based VMT per household and the general mix and mean (non-work) entropy measures;
- negative association between auto ownership and the general mix and tract-confined entropy measures; and
- positive association between walking/ bicycling and the mean (non-work) entropy measure for both the origin and destination of trips.

CHAPTER THREE: Direct Influences on Non-Motorized Mode Use

In addition to considering indirect influences on non-motorized travel, station-area planners should consider direct influences. A solid theoretical and empirical understanding of such influences is key to identifying characteristics of suburban work environments that may influence mode choices for transit access or for mid-day trips. Identification of walk and bicycle-supportive suburban characteristics, in turn, enables design of access systems with maximum potential for increased rates of non-motorized transport.

Categories of direct influence include:

- the personal characteristics of travelers
- trip-specific factors
- environmental conditions
- factors involving use of the outdoor public realm
- bicycle-specific factors

This chapter accomplishes two tasks. The first task is to review empirical literature that investigates direct influences on walking and cycling. The second task is to hypothesize associations between non-motorized behavior and the potential direct influences that are not considered in the empirical literature. These tasks accomplish the same purposes as those of Chapter Two.

3.1 PERSONAL AND HOUSEHOLD CHARACTERISTICS OF TRAVELERS

All other things being equal, we should expect a strong association between the personal and household characteristics of individuals and the likelihood of using a non-motorized mode. In particular, we might expect gender, age, physical condition, marital status, parental status, occupation, income, education, and auto-ownership level to be particularly influential variables.

3.1.1 Gender

In general, men are more likely than women both to walk and to ride bicycles (Kockelman, 1997; Loutzenheiser, 1997). Moreover, men are probably less sensitive to travel distances for all types of trips by both modes. Much of this gender difference is probably related to differential concerns over personal security when individuals must walk or bicycle alone or at night.

3.1.2 Age

For persons of working age, there is probably no strong relationship between age and (a) rates of walking for non-recreational trips, and (b) distance traveled for all types of trips made by foot. Younger persons may have more time and energy to walk, but older persons may be more inclined to walk for health reasons. The same relationship is not likely to hold, however, for (c) overall tolerance to factors that may inhibit walking (e.g., poor path quality, presence of slopes, busy streets, etc.). In this case, it seems reasonable to assume that there is a negative relationship with age. Finally, for persons age 65 and over, a negative relationship almost certainly exists with respect to all three of the factors discussed here.

For travel by bicycle, however, the situation is entirely different. Age is a very powerful predictor of individual decisions to commute to work by this mode. According to 1990 census data, persons age 15-to-24 are about twice as likely to commute by bike as persons age 25-to-34,

and about three to five times as likely to commute by bike as persons age 35 and above (Williams & Larson, 1996). While the growth of interest in health and fitness, coupled with newer and better bicycle designs, may have galvanized much interest in bicycling among older age groups in recent years, most of this interest may be focused on recreational use of bikes.

3.1.3 Physical Condition

The sensitivity of individuals to the physical exertion required by walking and bicycling should increase with body-weight-to-height ratios, and decrease with overall health and personal mobility.

3.1.4 Marital Status

Bicycle commuters tend to be single, even when controlling for age (Williams & Larson, 1996).

3.1.5 Parental Status

Persons responsible for the care of children are probably less likely to choose walking as a mode of travel for non-recreational, home-based trips. Parental status should not be associated with walking for work-based mid-day travel.

While persons responsible for the care of children are probably less likely to choose bicycling for non-recreational, home-based trips than persons without such responsibility, the difference in likelihood is probably not as great as in the case of walking. This is because children can more easily accompany parents by riding in bicycle child seats or trailers. Parental status should not be associated with bicycling for work-based mid-day travel.

3.1.6 Race and Ethnicity

According to national 1990 US census data, blacks are least likely to commute by bicycle. Whites are about 1.5 times more likely than blacks to ride a bike, while Asian/Pacific Islanders and Native Americans are about 1.8 and 2.1 times more likely than blacks, respectively. Hispanics, the group most likely to commute by bicycle, are about 2.3 times more likely than blacks to ride a bike (Williams & Larson, 1996).

3.1.7 Occupation

Persons with time-sensitive or auto-dependent occupations are probably less likely to walk or bicycle to and from work or at mid-day than persons with less time-sensitive or auto-dependent occupations. Here, “time-sensitive” generally means that the person must be available “on-call” (e.g., doctors, some types of maintenance workers, etc.). “Auto-dependent” means that the person must have access to a motor vehicle in order to accomplish his or her job.

Part-time workers are more likely than full-time workers to commute by bicycle (Williams & Larson, 1996).

3.1.8 Income

The relationship between household income and rates at which people choose walking as a mode of travel for non-recreational trips appears to be rather ambiguous (Kockelman, 1997; Loutzenheiser, 1997). While lower-income persons may have a cost incentive to walk, higher-income persons may have a greater interest in (a) health and fitness, and (b) environmentally “friendly” transportation. For distance traveled, there is probably a negative relationship with income. For groups age 15 to 44, there seems to be a negative association between income and

rates of bicycle commuting. For older age groups, however, the opposite is true (Williams & Larson, 1996).

3.1.9 Educational Level

According to national 1990 census data, rates of bicycle commuting are highest among the poorly educated, and lowest among those with high school degrees or 1-to-3 years of college. Persons without a high school degree are about twice as likely to bicycle as persons with a high school degree or 1-to-3 years of college, and about 1.3 times more likely to bicycle as a college graduate (Williams & Larson, 1996).

3.1.10 Auto-Ownership Level

As would be expected, there seems to be a negative relationship between household auto-ownership levels and the rates at which people choose walking as a mode of travel for non-recreational trips (Kockelman, 1997; Loutzenheiser, 1997). There is also probably a negative relationship between household auto-ownership levels and the rates at which people choose bicycling for commuting purposes (Noland & Kunreuther, 1995).

3.2 TRIP-SPECIFIC FACTORS

In addition to environmental and personal factors, individual choices to travel by foot or bicycle also depend on a variety of trip-specific factors. These include:

- travel distance and travel time
- the purpose of the trip
- the time-of-day when travel takes place
- trip-chaining possibilities
- the relative attractiveness of travel by other modes

3.2.1 Travel Distance and Travel Time

Numerous empirical studies have confirmed the strong sensitivity of non-motorized mode use to travel distance and travel time (see Chapter Two). In the case of walking, rates of travel fall rapidly as distance between origin and destination increases. Two obvious reasons for this relate to personal physical limitations and the relatively slow speed of the pedestrian mode. Another relates, however, to the time required to engage or disengage use of other modes versus the time required to walk. When distances are short, other-mode engagement and disengagement time will constitute a relatively larger proportion of total trip time than when distances are long. Since walking requires only minimal engagement and disengagement time, it is more competitive with other modes when trips are short than when they are long.

In the case of bicycling, use generally falls with distance; however, the rate of decline is substantially less than in the case of walking. When topography is flat and high rates of speed can be maintained over long distances, cyclists can reasonably be expected to travel up to five or more miles. For the shortest trips, however, the time required to engage or disengage use of a bicycle (i.e., put on or take off a helmet, unlock or lock the bike, etc.) may make bicycling relatively uncompetitive compared to walking.

3.2.2 Trip Purpose

We might expect walking and bicycling to be most attractive when trips involve commuting, transit access, mid-day restaurant access or convenience shopping, and least attractive when trips involve major shopping or child drop-off or pick-up. The primary reason for this relates to the ease with which the non-motorized modes provide mobility in each case. In the first

instance, travelers are not usually required to carry, hold or be responsible for bulky objects or other people while moving. In the second instance, however, trip making does involve these tasks.

3.2.3 Time-of-Day when Travel Takes Place

Time-of-day when travel takes place affects the attractiveness of walking and bicycling in several different ways. First, during peak commuting periods, travel by the motorized modes may be both more costly (where cost is measured in terms of out-of-pocket expenditures and time consumed) and less comfortable than during non-peak periods. Since the monetary and time costs of walking and bicycling do not generally vary by time-of-day, and since the comfort level of these modes may vary only moderately through the day, we might expect the non-motorized modes to be relatively more attractive at peak periods than at other times of day. Second, walking and bicycling may be relatively less attractive during periods of the day when temperatures rise above or fall below comfortable levels. Finally, walking and bicycling at night may be uncomfortable because of the increased difficulty associated with travel in a darkened environment and because of increased concerns over personal security. Some travelers, however, may consider bicycling at night to be more secure than walking.

3.2.4 Trip-Chaining Possibilities

The degree to which individuals can stop at intermediate points when traveling by foot or bicycle to some ultimate destination (e.g., a transit station or a work site) should strongly affect willingness to use these modes. For trips made at different periods of the day, the types of stops that travelers could reasonably be expected to make include the following:

<u>Morning</u>	<u>Mid-Day</u>	<u>Early Evening</u>	<u>Late Evening</u>
Bank/ATM	Bank/ATM	Bank/ATM	Bank/ATM
Cafe	Barber/Hair Salon	Barber/Hair Salon	Bookstore
Child Care Center	Bookstore	Bookstore	Convenience Store
Convenience Store	Cafe	Cafe	Grocery Store
Doctor/ Dentist	Card/Gift Shop	Card/Gift Shop	Health Club
Drug Store/ Pharmacy	Convenience Store	Child Care Center	
Dry Cleaner	Doctor/ Dentist	Convenience Store	
Health Club	Drug Store/ Pharmacy	Doctor/Dentist	
Post Office	Florist	Drug Store/ Pharmacy	
School	Health Club	Dry Cleaner	
	Photo Developer	Florist	
	Post Office	Grocery Store	
	Restaurant	Health Club	
	Stock Brokerage	Photo Developer	
	Travel Agency	Post Office	
		Restaurant	
		School	
		Stock Brokerage	
		Travel Agency	

3.2.5 Attractiveness of Other Modes

Consciously or subconsciously, people appraise the attractiveness of travel by a non-motorized mode versus travel by alternative modes (automobiles, buses, and shuttles) by comparing walking or bicycling with the perceived attributes of the available alternatives for each trip. We might expect this appraisal process to vary with all of the other factors considered in this section. Thus, understanding the role of other modes requires understanding something about how different groups of people assess satisfaction derived from travel by those modes in comparison with satisfaction derived from a non-motorized mode when attributes of the pedestrian and bicycling environment, trip purpose, trip length, etc. are all held constant.

Attributes of other modes which may have particularly strong influence on the choice to use a non-motorized mode include:

- *For Automobiles:* (a) the ease or difficulty faced by the traveler in accessing his or her automobile at the origin end of the trip; (b) the availability, convenience and cost of parking at the destination end of the trip; and (c) levels of congestion on the road network.

- *For Buses and Shuttles:* (a) frequency of service; (b) reliability of service; (c) perceived security of service; and (d) fare level/ payment method.

3.3 ENVIRONMENTAL CONDITIONS

Environmental conditions strongly influence how and the extent to which other factors affect the choice to walk or ride a bike. Environmental attributes that may influence the choice to travel by foot or bicycle include:*

- | | |
|---|---|
| <ul style="list-style-type: none"> • Path Availability • Availability of Route Choices • Path Topography • Legibility of Path Network • Path Type and Condition • Nighttime Visibility • Variety, Interest and Attractiveness of Pedestrian and Bicycle Travel Routes • Climate Moderation Elements | <ul style="list-style-type: none"> • Protection from Weather Extremes • Local-Area Traffic Noise Levels • Local Air Quality • Availability of Resting and Relief Points • Physical Elements Affecting Personal Safety • Physical Elements Affecting Personal Security • Cleanliness and Condition of Public Spaces and Buildings • Cleanliness of Bicycle Riding Surfaces |
|---|---|

These attributes may be divided into two useful categories: (1) attributes that relate to the availability of walking and bicycling facilities; and (2) attributes that affect personal comfort of travel by the non-motorized modes. Grouping the attributes into these two categories produces the following classification scheme:

<u>Availability Variables</u>	<u>Comfort Variables</u>
Path Availability	Path Topography
Path Topography	Path Type & Condition
Path Type & Condition	Legibility of Path Network
Legibility of Path Network	Nighttime Visibility
Nighttime Visibility	Variety, Interest and Attractiveness
Quantity, Type and Location of Bicycle Parking	Climate Moderation Elements
	Protection from Weather Extremes
	Local-Area Traffic Noise Levels
	Local Air Quality
	Availability of Resting & Relief Points
	Elements Affecting Personal Safety
	Elements Affecting Personal Security
	Cleanliness and Condition of Public Spaces
	Cleanliness of Riding Surfaces

* For definitions of these attributes, see **Appendix A**.

3.4 FACTORS INVOLVING USE OF THE OUTDOOR PUBLIC REALM

Factors involving use of the outdoor public realm include:

- the non-travel benefits of non-motorized mode use
- personal safety concerns
- personal security concerns
- weather and climatic conditions
- institutional support for non-motorized mode use
- social status and encouragement of non-motorized mode use

3.4.1 The Non-Travel Benefits of Non-Motorized Travel

Because being a pedestrian or cyclist involves physical exertion and direct contact with the outdoor public realm, it is important to consider the non-travel benefits offered by the non-motorized modes. These benefits include (a) the contribution walking or bicycling may make to personal health and fitness, (b) the relaxation a person may experience when walking or bicycling, and (c) the positive social aspects involved with encountering others along journeys.

A variety of physical factors may influence the degree to which individuals may derive non-travel benefits from walking. These include all of the items categorized as “comfort variables” in Section 3.1.

3.4.2 Personal Safety

In the context of non-motorized planning, personal safety relates to risks associated with collisions between foot travelers, bicycles, automobiles and other vehicles; slipping and tripping; and injury from flying objects. While collisions occur most frequently at points where pedestrians cross streets, they can occur in other places as well (e.g., in parking lots or on sidewalks). Slipping and tripping may occur just about anywhere. Injury from flying objects most likely occurs along

streets with heavy traffic. Vehicle and bicycle travel speeds, as well as traveler attentiveness, are particularly important factors in personal safety.

One other important consideration in the area of personal safety relates to bicyclist fear of riding near or in moving automobile traffic. Such fear is one of the most significant deterrents to using a bicycle for most people (Noland & Kunreuther, 1995). A variety of low cost measures are available to make roadways safer for cyclists (Thom & Clayton, 1992). These include widening curb lanes, adding dedicated bicycle lanes to streets, clarifying the destination of street lanes (i.e., straight, left, or right), and traffic signal modification. Improved cyclist training and motorist education are also important means of improving bicycle safety.

3.4.3 Personal Security

Personal security refers to the degree to which people are or perceive themselves to be safe from crime while traveling through an area. When real or perceived levels of safety are high, people are more likely to use a non-motorized mode. Perception may be subject to a number of influences (Nasar, *et al.*, 1993). These include:

- levels of crime awareness
- levels and types of activity taking place in and around walking and bicycle riding areas
- the degree to which walking and riding areas are within sight of surrounding indoor activities
- levels of building disrepair, graffiti, etc. along pedestrian and bicycle routes
- the existence of possible hiding or “concealment” places for criminals
- the ability of travelers to see ahead along paths, and
- the frequency of places in which travelers may be unable to escape easily if attacked.

Traveler perceptions of personal security may be enhanced by the availability of a “safe” substitute travel mode such as a night-time shuttle service, even if the traveler chooses not to use the service.

While perceptions of personal security should be strongly associated with the choice to walk, the association may not be as strong for the case of bicycling. This is because a bicycle may give travelers greater ability to avoid or escape dangerous situations than available to pedestrians.

3.4.4 Weather and Climatic Conditions

Weather conditions may have some influence on the choice to use a non-motorized mode. All other things being equal, when weather is poor (i.e., there is rain, snow, extreme heat, strong wind, etc.) we should expect the likelihood that a person chooses to walk or bicycle to be less than when weather is good. Similarly, walking and bicycling may be less attractive travel options in very warm than in more moderate climates. Also, air temperature and pressure may affect ambient levels of traffic noise and other sounds that may discomfort pedestrians and cyclists.

The adverse effects of both weather and climate on willingness to use a non-motorized mode may be reduced by the presence of street trees, shelters, fountains, etc. Substitute bus or shuttle services may also contribute to reduced impact of weather and climate on non-motorized mode use. This is because such services offer individuals the option to travel by foot or bicycle during comfortable periods of the day, and by bus or shuttle during uncomfortable periods.

3.4.5 Institutional Support

When institutions support non-motorized mode use, we may expect some increase in the level of pedestrian and bicycle activity. Supportive institutions include (a) travel demand management associations, (b) programs designed to educate travelers on the benefits of non-motorized travel, (c) programs designed to educate the pedestrians, cyclists and motorists on pedestrian and bicycle safety, and (d) financial incentives/ disincentives to alternative mode use (e.g., transit pass subsidies, parking cash-out, bicycle purchase subsidies, etc.).

3.4.6 Social Status and Encouragement

Social status and encouragement that peer groups (at home, work, or school) provide to walking or bicycling may strongly influence an individual's willingness to travel by these modes. That is, if use of non-motorized transport is culturally acceptable and stylish, personal likelihood of walking and cycling may be higher (Litman, 1994).

3.5 BICYCLE-SPECIFIC FACTORS

Several factors specific to willingness to ride a bicycle should also be considered in any serious non-motorized planning effort. These include

- bicycle availability
- bicycle parking conditions
- the availability of showering and changing facilities
- bikes-on-transit policies

3.5.1 Bicycle Availability

The availability of a bicycle is critical to the choice to ride a bike. Bicycle ownership rates should be positively associated with rates of bicycle use. Also important, however, may be the ability of travelers to rent or borrow bicycles at critical locations (e.g., at transit stations).

3.5.2 Bicycle Parking

The availability and acceptability of bicycle parking at or near potential travel destinations may be critical to realizing high rates of bicycle use. Generally, where bicycle parking is available within short walking distance of a destination, rates of bicycling rates should be higher. The acceptability of bicycle parking facilities depends on a number of factors. These include (1) the duration of the parking period; (2) real or perceived threats of bicycle theft; and (3) weather

conditions (Replogle, 1993). For long-duration parking, attended bicycle storage may have a positive influence on rates of use. Bicycle use rates may also be higher if long-duration parkers have the option of leasing bicycle lockers (at transit stations, for example). These generally offer more security from theft than racks, and also protect bicycles from poor weather. For short-duration parking, the best bicycle storage equipment may be simple inverted-U or ribbon racks, both of which offer cyclists the ability to lock and unlock bicycles easily.

3.5.3 Showering and Changing Facilities

Two important concerns frequently expressed by cyclists relate to difficulties of bicycle travel in work clothes, and to the problem of sweating. Showering and changing facilities available at or near the work site can provide a solution to this problem.

3.5.4 Bikes-on-Transit Policies

Transit agency policies related to carrying bicycles in or on transit vehicles may affect willingness to use a bicycle. Individuals may be more willing to bike to and from public transit services if they are able to bring their bikes on board the transit vehicles rather than storing them at the transfer point.

Other important issues in this area relate to the bicycle carrying capacity of transit vehicles, and to the times of day when bicycles may be brought on board the vehicles. In general, rates of bicycling should be higher when sufficient capacity exists throughout the day to meet the demand for bicycle portage. Capacity may vary by time of day either because of transit agency policy (i.e., restrictions on carrying bikes aboard transit vehicles at certain times of day) or because of crowds on board transit vehicles, or both.

CHAPTER FOUR: Measures of Path Network Efficiency

Empirical literature reviewed in Chapters Two and Three suggests that willingness to travel by foot or bicycle declines rapidly with distance between origin-destination pairs. This implies that reducing travel distances should be a primary goal of any station-area non-motorized planning and design effort. One means of reducing travel distances is to enhance the “efficiency” of pedestrian and bicycle path networks. Enhancing network efficiency, however, requires a means of measuring current (or proposed) efficiency conditions. The purpose of this chapter is to provide such means.

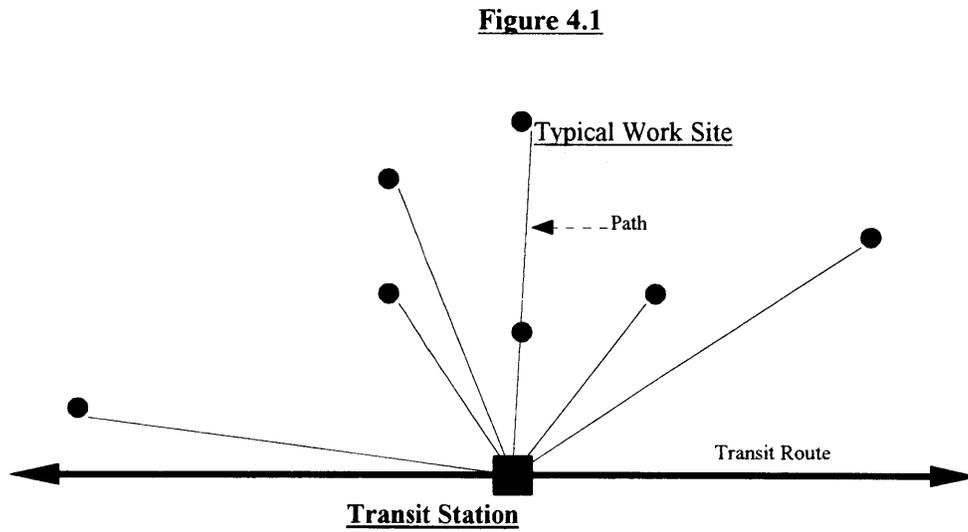
The chapter begins by offering a working definition of network efficiency, and discussing how efficiency levels may vary with changes in network structure. Next, the chapter moves to a discussion of the currently most commonly used measure of efficiency -- the “detour factor”. The chapter then continues by developing an entirely new measure of efficiency -- the “accessibility ratio”. Finally, the chapter closes with a brief discussion and graphic illustration of the relationship between detour factors and accessibility ratios.

4.1 MEASURING PATH NETWORK EFFICIENCY

In a non-motorized planning context, an efficient path network may be defined as one that meets the distance-related needs of pedestrians and cyclists. In general, pedestrians and cyclists demand travel over the shortest possible routes between origin-destination pairs. Thus, path

networks that maximize opportunities for direct (i.e., non-circuitous) travel between given sets of points may be regarded as efficient for users of the non-motorized modes.

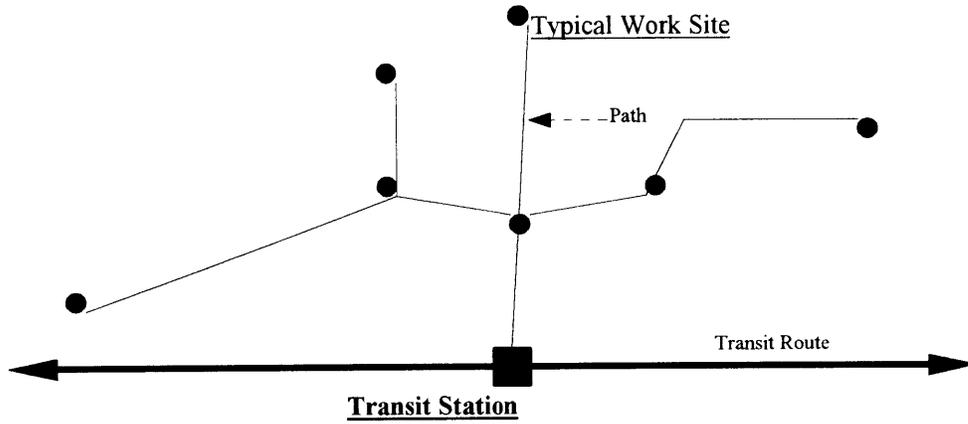
By this definition, the most efficient network for travel from a transit station to nearby work sites looks something like **Figure 4.1**.



Here, minimization of travel distances is achieved by locating paths along “airline” routes between the station and each of the work sites. In a real-world context, of course, such a network would not likely be practical or even desirable. There are three reasons for this. First, constructing a network that connects a station to each work site with only minimal opportunity for sharing routes between work sites would be cost-prohibitive. Second, topography, barriers, and other physical constraints would make linear path alignments very difficult to achieve. Third, the need to maintain interest and variety for pedestrians and cyclists would demand some (small) variation in alignment along route segments.

More realistic than the network shown in Figure 4.1 is the network shown in **Figure 4.2**.

Figure 4.2



In this case, the distribution of activity sites has remained the same, but travel distances have changed dramatically. For most work sites, distances to the transit station have increased with the shifting of path alignments away from the airline routes. A degree of “circuitry” between origin-destination pairs has been introduced into the travel environment. The network has thus become less efficient at connecting these pairs than before.

How can an efficiency change such as this be measured? One commonly used approach to accomplishing this task involves calculation of detour factors.

4.2 DETOUR FACTOR APPROACH

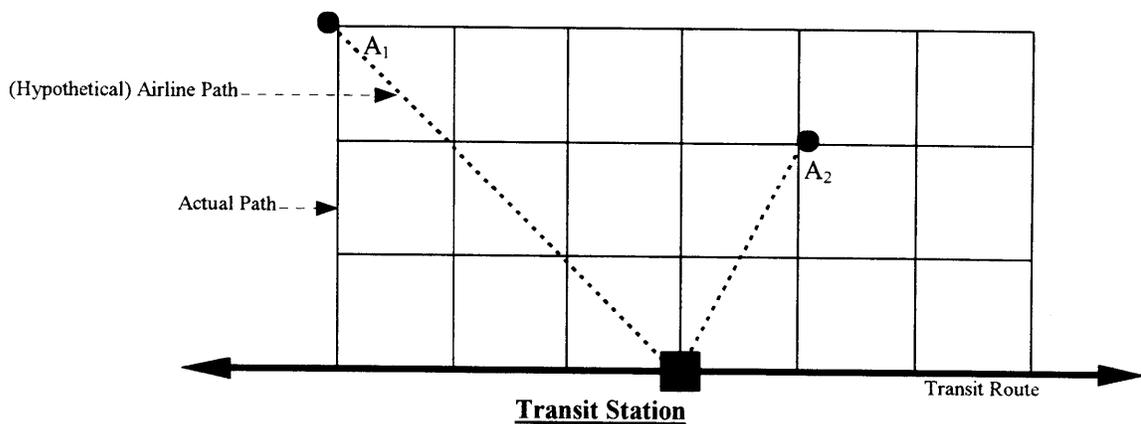
Transportation researchers and planners have long used detour factors as measures of network efficiency. A detour factor is simply the ratio between the length of a given route (“A”) and the length of a reference route (“B”) between an origin-destination pair (Lam & Morrall, 1982; Vuchic & Kikuchi, 1982). When A and B are identical in length, the detour factor assumes a value of 1.00 (i.e., no circuitry). When A is longer than B, the detour factor assumes a value

greater than 1.00. Finally, when **A** is shorter than **B**, the detour factor assumes a value smaller than 1.00.

To use the detour factor as a measure of network efficiency, shortest-path values are compared to airline distance values for each activity site that is connected to some reference location (e.g., a transit station). First, the shortest-path distances between the individual sites and the reference location are measured. Then, these shortest-path distances are divided by their respective airline distances to form individual detour factor values. The average of the individual factors acts as the measure of network efficiency. The value of this measure ranges upwards from 1.00 (i.e., the value of a perfectly efficient network).

To illustrate the use of the detour factor approach to measure network efficiency, consider the example shown in **Figure 4.3**.

Figure 4.3



In this case, the detour factors associated with travel between the transit station and activity sites A_1 and A_2 equal approximately 1.414 and 1.342, respectively. By the detour-factor measure, network efficiency can be defined as the average of the detour factor values associated

with each activity site. In the example, this average equals $(1.414 + 1.342)/2$ or about 1.378.

Thus, on average, travel via a shortest-path route from the transit station to a work site involves about 37.8-percent more walking (or bicycling) than would be the case if paths followed airline routes.

The key advantage of the detour factor approach lies in its simplicity -- it is easy to calculate and understand. Its key disadvantage, however, lies in its failure to account for (a) the spatial distribution and sizes of travel destinations (i.e., activity sites), and (b) the decay in willingness to travel between origin-destination pairs as travel distances increase. The importance of these factors to non-motorized travelers suggests that a better measure of network efficiency could be developed.

4.3 ACCESSIBILITY RATIO APPROACH

A potentially useful alternative to the detour factor for measuring network efficiency is a measure based on accessibility indices. This simple measure was developed by the author to support the evaluation framework presented in this thesis.

In recent years, researchers have focused increasing attention on using accessibility indices for sub-metropolitan-scale transportation analyses (see, for example, Ewing, *et al.*, 1994; Handy, 1993; Kockelman, 1997; and Lee & Goulias, 1997). To measure the accessibility of a given point (“*i*”) relative to other points (“*j*”) in a study area, these indices have generally assumed the following mathematical form:

$$\text{Accessibility Index } (A_i) = \sum_j [S_j V(t_{ij})]$$

where

- i* = point of origin
- j* = index of travel destinations (i.e., other points) in the study area
- S_j = size (e.g., number of employees) of *j*th destination
- $V(t_{ij})$ = travel-time impedance function evaluated at travel time, t_{ij}
- t_{ij} = travel time between point *i* and *j*th destination.

Evaluating an accessibility index such as this for $\{t_{ij} = \text{shortest-path travel time}\}$, and dividing this value by the value of the index evaluated at $\{t_{ij} = \text{airline-distance travel time}\}$ enables definition of a new network efficiency measure: the “accessibility ratio”. Expressed mathematically, this measure has the following general form:

$$\text{Accessibility Ratio} = A_{ij}^s / A_{ij}^a$$

where

A_{ij}^s = accessibility index based on shortest-path travel time from i th origin to j th destination

A_{ij}^a = accessibility index based on (hypothetical) airline-distance travel time from i th origin to j th destination

Accessibility ratios may be constructed to analyze the degree to which a network efficiently enables travel for a variety of purposes and with varying number of stops (i.e., zero, one, two, etc.) between origin-destination pairs. For example, accessibility ratios may be constructed to measure how well a network enables travel between a transit station and a work site, travel between a transit station and a work site with a stop at a cafe, travel between a work site and nearby restaurants, etc.

Ideally, the forms and coefficients of the impedance functions used to calculate accessibility ratios should be estimated on the basis of (a) local context, (b) the specific characteristics of the traveler group analyzed (e.g., office workers, the elderly, handicapped people, high school students, etc.), and (c) the particular type of trip that the travelers make (e.g., work, shopping, etc.). Unfortunately, however, data and time are not always available to perform such estimation. For example, analytic work conducted for the case study of this thesis relies on a set of “generic” impedance formulations.

These generic formulations are walk-to-transit and walk-to-other functions estimated by Levinson & Kumar (1994). The forms and coefficients of these functions are based on travel survey data from the Washington, DC metropolitan area. This data permits differentiation by two trip purposes: (1) walk to transit on the way to work; and (2) walk to a non-work destination. The specific functions associated with these purposes are as follows:¹

<u>Walk-to-Transit (for Work):</u>	$V(t_{ij}) = e^{(-0.08t + 0.265 t^{0.5} - 1.9t)}$	$\{t: t \geq (1.65625)^2\}$
	$V(t_{ij}) \cong 0.184419$	$\{t: t < (1.65625)^2\}$
<u>Walk-to-Non-Work Destination:</u>	$V(t_{ij}) = e^{(-0.19t - 0.19)}$	$\{t: t \geq 0\}$

where

t_{ij} = walk time from the i th origin to the j th destination.

In the case study of Chapter Six, a functional value of approximately 0.184 is assumed for all walk-to-transit travel times less than about 2.7 minutes.² This is necessary in order to avoid the counter-intuitive situation (implied by the coefficients estimated by Levinson & Kumar) in which rates of walking to transit are less for very short travel times than for medium travel times.

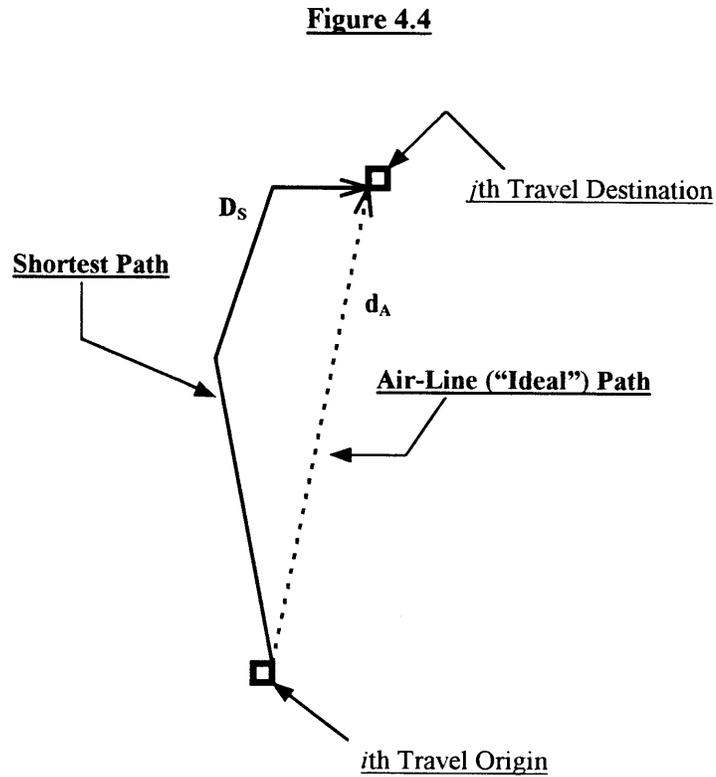
4.3.1 Accessibility Ratios: Construction and Use

The method for constructing accessibility measures outlined in the preceding section associates two accessibility values (i.e., a shortest-path value and an airline value) with each travel destination. Comparing these values can provide valuable insight into the degree to which existing network travel conditions deviate from conditions of greatest possible (or “ideal”) accessibility. More specifically, calculating the ratio of the two values permits determination of the percentage of ideal accessibility that is achieved under existing conditions. These percentages can be compared between destinations, as well as mapped thematically for analytic purposes.

¹ A table of values for these functions, evaluated at travel times up to and including 45 minutes, is included in **Appendix B**.

² This is the maximum value of the walk-to-transit function.

To illustrate the construction and use of accessibility ratios, consider the example illustrated by **Figure 4.4**.



Assume that the shortest-path distance (D_s) in this case equals 2000 feet, and the airline distance (d_A) equals 1000 feet. Further, assume we are interested in examining accessibility for foot travel from a transit station to a work destination of size, $S_j = 250$ employees. Converting the travel distances to travel times (using a reasonable walking speed of 262 feet per minute),³ entering the travel times into the Levinson & Kumar walk-to-transit equation, and multiplying the results by the size of the employment site produces the following accessibility index values for travel from the station (i.e., the i th origin) to the j th destination:

$$\text{Shortest-Path Accessibility Index } (A_{ij}^s) = 41.80$$

³ This conversion factor corresponds to the average summertime walking speed found by Lam & Morrall (1982) in their investigation of transit-rider behavior in Calgary (see Chapter Two).

$$\text{Airline Accessibility Index (A}_{ij}^A) = 45.78$$

In this case, the accessibility ratio is 0.8973 (= 41.08 / 45.78), indicating that the shortest existing path provides 89.73-percent of the accessibility provided by the ideal path.

4.3.2 Accessibility Ratios for Network Analysis

The example of Figure 4.4 refers to a single path connecting a single origin to a single destination. Measuring the efficiency of an entire network is a somewhat more computationally intensive process. More specifically, calculating a network accessibility ratio requires determining shortest-path and airline accessibility values for a much larger number of origin-destination pairs, summing these values, and then finding the ratio of the summed values.

Network accessibility ratios can assume a variety of different forms. Ratios can be constructed with reference to a single origin point (the i th origin), several origin points (e.g., $i = 1, 2$ and 3), or all potential origin points ($i = j = 1, 2, 3, \dots, n$). For most of the analyses conducted in this thesis, ratios shall be constructed with reference to a single origin point: a high-capacity transit station located at the center of a study area. Exceptions will arise, however (see Section 4.3.4 and Chapter 6).

Expressed mathematically, the general form of the network accessibility ratio used for analysis in the thesis is as follows:

$$\text{Network Accessibility Ratio (A}^N) = \frac{\sum_j S_j V(t_{ij})}{\sum_j S_j V(u_{ij})}$$

4.3.3 Accessibility Ratios for Chained Trips

The discussion to this point has considered accessibility solely in terms of travel directly between origin-destination pairs with no stops (i.e., without trip chaining). Because providing

opportunities for trip-chaining should be an important part of any non-motorized planning effort, however, our development of accessibility ratios should take into account the efficiency of a network to accommodate multiple-stop travel.

Accessibility analysis for chained trips is a slightly more complicated matter than analysis for non-stop trips. In particular, it requires comparing not simply the shortest existing path to the airline path, but a multitude of path segments to each other. Because of this inherent complexity, we shall confine our investigation of trip-chain accessibility to two cases: (1) single-stopover trips, and (2) double-stopover trips.

Under ideal accessibility conditions, the shortest travel distance between any two points, i and j , via a stopover point, k , should be no greater than the shortest travel distance between points i and j alone. That is, k should lie somewhere along the most direct available path between i and j . In many real-world situations, however, stopover points do not lie along the most direct available paths used by pedestrians or cyclists. Deviations from the otherwise best travel routes are often necessary in order to make trip chaining possible.

Fortunately, there is an easy way to account for this fact while still enabling use of the accessibility ratio approach to measure network efficiency. This involves simply calculating accessibility ratios on the basis of shortest paths that enable visits to stopover points. Thus, for trips involving one and two stopovers, respectively, the accessibility ratio assumes two slightly modified forms:

$$\begin{aligned} \text{One-Stop Accessibility Ratio (A}^N_1\text{)} &= \frac{\sum_j S_j V(t_{ijk})}{\sum_i S_i V(u_{ij})} \\ \text{Two-Stop Accessibility Ratio (A}^N_2\text{)} &= \frac{\sum_j S_j V(t_{ijkl})}{\sum_i S_i V(u_{ij})} \end{aligned}$$

where

- t_{ijk} = travel time via shortest paths between i th origin and j th destination with stopover at point k .
- t_{ijkl} = travel time via shortest paths between i th origin and j th destination with stopovers, first, at point k and, second, at point l .

4.3.4 Accessibility Ratios for Mid-Day Trips

For the purposes of this thesis, mid-day trips shall be defined as trips made to restaurants at lunch-time by employees working in a study area. To measure the efficiency of a network in accommodating these types of trips, accessibility ratios shall be based on multiple origin reference points. These multiple reference points shall include all work sites generating lunch-time trips.

Two types of accessibility ratios will be constructed for analysis of mid-day travel: (1) a general ratio, and (2) a ratio based on the sum of distances from each employment site to the three closest restaurants.⁴ The mathematical forms of these ratios are as follows:

$$\begin{aligned} \text{Lunch-Trip General Accessibility Ratio } (A^N_L) &= [\sum_i \sum_q S_j W(t_{jq})] / [\sum_i \sum_q S_j W(u_{jq})] \\ \text{Lunch-Trip MIN-3 Accessibility Ratio } (A^N_{MN-3}) &= [\sum_i \sum_m S_j W(t_{jm})] / [\sum_i \sum_M S_j W(u_{jM})] \end{aligned}$$

where

- $W(\bullet)$ = impedance function for mid-day (i.e., non-work trip) travel
- t_{jq} = travel time via shortest paths between j th employer and restaurant set
($q: q = 1, 2, 3, \dots, n$)
- t_{jm} = travel time via shortest paths between j th employer and three closest restaurants
- u_{jq} = (hypothetical) airline travel time between j th employer and restaurant set
($q: q = 1, 2, 3, \dots, n$)
- u_{jM} = (hypothetical) airline travel time between j th employer and three closest restaurants

4.3.5 Actual-to-Ideal Accessibility Ratios

One final type of accessibility ratio is worth considering. Actual-to-ideal accessibility ratios compare current shortest path travel conditions to conditions of maximum accessibility. This “ideal of ideals” shall be defined by the following: (1) all employment sites are located at or very near the transit access point; (2) all employment sites are connected to the transit access point by airline paths; (3) all potential stop-over locations are located along the airline routes connecting

⁴ Here, “closest” is defined in terms of the distance measure used in the impedance function. Thus, to calculate the MIN-3 accessibility ratio, distances are first found to the three restaurants lying closest via shortest-path routes. Then, the accessibility value based on these distances is divided by an airline accessibility value based on distances to the three restaurants lying closest via airline travel.

the transit access point to the employment sites; and (4) each employment site (or cluster of employment sites) co-locates with three restaurants. Expressed mathematically, the actual-to-ideal (A-to-I) accessibility ratios for non-stop, one-stop, two-stop, and lunch-time travel are as follows:

$$\begin{aligned}
 \text{Non-Stop A-to-I Ratio (A}^{A_1}\text{)} &= \sum_j S_j V(t_{ij}) / \sum_j S_j [\max V(\bullet)] \\
 \text{One-Stop A-to-I Ratio (A}^{A_1}\text{)} &= \sum_j S_j V(t_{ijk}) / \sum_j S_j [\max V(\bullet)] \\
 \text{Two-Stop A-to-I Ratio (A}^{A_2}\text{)} &= \sum_j S_j V(t_{ijkl}) / \sum_j S_j [\max V(\bullet)] \\
 \text{Lunch-Trip MIN-3 A-to-I Ratio (A}^{A_1}_{\text{MIN-3}}\text{)} &= [\sum_j \sum_m S_j W(t_{jm})] / [(\sum_j S_j)(3)(\max W(\bullet))]
 \end{aligned}$$

4.4 RELATIONSHIP BETWEEN ACCESSIBILITY RATIOS AND DETOUR FACTORS

Figures 4.5 and 4.6 give insight into the relationship between accessibility ratios and detour factors. They illustrate how sample accessibility ratio values vary with airline distances and detour factors for two different impedance functions.

Figure 4.5

**Relationship Between Airline Distance and Detour Factors
for Three Walk-to-Transit Accessibility Ratio (AR) Values**

(based on Levinson & Kumar Walk-to-Transit Impedance Function)

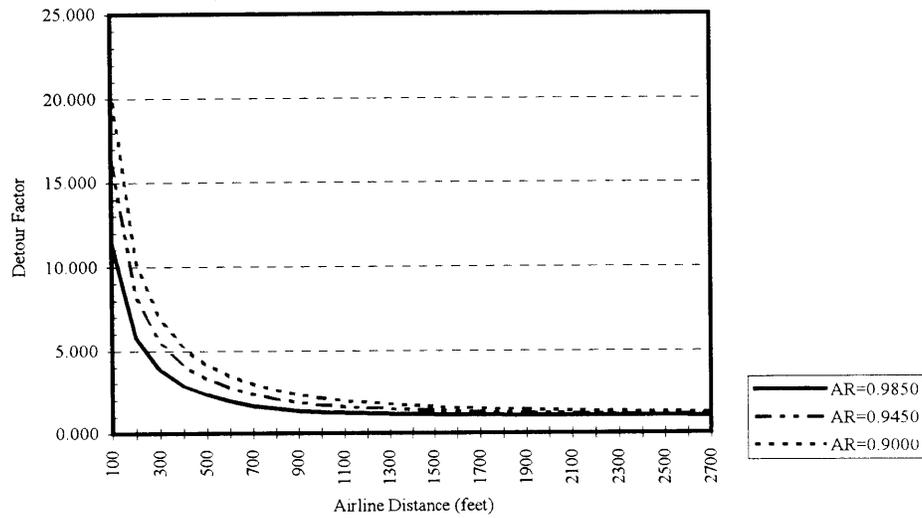
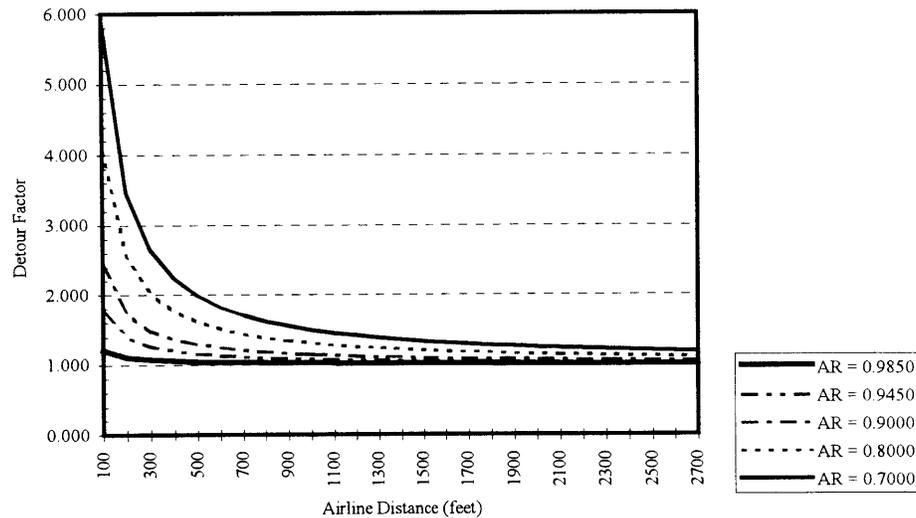


Figure 4.6

**Relationship Between Airline Distance and Detour Factors
for Six Walk-to-Other Accessibility Ratio (AR) Values**

(based on Levinson & Kumar Non-Work-Trip Impedance Function)



CHAPTER FIVE: Evaluating Non-Motorized Travel Conditions

The aim of this chapter is to develop a systematic approach to evaluating current physical and institutional conditions in suburban employment centers served by high-capacity transit (HCT). The purpose of the evaluation is to determine the degree to which conditions satisfy (or fail to satisfy) the needs of pedestrians and cyclists. The heart of the approach, which relies heavily on the material of Chapters Two and Three, is a set of evaluation criteria.

Chapter Six illustrates the approach with a case study of an employment area served by the Santa Clara Valley (San Jose, California) light rail system.

5.1 OVERVIEW OF APPROACH

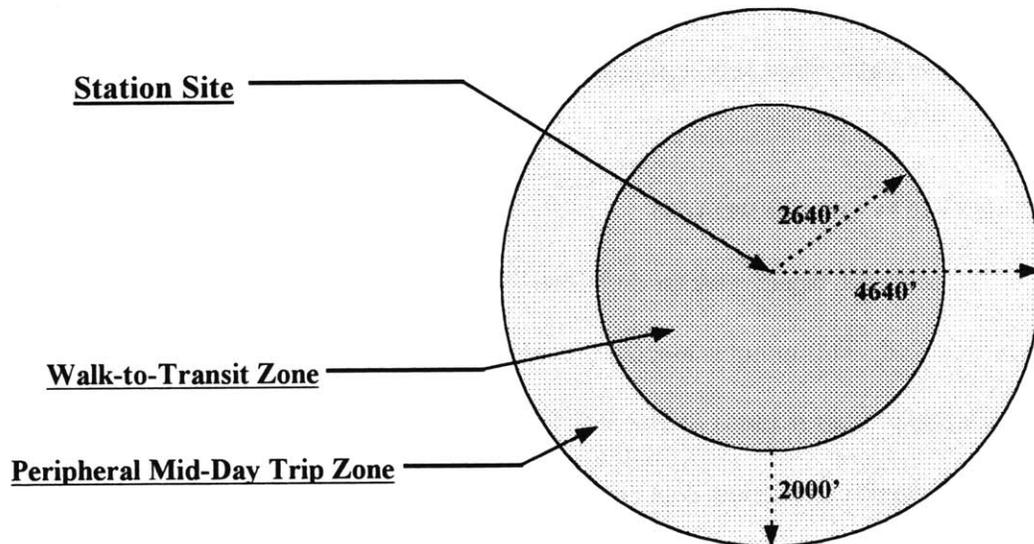
The approach begins with the definition of an area for analysis. Next, a “client” traveler group is identified. This group is associated with a set of path types they may be capable of using. The association process requires coding and classifying network path segments and travel barriers. The third step involves collecting data on land uses and non-motorized travel conditions within the study area. The fourth step is to describe current conditions. The fifth step is to differentiate primary and secondary travel routes. Step Six consists of evaluating current travel conditions. The evaluation is based on a set of criteria developed specifically for this purpose. Its intent is to shed light on how study-area physical and institutional conditions meet or fail to meet the needs of pedestrians and cyclists. Such an exposition permits identification of problems that non-motorized

travelers face in the study area. Finally, Step Seven involves outlining potential problem solutions or improvements.

5.2 STUDY AREA DEFINITION

The unit of analysis for the evaluation approach is a study area consisting of two zones (see **Figure 5.1**): (1) a circular “walk-to-transit zone,” centered on an HCT station and having a radius of one-half mile; and (2) an annular “peripheral mid-day-trip zone,” also centered on the station, but with an inside radius of one-half mile and a width of 2000 feet.⁵ The inclusion of the

Figure 5.1
Study-Area Definition



⁵ The radius of the walk-to-transit zone corresponds roughly to the 75th percentile of walking distances found by O’Sullivan & Morrall (1996) in an investigation of the pedestrian behavior of Calgary’s light rail users.

peripheral zone is intended to ensure that all potential mid-day travel destinations of transit users (particularly those who work at or near the outer edges of the walk-to-transit zone) are considered in the analysis.

5.3 CODING AND CLASSIFYING NETWORK PATH SEGMENTS AND TRAVEL BARRIERS

Coding and classifying pedestrian and bicycle path segments and travel barriers enables identification of primary and secondary travel routes, distance-based travel analyses using GIS, and association of path types to a “client” group of users (e.g., the elderly and handicapped, office workers, high school students, etc.). Systems developed by the author for coding and classifying pedestrian paths, bicycle paths, and crosswalks are shown in **Appendices C, D, and E**. A coding system developed by the author for mapping travel barriers is shown in **Appendix F**.

5.4 DATA NEEDS

Data required for evaluating pedestrian and bicycle travel conditions relate directly to the factors identified in Chapters Two and Three as potential influences on the choice to use a non-motorized mode. **Table 5-1** summarizes these influences.

Data sources may include site surveys, planning documents, aerial photographs, the US Census, USGS maps and digital orthophotos, telephone interviews, and transit agency literature. The data collected through site surveys includes information on (1) all land uses in each walk-to-transit zone; (2) retail, service and transportation land uses within the peripheral mid-day trip zone; (3) the location of pedestrian and bicycle travel paths (appropriately coded and classified -- see Section 5.4); and (4) physical attributes of the pedestrian and bicycling environments in both the walk-to-transit and the peripheral mid-day trip zones.

Table 5-1: Influences on the Use of the Non-Motorized Travel Modes

<u>INDIRECT INFLUENCES</u>	
Network Structure & Travel Barriers	
Population Density	
Employment Density	
Land-Use Mix	

<u>DIRECT INFLUENCES</u>	
<p><u>Personal Characteristics</u></p> <ul style="list-style-type: none"> Gender Age Physical Condition Marital Status Parental Status Occupation Income Education Auto-Ownership Level <p><u>Trip-Specific Factors</u></p> <ul style="list-style-type: none"> Travel Distance Travel Time Trip Purpose Travel Time-of-Day Trip-Chaining Possibilities Attractiveness of Travel by Alternate Modes <p><u>Factors Involving Use of Outdoor Public Realm</u></p> <ul style="list-style-type: none"> Non-Travel Benefits of Walking and Bicycling Personal Safety Concerns Personal Security Concerns Weather and Climatic Conditions Institutional Support for Non-Motorized Mode Use Social Status and Encouragement of Walking & Biking 	<p><u>Environmental Variables</u></p> <ul style="list-style-type: none"> Path Availability Availability of Route Choices Path Topography Legibility of Path Network Path Type and Condition Nighttime Visibility Variety, Interest and Attractiveness Climate Moderation Elements Protection from Weather Extremes Local-Area Traffic Noise Local Air Quality Availability of Resting and Relief Points Physical Elements Affecting Personal Safety Physical Elements Affecting Personal Security Cleanliness and Condition of Public Spaces and Bldgs Cleanliness of Bicycle Riding Surfaces <p><u>Bicycle-Specific Factors</u></p> <ul style="list-style-type: none"> Bicycle Ownership and Availability Bicycle Parking Bikes-on-Transit Policies Showering and Changing Facilities

5.5 DESCRIPTION OF CURRENT TRAVEL CONDITIONS

The description of current travel conditions should include: (1) an overview of the study area's location in the metropolitan region, development history, current land uses, urban character, station characteristics, and transit services; (2) an overview of the study area's planning and regulatory context; (3) a profile of the study area's "indirect" influences on non-motorized mode use (i.e., path network structures and travel barriers, employment and population densities, and

land use mix); and (4) a profile of “direct” influences on personal willingness to use a non-motorized mode.

5.6 DIFFERENTIATION OF PRIMARY AND SECONDARY TRAVEL ROUTES

Primary and secondary travel routes may be defined for both transit access and mid-day trips. For transit access, primary travel routes should generally be defined as the shortest routes between the transit station and worksites. For mid-day travel, primary routes are those that connect worksites to lunch-time destinations via shortest paths. Exceptions to this may be made when shortest paths (1) traverse unseemly or dangerous areas that may not practically be improved, (2) by-pass important retail and service areas, and (3) by-pass other areas of interest (e.g., a sculpture garden, a plaza, a park, etc.). Secondary travel routes are all routes not classified as primary.

5.7 EVALUATION OF CURRENT TRAVEL CONDITIONS

The evaluation of current travel conditions is intended to shed light on how well or poorly pedestrian and cyclist needs are satisfied in the study area. Applying a set of evaluation criteria accomplishes this task. These criteria are shown in **Figure 5.2**.

5.7.1 Evaluation Criteria for Pedestrian and Bicycle Travel

The evaluation criteria are based on the background material provided in Chapters Two and Three. They were developed to examine study area physical and institutional conditions as they relate to the factors that influence non-motorized mode use summarized in Table 5-1. **Table 5-2** illustrates this complex relationship, and permits easy reference by evaluators to background material in Chapters Two and Three.

The criteria are structured as a set of questions. A negative response to any question implies a deficiency or problem in the area to which the criterion refers.

Application of the criteria is intended to occur with respect to a specific “client” traveler group. Such a group might consist, for example, of the elderly, handicapped persons, able-bodied office workers, high school students, experienced cyclists, beginning cyclists, etc. Analyses performed and conclusions reached in the evaluation process should relate specifically to the needs and preferences of this group. Examination of material related to “Personal Characteristics” in Chapter Three may permit greater insight into client-group needs and preferences.

5.7.2 Guidelines for Applying the Evaluation Criteria

As a further aid to applying the evaluation criteria, evaluators may wish to refer to the guidelines shown in **Figure 5.3**. The guidelines briefly summarize justifications for meeting the criteria, and suggest approaches to answering the evaluation questions. As noted in the guidelines, the material of Chapter Four and Appendices C, D, E and F also facilitates application of the criteria.

5.7.3 Issues in Applying the Evaluation Criteria

While various objective measures may be used to aid the process of applying the evaluation criteria, evaluation is generally a subjective process. A decision regarding whether or not the study area meets any given criterion must depend substantially on the judgment of the evaluator. This should not imply, however, that the evaluation must be entirely arbitrary. On the contrary, the evaluation should be informed by a comprehensive background of theory and information regarding traveler behavior. The theory and information provided in Chapters Two and Three are intended to serve this purpose.

Ideally, evaluations should be conducted with as broad a participatory base as possible. Persons who might reasonably perform evaluations include teams of transportation, land use, and urban design professionals, and stakeholder groups (e.g., study area employees). Enabling stakeholder participation might involve any number of different approaches -- surveys, focus groups, public forums, etc. Such participation could be useful not only for general evaluation of current conditions, but also for pinpointing particular areas of stakeholder concern.

5.7.4 Outline of Improvement Options

Applying the evaluation criteria enables evaluators to differentiate between problematic and non-problematic conditions in the study area. Problematic conditions may be either amenable or not amenable to resolution. Similarly, non-problematic conditions may be either open to improvement or not open to improvement.

Outlining potential resolution or improvement options in the study area is the final task in the evaluation process. Generating options should involve soliciting input from professionals as well as from interested non-professionals. In general, however, the need for detailed knowledge of the types and likely feasibility of improvement options will tend to orient the identification process toward higher levels of input from planning and design professionals.

Figure 5.2
Pedestrian and Bicycle Evaluation Criteria

Base Conditions

1. *Path Network Availability.* Are basic walkway and bikeway networks available for travel between all or most points in the study area?
2. *Population and Employment Density.* Are aggregate population and employment densities great enough to generate continuous pedestrian and cyclist activity throughout the day?
3. *Aggregate Land Use Mix.* Do study area land uses include a diverse mix of residential, employment, retail, and service activities?
4. *Overall Level of Crime.* Is the study area generally free of serious crime?
5. *Serious Conflicts between Pedestrians, Cyclists, Automobiles, and Other Traffic.* Is the study area generally free of serious conflicts between pedestrians, cyclists, automobiles, and other traffic?

Travel Distances and Impediments

6. *Travel Distances for Transit Access.* Are travel distances for transit access as short as reasonably possible?
 7. *Travel Distances for Mid-Day Trips.* Are travel distances for mid-day travel as short as reasonably possible?
 8. *Trip-Chaining Opportunities.* Are opportunities for easy trip-chaining maximized?
 9. *Path Network Gaps.* Are the path networks without significant gaps?
 10. *Short-Cut Opportunities.* Is the study area generally free of barriers that would inhibit opportunities for taking short cuts using informal paths or building pass-throughs?
 11. *Topography.* Is the topography of the study area conducive to walking and bicycling?
 12. *Street Crossing Wait Times.* Do pedestrians and cyclists face minimal waiting times at street crossings?
 13. *Traffic Calming.* Are street segments and intersections designed to calm traffic and minimize the risk of vehicle-pedestrian, vehicle-bicycle, and bicycle-pedestrian collisions?
-

Pedestrian and Bicycle Evaluation Criteria (cont' d)

14. *Comfort and Safety of Path Surfaces.* Are walking and cycling surfaces along primary travel routes safe and comfortable to use?
15. *Cleanliness and Maintenance of Pathways.* Are primary walkways and bikeways generally clean and well maintained?
16. *Cleanliness and Maintenance of Buildings and Property.* Are buildings and other property along walkways and bikeways generally clean and well maintained?
17. *Shelter from Intense Sun and Poor Weather.* Are primary travel routes sheltered from intense sun and poor weather?
18. *Pleasant Visual, Acoustic and Other Sensory Stimuli.* Do primary travel routes offer pleasant visual, acoustic and other sensory stimuli to pedestrians and cyclists?
19. *Route Choice.* Do pedestrians and cyclists generally benefit from a choice of travel routes between origin-destination pairs?
20. *Insecure Locations.* Is the study area free from any specific locations where pedestrians or cyclists might feel personally threatened by crime while traveling during daylight hours?
21. *Nighttime Travel Conditions.* Are night-time travel conditions along primary travel routes safe, secure and comfortable?
22. *Noise Levels.* Do traffic noise levels along primary pedestrian and bicycle travel routes generally permit pleasant and easy conversation?
23. *Local Air Quality.* Is local air quality conducive to walking and cycling?

Traveler Support

24. *Rest and Relief Amenities.* Do primary travel routes include “rest and relief” amenities?
 25. *Network Legibility.* Are the networks of primary walkways and bikeways generally “legible” to (i.e., easily navigated by) travelers?
 26. *Adequate Bicycle Parking.* Are adequate bicycle parking facilities generally available in close proximity to travel origins and destinations?
 27. *Bicycles on Transit.* Does local transit offer convenient and adequate bicycle portage services?
-

Pedestrian and Bicycle Evaluation Criteria (cont'd)

28. *Transit for Substitute Travel.* Do study-area transit services provide a reasonable substitute means of travel at night, when the weather is poor, or under other special circumstances?
 29. *Showering and Changing Facilities.* Are showering and changing facilities conveniently available to bicycle commuters?
 30. *Institutional Support.* Does strong institutional support for walking and cycling exist in the study area?
-

Table 5-2: Relationship Between Evaluation Criteria and Factors that Influence Non-Motorized Mode Use

Criterion	Related Factors	CH 2&3 References
1. <i>Path Network Availability</i>	Network Structure Path Availability	§2.1.3 §3.3
2. <i>Population and Employment Density</i>	Population Density Employment Density	§2.2 §2.2
3. <i>Aggregate Land Use Mix</i>	Land-Use Mix	§2.3
4. <i>Overall Level of Crime</i>	Personal Security Concerns Physical Elements Affecting Personal Scty	§3.4.3 §3.3
5. <i>Serious Conflicts between Pedestrians, Cyclists, Automobiles, and Other Traffic</i>	Personal Safety Concerns Physical Elements Affecting Personal Scty	§3.4.2 §3.3
6. <i>Travel Distances for Transit Access</i>	Network Structure Travel Barriers Travel Distance Trip Purpose	§2.1.3 §2.1.4 §2.1.1, §2.1.2, §3.2.1 §3.2.2
7. <i>Travel Distances for Mid-Day Trips</i>	Network Structure Travel Barriers Travel Distance Trip Purpose	§2.1.3 §2.1.4 §2.1.1, §2.1.2, §3.2.1 §3.2.2
8. <i>Trip-Chaining Opportunities</i>	Land-Use Mix Trip-Chaining Possibilities	§2.3 §3.2.4
9. <i>Path Network Gaps</i>	Network Structure Travel Barriers	§2.1.3 §2.1.4
10. <i>Short-Cut Opportunities</i>	Travel Barriers Travel Distance	§2.1.4 §2.1.1, §2.1.2, §3.2.1
11. <i>Topography</i>	Path Topography	§3.3
12. <i>Street Crossing Wait Times</i>	Travel Time Travel Time-of-Day	§2.1.1, §2.1.2, §3.2.1 §3.2.3
13. <i>Traffic Calming</i>	Personal Safety Concerns Social Status and Encouragement of W&B Physical Elements Affecting Personal Safety	§3.4.2 §3.4.6 §3.3
14. <i>Comfort and Safety of Path Surfaces</i>	Travel Distance Personal Safety Concerns Path Type and Condition Physical Elements Affecting Personal Safety	§2.1.1, §2.1.2, §3.2.1 §3.4.2 §3.3 §3.3

Table 5-2: Relationship Between Evaluation Criteria and Factors that Influence Non-Motorized Mode Use (cont'd)

Criterion	Related Factors	CH 2&3 References
15. <i>Cleanliness and Maintenance of Pathways</i>	Travel Distance	§2.1.1, §2.1.2, §3.2.1
	Personal Safety Concerns	§3.4.2
	Personal Security Concerns	§3.4.3
	Social Status and Encouragement of W&B	§3.4.6
	Physical Elements Affecting Personal Safety	§3.3
	Physical Elements Affecting Personal Scty	§3.3
	Cleanliness of Bicycle Riding Surfaces	§3.3
16. <i>Cleanliness and Maintenance of Buildings and Property</i>	Travel Distance	§2.1.1, §2.1.2, §3.2.1
	Personal Security Concerns	§3.4.3
	Social Status and Encouragement of W&B	§3.4.6
	Physical Elements Affecting Personal Scty	§3.3
	Cleanliness and Cond. of Public Spc & Bldgs	§3.3
17. <i>Shelter from Intense Sun and Poor Weather</i>	Travel Distance	§2.1.1, §2.1.2, §3.2.1
	Travel Time-of-Day	§3.2.3
	Weather and Climatic Conditions	§3.4.4
	Climate Moderation Elements	§3.3
	Protection from Weather Extremes	§3.3
18. <i>Pleasant Visual, Acoustic, and Other Sensory Stimuli</i>	Travel Distance	§2.1.1, §2.1.2, §3.2.1
	Non-Travel Benefits of Walking and Bicycling	§3.4.1
	Social Status and Encouragement of W&B	§3.4.6
	Variety, Interest and Attractiveness	§3.3
19. <i>Route Choice</i>	Personal Security Concerns	§3.4.3
	Availability of Route Choices	§3.3
	Variety, Interest and Attractiveness	§3.3
	Physical Elements Affecting Personal Scty	§3.3
20. <i>Insecure Locations</i>	Travel Time-of-Day	§3.2.3
	Personal Security Concerns	§3.4.3
	Availability of Route Choices	§3.3
	Physical Elements Affecting Personal Scty	§3.3
21. <i>Nighttime Travel Conditions</i>	Travel Time-of-Day	§3.2.3
	Personal Safety Concerns	§3.4.2
	Personal Security Concerns	§3.4.3
	Path Availability	§3.3
	Availability of Route Choices	§3.3
	Legibility of Path Network	§3.3
	Nighttime Visibility	§3.3
	Physical Elements Affecting Personal Safety	§3.3
Physical Elements Affecting Personal Scty	§3.3	
22. <i>Noise Levels</i>	Travel Time-of-Day	§3.2.3
	Non-Travel Benefits of Walking and Bicycling	§3.4.1
	Weather and Climatic Conditions	§3.4.4
	Social Status and Encouragement of W&B	§3.4.6
	Local-Area Traffic Noise	§3.3

Table 5-2: Relationship Between Evaluation Criteria and Factors that Influence Non-Motorized Mode Use (cont'd)

Criterion	Related Factors	CH 2&3 References
23. <i>Local Air Quality</i>	Travel Time-of-Day	§3.2.3
	Non-Travel Benefits of Walking and Bicycling	§3.4.1
	Local Air Quality	§3.3
24. <i>Rest and Relief Amenities</i>	Travel Distance	§2.1.1, §2.1.2, §3.2.1
	Travel Time-of-Day	§3.2.3
	Weather and Climatic Conditions	§3.4.4
	Social Status and Encouragement of W&B	§3.4.6
	Climate Moderation Elements	§3.3
	Availability of Resting and Relief Points	§3.3
25. <i>Network Legibility</i>	Travel Distance	§2.1.1, §2.1.2, §3.2.1
	Travel Time	§2.1.1, §2.1.2, §3.2.1
	Trip-Chaining Possibilities	§3.2.4
	Personal Security Concerns	§3.4.3
	Instit. Support for Non-Mtrzed Mode Use	§3.4.5
26. <i>Adequate Bicycle Parking</i>	Travel Distance	§2.1.1, §2.1.2, §3.2.1
	Travel Time	§2.1.1, §2.1.2, §3.2.1
	Trip-Chaining Possibilities	§3.2.4
	Personal Security Concerns	§3.4.3
	Physical Elements Affecting Personal Scty	§3.3
	Bicycle Parking	§3.5.2
27. <i>Bicycles on Transit</i>	Network Structure	§2.1.3
	Travel Barriers	§2.1.4
	Travel Distance	§2.1.1, §2.1.2, §3.2.1
	Travel Time	§2.1.1, §2.1.2, §3.2.1
	Path Topography	§3.3
	Bikes-on-Transit Policies	§3.5.4
28. <i>Transit for Substitute Travel</i>	Travel Time-of-Day	§3.2.3
	Attractiveness of Travel by Alternate Modes	§3.2.5
	Personal Safety Concerns	§3.4.2
	Personal Security Concerns	§3.4.3
	Weather and Climatic Conditions	§3.4.4
	Path Topography	§3.3
	Nighttime Visibility	§3.3
	Physical Elements Affecting Personal Safety	§3.3
	Physical Elements Affecting Personal Scty	§3.3
29. <i>Showering and Changing Facilities</i>	Travel Distance	§2.1.1, §2.1.2, §3.2.1
	Travel Time-of-Day	§3.2.3
	Weather and Climatic Conditions	§3.4.4
	Path Topography	§3.3
	Climate Moderation Elements	§3.3
	Protection from Weather Extremes	§3.3
	Showering and Changing Facilities	§3.5.3
30. <i>Institutional Support</i>	Instit. Support for Non-Mtrzed Mode Use	§3.4.5

Figure 5.3
Guidelines for Applying the Evaluation Criteria

Base Conditions

1. ***Path Network Availability.*** Determination of the availability of a basic path network should involve specifying a minimum level for employee or resident accessibility to paths in the network. For example, a condition for meeting the criterion could be specified in terms of a certain percentage (say, 90-percent) of employees or residents being connected to the larger network by at least one path. [⊕]
2. ***Population and Employment Density.*** High population and employment densities in a study area can generate high pedestrian and cyclist traffic volumes. High volumes along primary travel routes can contribute to traveler security and make outdoor public spaces more vibrant and interesting.
3. ***Aggregate Land Use Mix.*** One approach to measuring aggregate land use mix might involve applying entropy or dissimilarity indices such as those used by Cervero (1989) Frank & Pivo (1994) and Kockelman (1997). Constructing such indices may be complicated, however, when land uses are mixed very finely on individual sites. For example, when office buildings contain retail and service activities at ground level, constructing an entropy index as a function of proportions of total land area devoted to different uses is not possible. There is no way of differentiating between land area used as office space and land area used for retail and service activities. If use of an entropy or dissimilarity index is not possible, then simple description of the types and number of different land uses in the study area may be substituted.
4. ***Overall Level of Crime.*** Examination of crime statistics, survey of residents or employees, interviews with police, etc. can indicate the general degree to which crime represents a real or perceived threat to personal security in the study area.
5. ***Serious Conflicts between Pedestrians, Cyclists, Automobiles, and Other Traffic.*** Accident statistics, coupled with employee surveys and information on the character of intersection and mid-block street crossings, can indicate the degree to which conflicts between pedestrians, cyclists, automobiles and other vehicles pose or are perceived to pose a problem in the study area. [⊕]

[⊕] Indicates that GIS-based analysis using the material in **Appendices C, D, E, or F** may assist application of evaluation criterion.

Figure 5.3 (cont'd)
Guidelines for Applying the Evaluation Criteria

Travel Distances and Impediments

6. ***Travel Distances for Transit Access.*** As the discussion in Chapter Two indicates, Americans tend to be intolerant of long walking and bicycling distances for public transit access. While maximum shortest-path walking distance for suburban high-capacity transit (HCT) access is approximately 4000 to 4500 feet, most HCT users are not willing to walk more than about 1700 to 2000 feet. Maximum bicycling distance is about three miles. Many cyclists, however, are not willing to travel more than about a third of this distance. These distances will vary, however, by individual traveler, total trip time, transit service frequency, and a variety of other factors (e.g., time-of-day, weather conditions, etc.). For walking, individuals with particularly low tolerance include the elderly and handicapped. High total trip times and low transit service frequencies will tend to shorten maximum tolerable walking and cycling distances.

Ideally, then, to maximize rates of walking and bicycling to transit, residential and employment sites should be located as close to transit access points as possible, and transit services should be rapid and frequent. Moreover, path networks should be designed to minimize the divergence between airline and actual (i.e., shortest-path) distances. As discussed in Chapter Four, useful measures of divergence include detour factors and accessibility ratios. [⊕]

7. ***Travel Distances for Mid-Day Trips.*** Time constraints associated with work-based, mid-day trips limit walking distances to about 2500 feet (i.e., the distance most pedestrians are able to walk in about ten minutes). Many individuals, however, will not tolerate walking more than about 1000 feet. Cyclists may be reasonably expected to travel up to about one mile. Ideal mid-day trip-making conditions, then, include close proximity between employment, retail, and service activity sites, as well as high levels of path network efficiency (as defined in Chapter Four). [⊕]
8. ***Trip-Chaining Opportunities.*** Rates of transit access and mid-day trip making by foot and bicycle will be higher if retail activities and services (such as those listed in Section 3.2.4) are located conveniently between transit stations and work sites, and work sites and primary lunch-time destinations (i.e., restaurants and cafes). Useful measures of trip-chaining convenience include the one and two-stop accessibility indices and ratios described in Chapter Four. [⊕]
9. ***Path Network Gaps.*** Filling gaps in travel path networks may enable pedestrians and cyclists to travel between previously unconnected (or awkwardly connected) origin-destination pairs. Identification of gaps should involve examination of study-area maps, as well as consideration of extreme detour factor values (e.g., values greater than 2.0). [⊕]

[⊕] Indicates that GIS-based analysis using the material in **Appendices C, D, E, or F** may assist application of evaluation criterion.

Figure 5.3 (cont'd)
Guidelines for Applying the Evaluation Criteria

Travel Distances and Impediments (cont'd)

10. **Short-Cut Opportunities.** Use of informal short-cuts across parking lots, vacant land, lawns, etc. may enable pedestrians and cyclists to reduce travel distances substantially. Common barriers to taking short cuts in suburban developed environments include fences, hedgerows, berms, wide buildings devoid of pass-throughs, limited access roadways, and busy streets. [⊕]

11. **Topography.** The necessity to climb steep hills or traverse long segments of moderately sloped paths can strongly deter walking and bicycling. Consideration of topography in a study area evaluation should include measurement and mapping of path segment gradients, as well as identification of means used to gain elevation (e.g., ramps, elevators, escalators, stairs, etc.). [⊕]

12. **Street Crossing Wait Times.** Pedestrian and cyclist wait times at street crossings (intersection or mid-block) may represent a substantial impediment to non-motorized travel. The best approach to solving this problem may be to reduce traffic volumes and speeds on individual street segments by diverting some traffic to alternate routes and narrowing street widths. Demand-responsive traffic signals can also mitigate the problem under some, but not all, circumstances. Another potentially effective solution is to install curbed medians in busy streets. Such medians allow pedestrians to begin crossing the street without having to wait for both directions of traffic to clear. Where none of these solutions is feasible, over or underpasses may be installed as a last resort.

13. **Traffic Calming.** Changing traveler behavior through traffic calming may increase the attractiveness of non-motorized travel by reducing real or perceived threats of collisions between motor vehicles, pedestrians, and cyclists. Desired behavioral changes include reduced vehicle and bicycle travel speeds, reduced lateral variability of vehicles, and increased traveler awareness of potential dangers. Key measures of traffic-calming effectiveness are motor vehicle and bicycle travel speeds, and accident rates.

[⊕] Indicates that GIS-based analysis using the material in **Appendices C, D, E, or F** may assist application of evaluation criterion.

Figure 5.3 (cont'd)
Guidelines for Applying the Evaluation Criteria

Urban Environmental Characteristics

14. ***Comfort and Safety of Path Surfaces.*** Careful selection of path surfacing materials for walking and cycling comfort and safety can reduce perceived travel distances, the physical burden of non-motorized travel, and the risk of slipping or tripping (particularly in wet weather). Ideal path surfaces should balance smoothness (for easy passage) and texture (for traction).[⊕]
15. ***Cleanliness and Maintenance of Pathways.*** Clean and well-maintained pathways can enhance pedestrian and cyclist perceptions of personal safety, security, status, and travel burden. Controlling vandalism and keeping pathways free of litter and graffiti may indicate to both travelers and criminals that socially irresponsible behavior will not be tolerated. The result may be a perceptual increase in traveler security and a reluctance on the part of criminals to commit crimes. Maintenance enhances personal safety by ensuring that walking and cycling surfaces remain free of broken pavement or other potential causes of accidents. Finally, walking and cycling on unclean or badly maintained paths may signal to travelers and others that walking and cycling are low-status modes of travel, and may increase perceptions of travel distance.
16. ***Cleanliness and Maintenance of Buildings and Property.*** Clean and well-maintained buildings and property along travel routes may enhance pedestrian and cyclist perceptions of personal security, status and travel burden. Reasons for this are identical to the case of pathway cleanliness and maintenance.
17. ***Shelter from Intense Sun and Poor Weather.*** To maximize pedestrian and cyclist comfort, and reduce perceived travel distances, primary travel routes should be sheltered from intense sun and inclement weather wherever practicable. Shelters include building awnings, arcades, atriums, street trees, etc. Shelters that cast cold, “hard” shadows should generally be avoided in favor of translucent varieties.
18. ***Pleasant Visual, Acoustic and Other Sensory Stimuli.*** Maintaining interest and variety contributes to pedestrian and cyclist comfort, and may reduce perceived travel distances. This may be achieved by incorporating visual, acoustic and other sensory stimuli into primary travel routes. These include artwork, shop window displays, interesting architecture, variegated pavement, attractive landscaping, creative outdoor lighting, etc.

[⊕] Indicates that GIS-based analysis using the material in **Appendices C, D, E, or F** may assist application of evaluation criterion.

Figure 5.3 (cont'd)
Guidelines for Applying the Evaluation Criteria

Urban Environmental Characteristics (cont'd)

19. **Route Choice.** Availability of alternative travel routes may encourage walking and cycling by giving individuals opportunities to customize travel experiences, and by increasing traveler perceptions of personal security. Increased traveler perceptions of personal security stems from traveler ability to chose the perceptually safest of all possible travel routes. One way to measure route choice involves simply counting the number of potential travel paths between a given origin-destination pair that are less than or equal to some percentage (e.g., 200-percent) of the shortest-path distance. [⊕]

 20. **Insecure Locations.** Specific places in which pedestrians and cyclists may feel especially vulnerable to crime include non-residential streets with little or no motorized or non-motorized traffic, alleys, areas characterized by illegal street activities (e.g., drug dealing), and areas that combine opportunities for criminal concealment and prospect with lack of easy escape for travelers.

 21. **Nighttime Travel Conditions.** Nighttime safety, security, and comfort may be enhanced by the presence of sidewalk-oriented retail or other activity, glare-free pedestrian and bicycle-oriented street lighting, high volumes of non-motorized traffic, and a non-aggressive police presence.

 22. **Noise Levels.** For pleasant and easy conversation, ambient noise levels should not exceed approximately 60 decibels. Conversation becomes virtually impossible when noise levels exceed about 90 decibels.

 23. **Local Air Quality.** Walking and cycling are both more comfortable and contribute more to personal health when local air quality is high. Since passage of the Clean Air Act Amendments of 1990, the Environmental Protection Agency has regulated six types of air pollutants that adversely impact the comfort and health of pedestrians and cyclists. These include ground-level ozone, volatile organic compounds, nitrogen dioxide, carbon monoxide, particulate matter, and air toxics.
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[⊕] Indicates that GIS-based analysis using the material in **Appendices C, D, E, or F** may assist application of evaluation criterion.

Figure 5.3 (cont'd)
Guidelines for Applying the Evaluation Criteria

Traveler Support Features

24. ***Rest and Relief Amenities.*** Rest and relief amenities situated along primary travel routes can improve travel comfort and decrease perceived travel distance. Amenities include street furniture, water features, clean publicly accessible restrooms, etc. These should generally be evenly distributed throughout a study area.
25. ***Network Legibility.*** For a walking or cycling network to be legible, it must enable travelers to retain a clear sense of direction, distance traveled, and location. These elements allow pedestrians and cyclists to minimize travel distances and experience higher levels of personal comfort and security. Travel distance minimization is achieved by giving travelers information useful for selection of routes. Personal comfort is enhanced by reducing frustration associated with wayfinding. Personal security is enhanced by reducing the fear of getting lost or appearing to be unfamiliar with one's surroundings. Network legibility stems from pattern recognition, path differentiation and hierarchy, signage, creative use of lighting, strategic placement of maps or axonometric diagrams, and distinctive landmarks.
26. ***Adequate Bicycle Parking.*** Adequate bicycle parking is essential for encouraging bicycle commuting and mid-day trip making. Adequacy may be defined in terms of accommodation of all common types of bicycles; security; ease of access; clear visibility from shop windows, offices, etc.; shelter from wet weather; and attractiveness.
27. ***Bicycles on Transit.*** Convenient and adequate bicycle portage capacity on public transit provides cyclists with a means of traveling long distances (i.e., greater than three to five miles), overcoming topographical challenges, and filling gaps in bicycle path networks. Key influences on the attractiveness and feasibility of using bikes-on-transit service include (1) the times-of-day during which cyclists may carry bicycles on board the transit vehicles; (2) transit vehicle bicycle-carrying capacity; (3) transit-service frequency and reliability; (4) topography; (5) total travel distance; and (6) total transit trip time. The contribution of bikes-on-transit to increasing overall rates of bicycling should be highest when time-of-day restrictions do not exist, carrying capacity is high, transit service is frequent and reliable, topography is not level, travel involves distances of greater than three to five miles, and transit services are speedy.
28. ***Transit for Substitute Travel.*** Fear of being stranded when the weather is poor, at night, or under other special circumstances may substantially deter walking or bicycling. This deterrent may be partially overcome, however, when safe and convenient transit services for both local and non-local travel are available as a substitute. Transit services that are demand-responsive may be particularly well-suited to this purpose.

Figure 5.3 (cont'd)
Guidelines for Applying the Evaluation Criteria

Traveler Support Features (cont'd)

29. *Showering and Changing Facilities.* For cyclists who commute long distances, showering and changing facilities are essential. Such facilities may be either private (i.e., located at work sites) or public (i.e., located at health clubs).

 30. *Institutional Support.* Institutional support for non-motorized travel may be provided by transportation management associations, employee transportation coordinators, transit agencies, etc. Forms of support include traveler information and education, alternative mode use pledge drives and contests, bicycle-purchase and transit pass subsidies, parking cash-out, and preferential parking for carpools and vanpools.
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CHAPTER SIX: Case Study of Karina Station Area San Jose, CA

To demonstrate how the evaluation approach developed in Chapter Five might be applied, the author collected data for a case study of a station area located on the Santa Clara Valley (San Jose, California) light rail transit (LRT) system. This chapter summarizes the case study findings.

The chapter's organization is as follows. Section 6.1 provides an overview of how the author conducted the case study. Section 6.2 discusses the data collected. Section 6.3 defines the "client" group and related path types to which the evaluation of case study travel conditions is intended to apply. Section 6.4 describes the study area's salient features. Section 6.5 discusses the planning and regulatory context of the study area. Section 6.6 profiles indirect influences on non-motorized travel, while Section 6.7 profiles direct influences. Section 6.8 identifies primary pedestrian and bicycle travel routes. Section 6.9 evaluates the current state of non-motorized travel conditions using the criteria developed in Chapter 5. Section 6.10 summarizes the evaluation. Finally, Section 6.11 outlines potential improvement options.

6.1 OVERVIEW OF CASE STUDY PROCESS

The discussion in Chapter Five suggests that any study area evaluation should be conducted with as broad a participatory base as possible. That is, ideally, evaluations should be performed by teams of professionals with substantial input from stakeholder groups. Given the resource limitations faced by the author, however, such could not be the case for the evaluation

presented in this chapter. Rather, the evaluation relies solely on the author's individual judgment and insights gained through site visits, review of plans, telephone interviews with San Jose area planners, etc. This does not constitute a problem, however, as the primary purpose of this case study is not to provide an optimal study-area evaluation, but simply to illustrate how the evaluation approach might generally be applied.

6.2 DATA COLLECTED FOR CASE STUDY

Data that the author collected for the case study include information on the study area's urban character, as well as the location and characteristics of pedestrian paths, bicycle paths, and 109 activity sites (i.e., individual buildings). Means of data collection included two separate site surveys, examination of aerial photographs, review of maps, telephone interviews, review of planning literature, and review of transit agency literature.⁶

The author's analysis of data related to path availability, path types, street crossing conditions, travel distances, path network gaps, short cut opportunities, topography, comfort and safety of path surfaces, and route choice was supported by the mapping, coding, and classifying systems shown in Appendices C, D, E, and F. This analysis was performed in combination with GIS and spreadsheet resources.⁷

Appendix G contains the data on individual activity sites. The location of each site is assumed to be the main building entrance. All sites are identified by unique ID numbers. For each building in the study area, Appendix G includes information on zonal location; airline distance and azimuth to the Karina light rail station; the primary activity taking place in the building; types of services available; number of floors; approximate square footage of the building's footprint; assumed square footage per employee; estimated number of primary employees; estimated number

⁶ The author's site surveys were conducted in August, 1996 and April, 1997.

⁷ TransCAD GIS and Excel spreadsheet software were used for the analyses.

of service employees; and estimated total number of employees. This data is used to estimate employment density and land-use mix levels, and as input to the distance analyses conducted for the case study.

6.3 DEFINITION OF “CLIENT” TRAVELER GROUP AND PATH SUITABILITY

The discussion of non-motorized travel conditions in this case study is intended to apply to a “client” traveler group consisting mostly of office workers. The primary pedestrian-related behavioral assumption regarding this group is that they are capable of using non-ADA-compatible paths, but will not tolerate extensive travel over unpaved formal or informal pathways, or along long stretches of non-residential streets that lack sidewalks. They will, however, be willing to travel across parking lots, and along short stretches (i.e., less than about 20 feet) of unpaved pathway. The pedestrian path network used for analysis in this case study shall include such travel routes.

For bicycling, the behavioral assumption is that the client traveler group will be willing to use any bicycle path, bicycle lane, safe bicycling route (marked or unmarked), or parking lot.

6.4 DESCRIPTION OF STUDY AREA

The Karina Study Area is a suburban employment district located in the heart of Silicon Valley, three miles north of downtown San Jose (**Figure 6.1**). At the center of the study area is Karina Station on the Valley Transportation Authority’s (VTA) “Guadalupe” light rail line (**Figure 6.2**). Since 1987, the light rail has connected the study area to residential neighborhoods in the downtown area and South San Jose, as well as to other employment districts located in the First Street corridor. A major LRT system extension in the nearby Tasman Corridor is scheduled for completion sometime after the year 2000 (Bertini, *et al.*, 1995). This will give the study area

substantially improved transit access to major residential and employment concentrations in Milpitas, the northern part of San Jose, Sunnyvale, Mountain View, and (via transfer to and from the CalTrain commuter rail service) cities and towns on the San Francisco peninsula (**Figure 6.3**). Other future extensions may also connect the area to Los Gatos, points in the Capitol freeway corridor, Fremont, and (via transfer to and from the BART and Altamont commuter rail systems) the cities and towns of the East Bay area.

6.4.1 Development History

Like most places in Silicon Valley, the study area was until relatively recently farmland and orchards. In the 1950s and 1960s, however, it and the surrounding area began developing into one of the most important centers of employment in the San Francisco Bay Area. Forces that produced this growth included expansion of light and heavy industry, as well as high technology research and manufacturing. Close proximity to San Jose International Airport, together with good highway and freight rail access, has also fueled growth.

The first generation of postwar development in the study area included land uses such as lodging, restaurants, small office complexes, warehouses, light manufacturing, and auto dealerships. More recently, however, large corporate office buildings and high-tech R&D/manufacturing facilities have been built.

6.4.2 Current Land Uses

Compared to other nearby station areas, the study area contains a relatively diverse mix of commercial and industrial land uses. These include large and small office buildings, office/R&D buildings, office/industrial buildings, retail/industrial buildings, warehouses, high- and low-tech

Figure 6.1

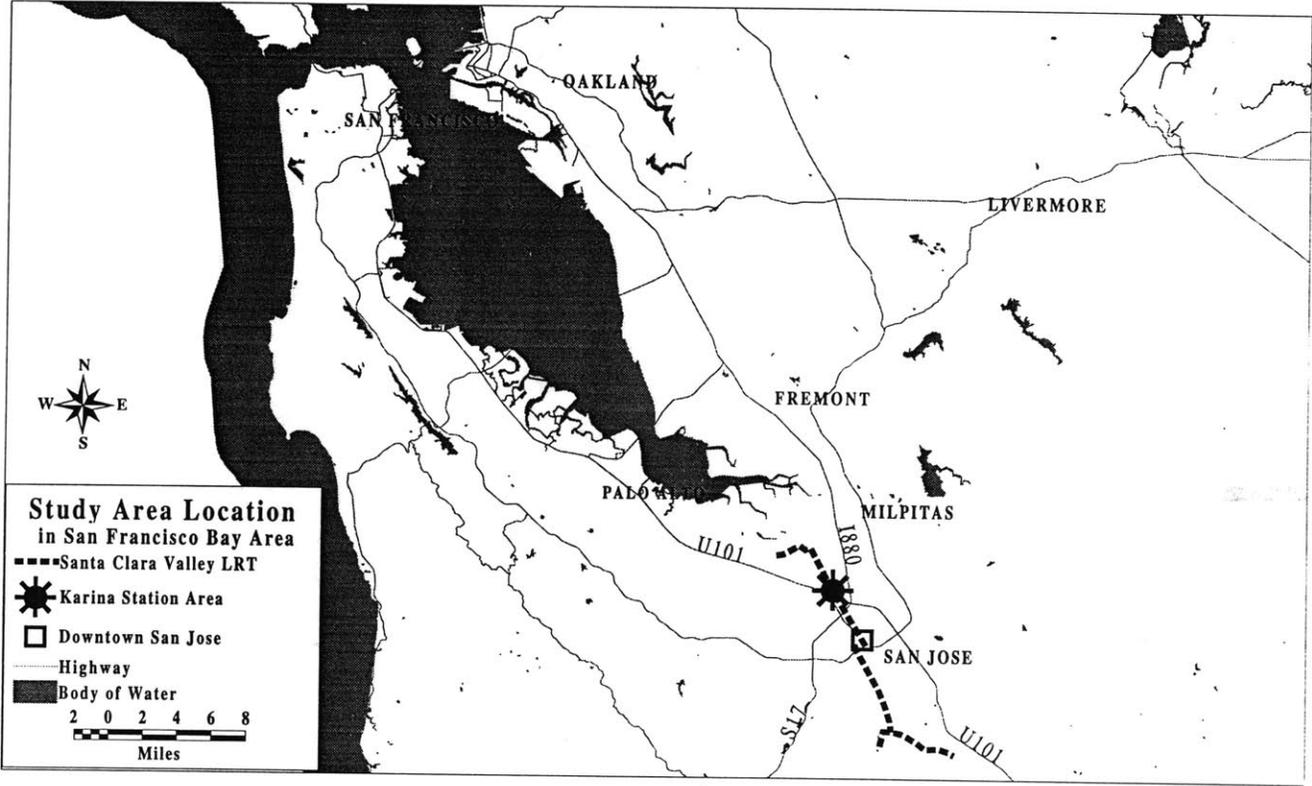


Figure 6.2

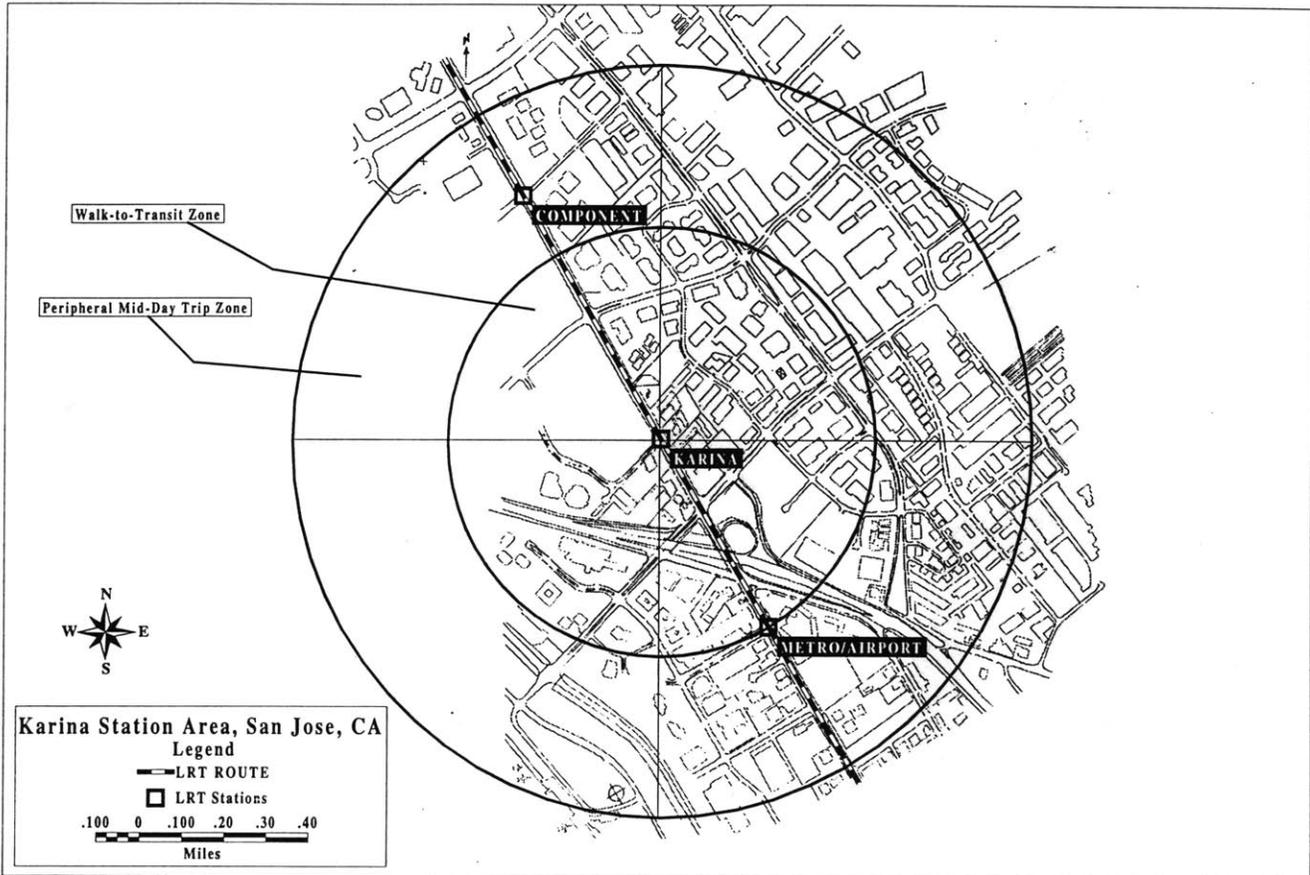
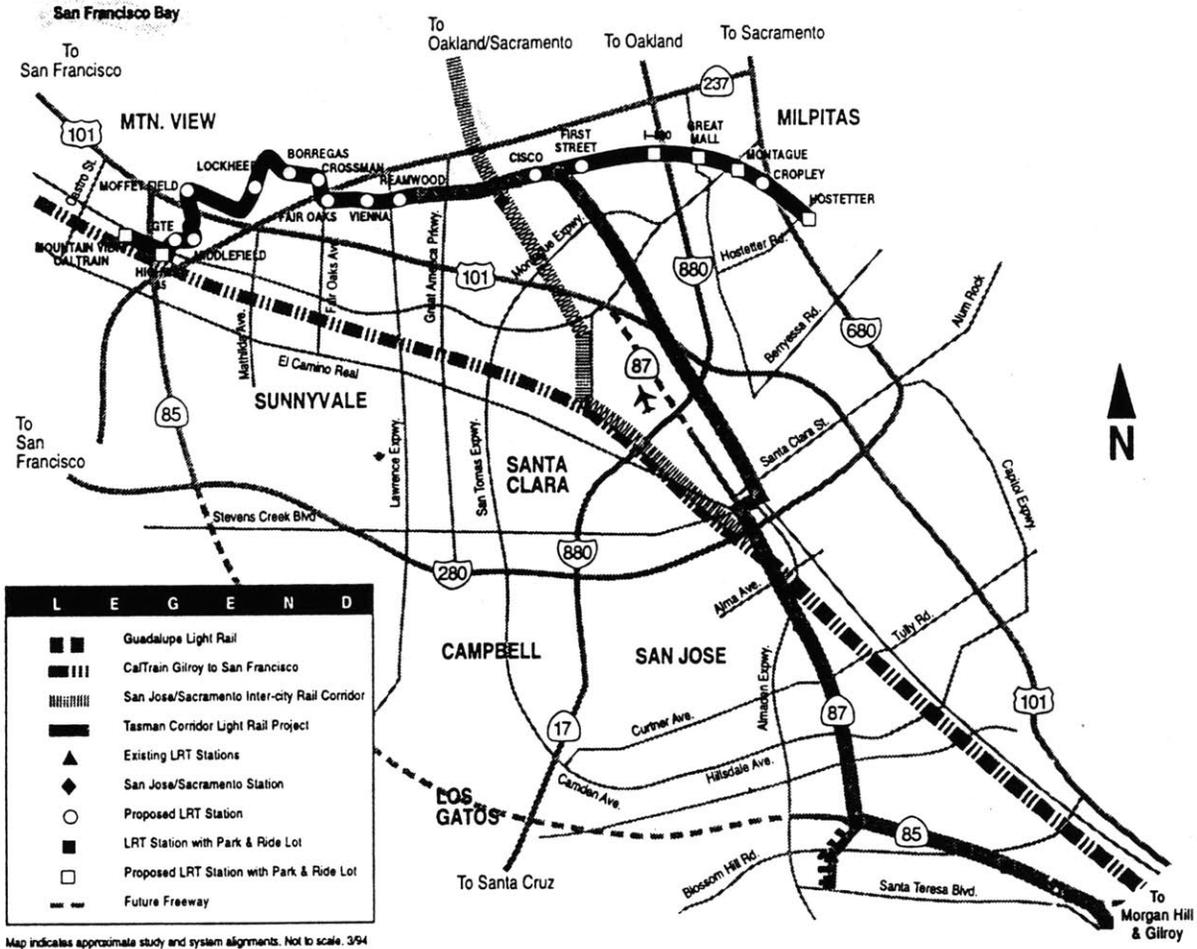


Figure 6.3



Light Rail in the Guadalupe and Tasman Corridors

(Map Reproduced from Bertini, *et al.*, 1995)

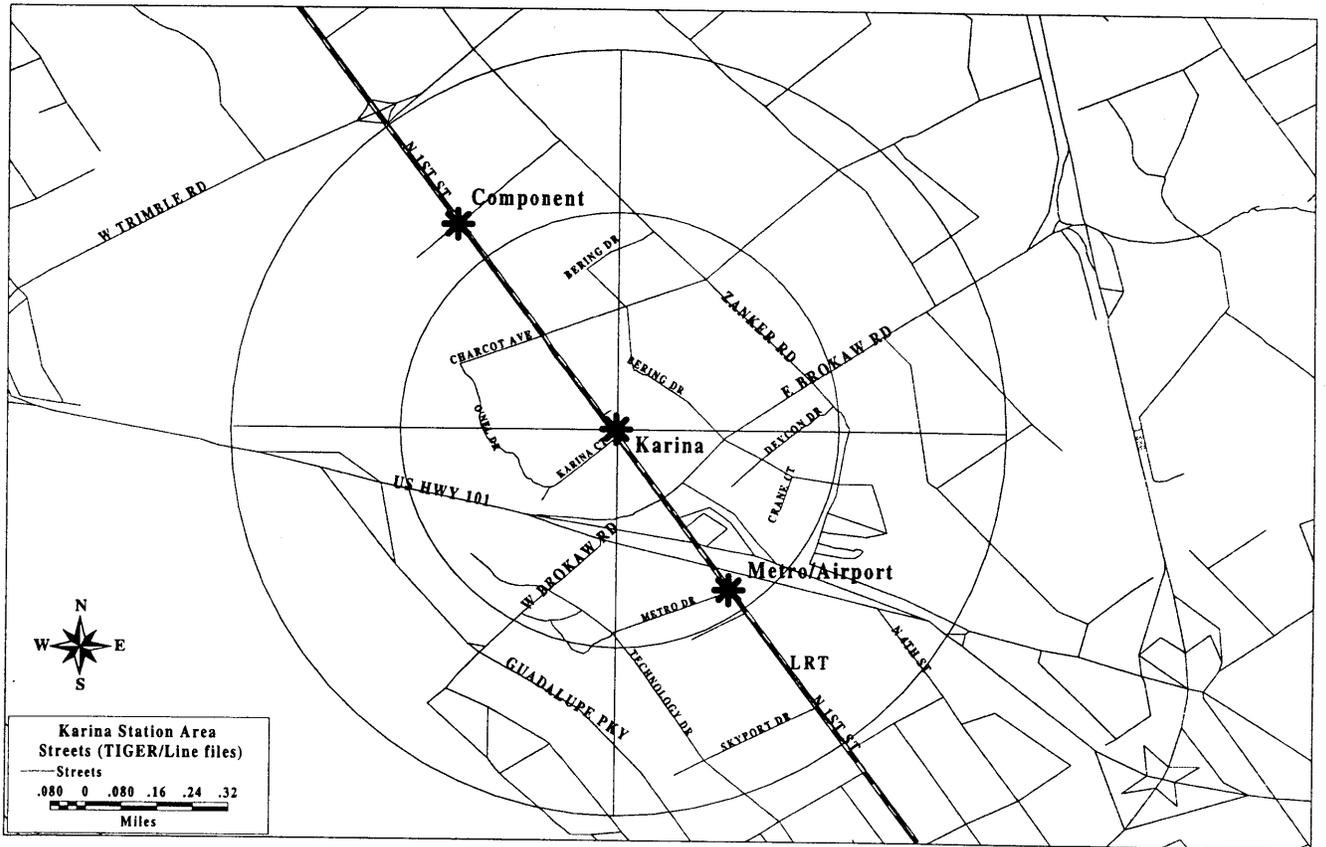
manufacturing facilities, hotels and motels, restaurants, banks, gas stations, a small strip mall, an auto dealership, and a casino. Most of the retail uses are located along or near First Street. The study area includes no residential uses.

Roadway and other transportation facilities also represent a significant land use in the study area (**Figure 6.4**). A major freeway, US 101, bisects the southern part of the area's walk-to-transit zone on an elevated and filled alignment. Right-of-way width of the freeway and its frontage road ranges from about 500 to 1000 feet. Underpasses permit pass-through of the right-of-way along two of the area's major arterial streets: First Street and Brokaw Road. These are six-lane facilities with average daily traffic (ADT) volumes of approximately 22,800 and 30,000 vehicles, respectively (City of San Jose, 1994). A third major arterial, Guadalupe Parkway, bisects the extreme southwestern portion of the peripheral mid-day trip zone. Its alignment follows the course of the Guadalupe River. Minor arterials and collector streets include Bering Drive, Charcot Avenue, Technology Drive, and Zanker Road. Numerous short local streets also serve the area.

Other transportation facilities located in the study area include two additional light rail stations ("Metro/Airport" and "Component") and part of San Jose International Airport. The main airport terminal is located just outside the outer boundary of the peripheral mid-day trip zone in the study area's southwest quadrant.

Vacant land in the walk-to-transit zone consists of approximately 30 acres located between Bering Drive and US 101 in the southeast quadrant, and about 100 acres located between First Street and US 101 in the northwest quadrant.

Figure 6.4



6.4.3 Urban Character

The character of the developed environment in the study area is typical of Silicon Valley. Campus-style site design predominates. Virtually all buildings have only one or two stories, and are constructed as discrete objects in space set far back from public streets. A few taller buildings exist, but these are mostly concentrated in the part of the study area lying south of US 101. Building entrances tend to be oriented to surface parking lots, which occupy a large proportion of total land area. On-street parking is sparse. Landscaping is copious and typically includes such elements as grassy berms and hedgerows along property lines and street frontages. The area is generally well shaded from the intense California sun by numerous mature trees.

6.4.4 Station Characteristics

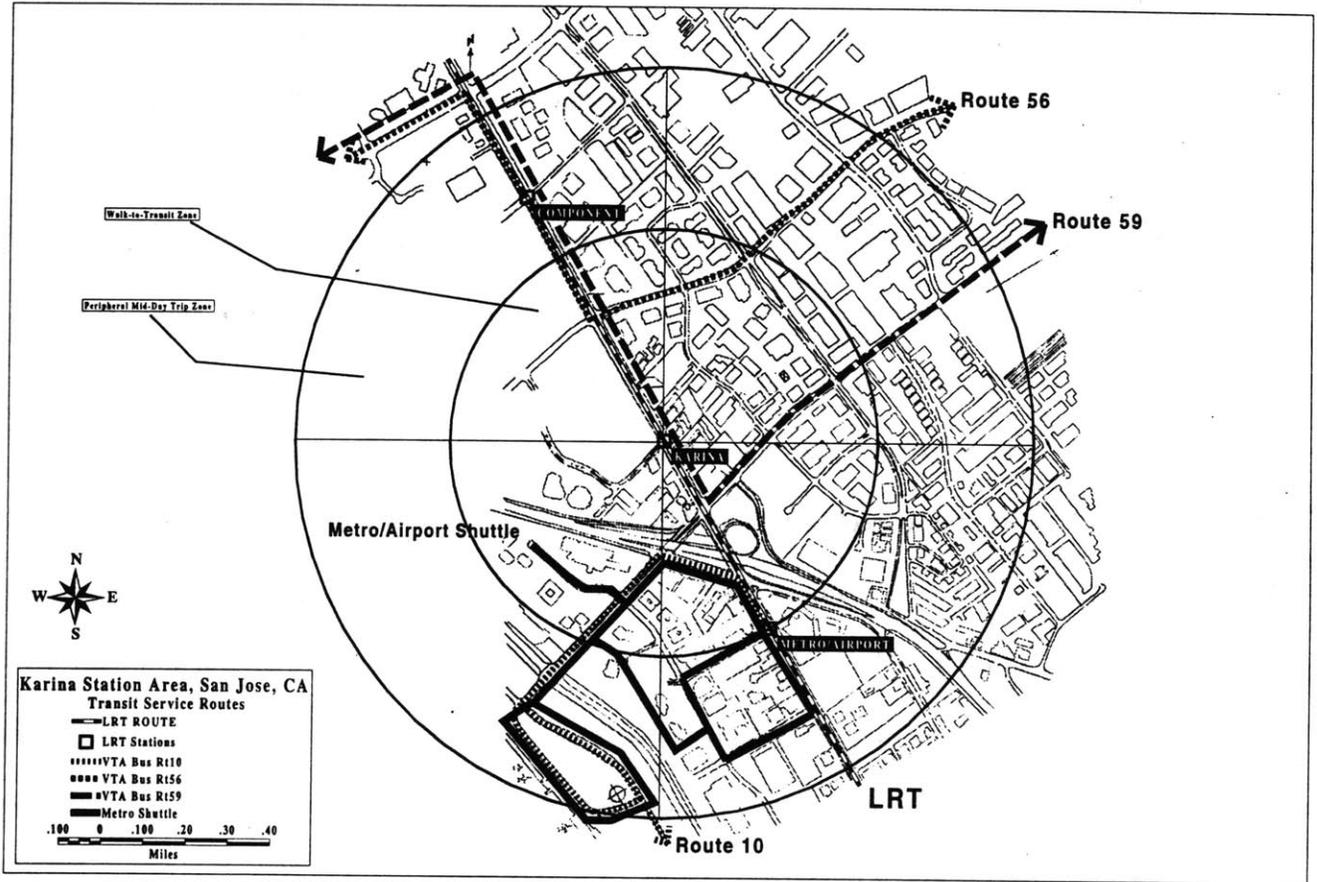
Like most stations on the VTA light rail system, the stations that serve the study area are non-staffed facilities of split-platform configuration. Amenities include variegated pavement, waiting area shelters, benches, and shade trees. Ticket-vending machines are located on each platform, as are maps of the transit system and other traveler information. This information does not include maps of the local area, however. The stations are generally kept clean and free of graffiti.

Light rail infrastructure in the study area consists of two tracks situated in the median of First Street. The location of the station platforms in the middle of the road requires transit users to cross one direction of travel lanes for access or egress.

6.4.5 Transit Services

Area transit services include, in addition to the light rail operation, three conventional bus routes and a shuttle (Figure 6.5). As noted previously, the light rail service connects the study

Figure 6.5



area to various points in the San Jose metropolitan region. On weekdays, it operates from 4:00 a.m. to 1:00 a.m. at 10-minute headways **during the day, and 30-minute headways at night.** On Saturdays, Sundays and holidays, the service runs at 15-to-30 minute headways from 5:30 am to 1:00 am.

Two of the bus routes (Routes 56 and 59) operate hourly on weekdays, while the third (Route 10) operates every half hour on **weekdays and every hour on Saturdays and Sundays.** Route 10 connects the Metro/Airport LRT station with San Jose International Airport and points in Santa Clara, including the Santa Clara CalTrain commuter rail station. Route 56 connects the Component LRT station area with points in Milpitas, Santa Clara and Sunnyvale, including the Sunnyvale CalTrain commuter rail station. **Finally, Route 59 connects the Karina and Component LRT stations with points in East San Jose and the Great America amusement park.**

The shuttle connects the Metro/Airport light rail stop to mid-rise office buildings located west of First Street and on the south side of the US 101 freeway. It also serves San Jose International Airport. Hours of shuttle operation are approximately from 6:00 a.m. to 7:00 p.m. on weekdays only. Headways are every ten minutes during morning and afternoon peak periods, and every fifteen minutes at other times. **Average monthly shuttle ridership was approximately 5600 passengers in 1994 (City of San Jose, 1994).**

6.5 STUDY AREA PLANNING AND REGULATORY CONTEXT

In general, real estate development in the study area is regulated by a euclidean zoning structure, a site review process, and various design guidelines. In addition, however, all new development taking place in the study area must conform to a set of congestion mitigation and air quality improvement requirements specified in the “Deficiency Plan for North San Jose” (City of

San Jose, 1994). Also, large employers in the study area must comply with the provisions of a trip reduction ordinance, the Bay Area Air Quality Management Trip Reduction Rule.

6.5.1 The Deficiency Plan for North San Jose

The Deficiency Plan applies specifically to the portions of the study area lying north of the US 101 freeway. Development projects south of the freeway, however, may be subject to the plan's requirements if they cause deficiencies or impact previously deficient roadway facilities within the plan area.

California state law requires cities to prepare deficiency plans as part of congestion management programs (CMPs). Deficiency plans allow cities to exceed CMP roadway level-of-service (LOS) standards "when it is impossible or undesirable to maintain the minimum LOS standard through roadway system improvements" (City of San Jose, 1994). In order for cities to do this, however, they must implement "improvements, programs, or actions which 1) improve the level of service of the overall CMP [roadway] system and 2) improve regional air quality." In short, deficiency plans "ensure that critical new development which would be stopped by strict application of the CMP... LOS standards...may be approved if the city and individual development projects implement sufficient actions to improve system-wide transportation and air quality conditions."

New development projects that are subject to the deficiency plan may be required to implement four types of actions related to non-motorized transport: bicycle and pedestrian actions, transit supporting actions, transportation demand management programs, and site design actions.

Bicycle and Pedestrian Actions. The bicycle and pedestrian actions include providing bicycle storage facilities at transit centers, improving roadside bicycle facilities (i.e., bicycle lanes, routes, etc.), and improving pedestrian circulation. Installation of bicycle storage facilities occurs off-site

at transit centers located in other parts of the metropolitan area. Such installation is financed by developers, but managed by the City of San Jose. It is intended to occur concurrently with the construction and occupancy of new development projects. Roadside bicycle facilities are intended particularly to “encourage the use of bicycles from residential areas that are located generally 4 to 5 miles from...the deficiency plan area.” Pedestrian circulation improvements consist of municipal efforts to incorporate sidewalks and pedestrian amenities within existing public rights-of-way where they are currently absent.

Transit Supporting Actions. The transit supporting actions include implementing shuttle services to and from rail transit stations, and providing transit stop improvements. The shuttles are intended to serve major employment centers. The transit stop improvements consist of installation of benches, lighting, trash receptacles, and landscaping at bus stops in the deficiency area. Improvements to bus stops along the frontage of new development projects are the responsibility of developers, while improvements to bus stops at other locations are the responsibility of the city.

Transportation Demand Management Programs. The transportation demand management (TDM) programs involve municipal distribution of alternative travel information to the public. Such information includes transit schedules, transit maps, rideshare applications, etc.⁸

Site Design Actions. The site design actions include parking preferences for high occupancy vehicles, provision of bicycle parking, provision of showering and changing rooms for bicyclists, orientation of buildings and building entrances toward streets and transit stops, the development of on-site pedestrian circulation systems, and site-related transit stop improvements.

⁸ Employers with 100 or more employees are also required to establish TDM programs. See Section 6.5.2.

Projects meeting square footage thresholds must set aside ten percent of all on-site employee parking spaces for the exclusive use of employees who carpool or vanpool to work. These spaces must be located closest to employee building entrances.

Provision of bicycle facilities involves installation of “conveniently located, well-lighted and easily visible” bicycle parking, and showering and changing rooms at all new employment sites generating 100 or more peak hour trips. Offices, R & D offices, industrial sites, and warehouses with 250 or less employees must provide a minimum of five bicycle parking spaces. Sites with between 250 and 900 employees must provide one bicycle parking space for every 50 code-required auto parking spaces. Sites with more than 900 employees must provide one bicycle space for every 50 auto spaces for the first 900 employees, but only one bicycle space for every 100 auto spaces thereafter. Retail centers must provide one bicycle space for every 50 code-required auto parking spaces. Showers and changing rooms are required only at non-retail places of employment. Employment sites with between 100 and 500 employees must provide two showers, while sites with 501 to 750 employees must provide three showers. For sites with over 750 employees, one additional shower must be provided for every 500 employees.

The building placement provision “requires new buildings to be sited in a manner designed to encourage the use of alternative modes of transportation.” All new buildings must “be oriented parallel to streets...and must have their entrances oriented toward light rail transit (LRT) stations, bus stops, and/or sidewalks for convenient access by public transit users and pedestrians.” In addition, all new buildings that are located 2000 feet or less from an LRT station should be no more than 150 feet from the street curb. Furthermore, parking should be provided in the rear or to the sides of these buildings.

The pedestrian circulation provision requires “installation of safe, attractive, useful and convenient public sidewalks and pathways in all new developments.” Direct access must be

provided from building entrances to “transit stops, on-site buildings and facilities, adjoining public sidewalks, neighboring land uses, and nearby commercial areas.” In addition, all pedestrian paths and sidewalks “must be designed with adequate lighting and signage for convenience and security” and must be fully accessible to the disabled. Finally, paths that cross parking areas must be “adequately buffered from parked cars.”

The transit-stop provision requires developers to improve transit stops and adjoining roadways concurrent with the construction of new buildings. “Improvements may include, but are not limited to, bus turnouts, bus bulbs, shelters, signs, maps, telephones, schedules, and lighting.”

6.5.2 Bay Area Air Quality Management Trip Reduction Rule

The Bay Area Air Quality Management Trip Reduction Rule requires employers with 100 or more employees at a single worksite to develop and implement trip reduction programs. These programs should be designed to increase rates of employee commuting by carpool, vanpool, bicycling and transit. Actions that employers might take to achieve this goal include providing employees with travel information, assistance, and other incentives to reduce rates of single-occupant vehicle use. The specific goal of the trip reduction ordinance is to achieve and maintain a “vehicle-employee ratio” of 0.74. That is, for every 100 employees who arrive at a worksite, only 74 motor vehicles will be used (City of San Jose, 1994).

6.6 PROFILE OF INDIRECT INFLUENCES

6.6.1 Path Network Structures

The street network structure in the study area is something of a hybrid between a rectilinear grid and a “loops and lollipop” system. This structure is complicated and interrupted,

however, by the presence of the US 101 freeway. A total of about 5.6 miles of public streets exist in the walk-to-transit zone.

Street block sizes tend to be large. On average, blocks lying fully or partially in the walk-to-transit zone encompass approximately 36 net acres. Even the three smallest blocks encompass an average of over 12 acres. The largest blocks are located along First Street in the vicinity of Karina's light rail access points.

The structure of the bikeways system is virtually identical to that of the public street network. Some important discontinuities exist in this system, however (**Figure 6.6**). Formal bicycle lanes extend along two street segments: Brokaw Road from Technology Drive to Zanker Road; and Zanker Road from Brokaw northward. Most other streets are generally suitable for safe bicycle travel. The exceptions are First Street, Guadalupe Parkway, and the portions of Brokaw Road that do not have bicycle paths. No off-road bike paths exist in the study area.

The network of formal pedestrian paths includes sidewalks located alongside public streets as well as walkways located inside the boundaries of various building complexes (**Figure 6.7**). Significant gaps in the sidewalk network are found along (a) most of the north side of Brokaw Road between US 101 and the outer edge of the peripheral mid-day trip zone; (b) a small portion of the west side of Zanker Road just north of its intersection with Brokaw; (c) all of the east side of Zanker Road from Brokaw northward; and (d) both sides of Bering Drive in the area just north of Brokaw. The ratio of total sidewalk distance to the length of public-street block faces in the walk-to-transit zone is approximately 0.86 (i.e., 86-percent of block faces have sidewalks).

An extensive network of informal pedestrian paths supplements the formal path network and offers travelers numerous short-cut possibilities (**Figure 6.8**). Most of these paths consist of routes through parking lots and planting strips forming borders between many properties.

Figure 6.6



Figure 6.7

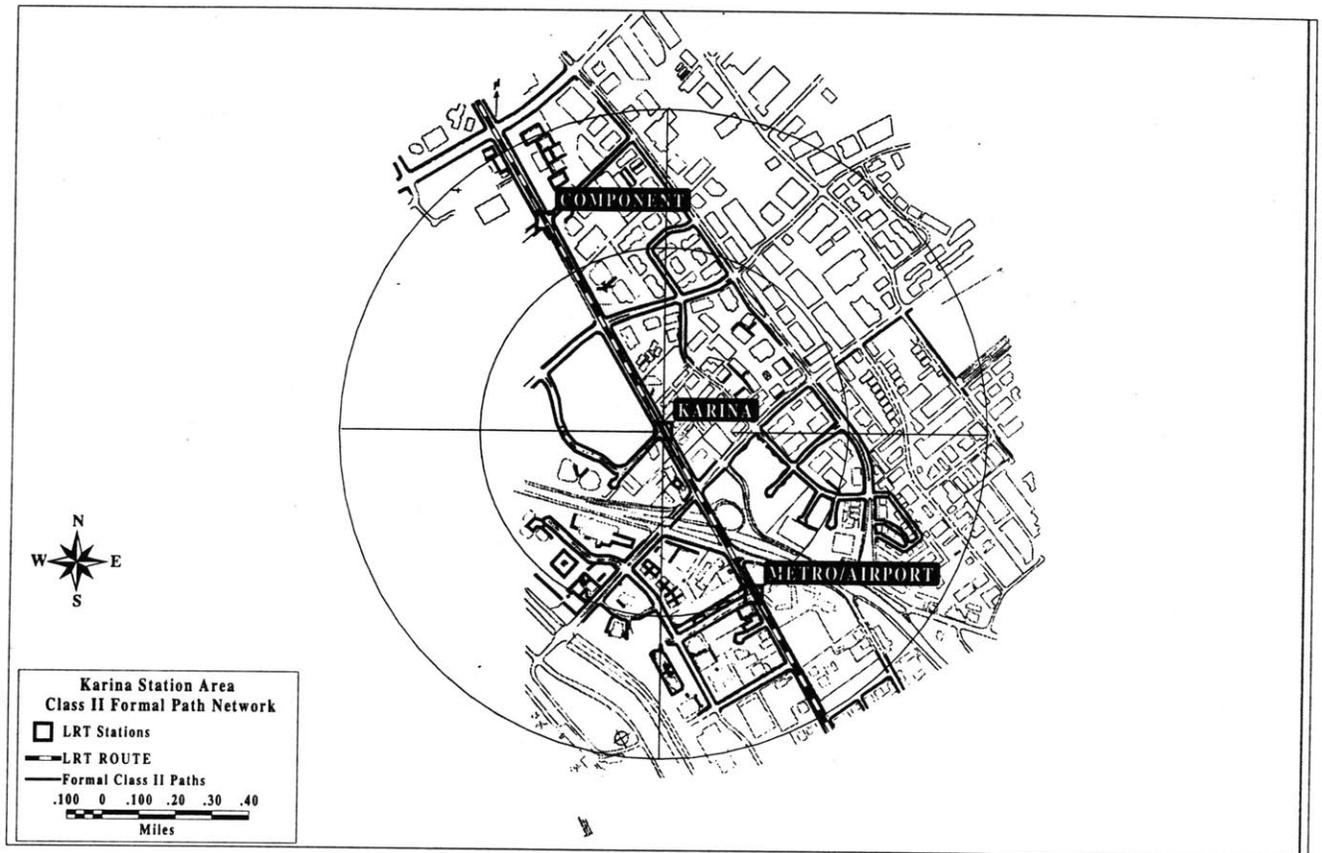
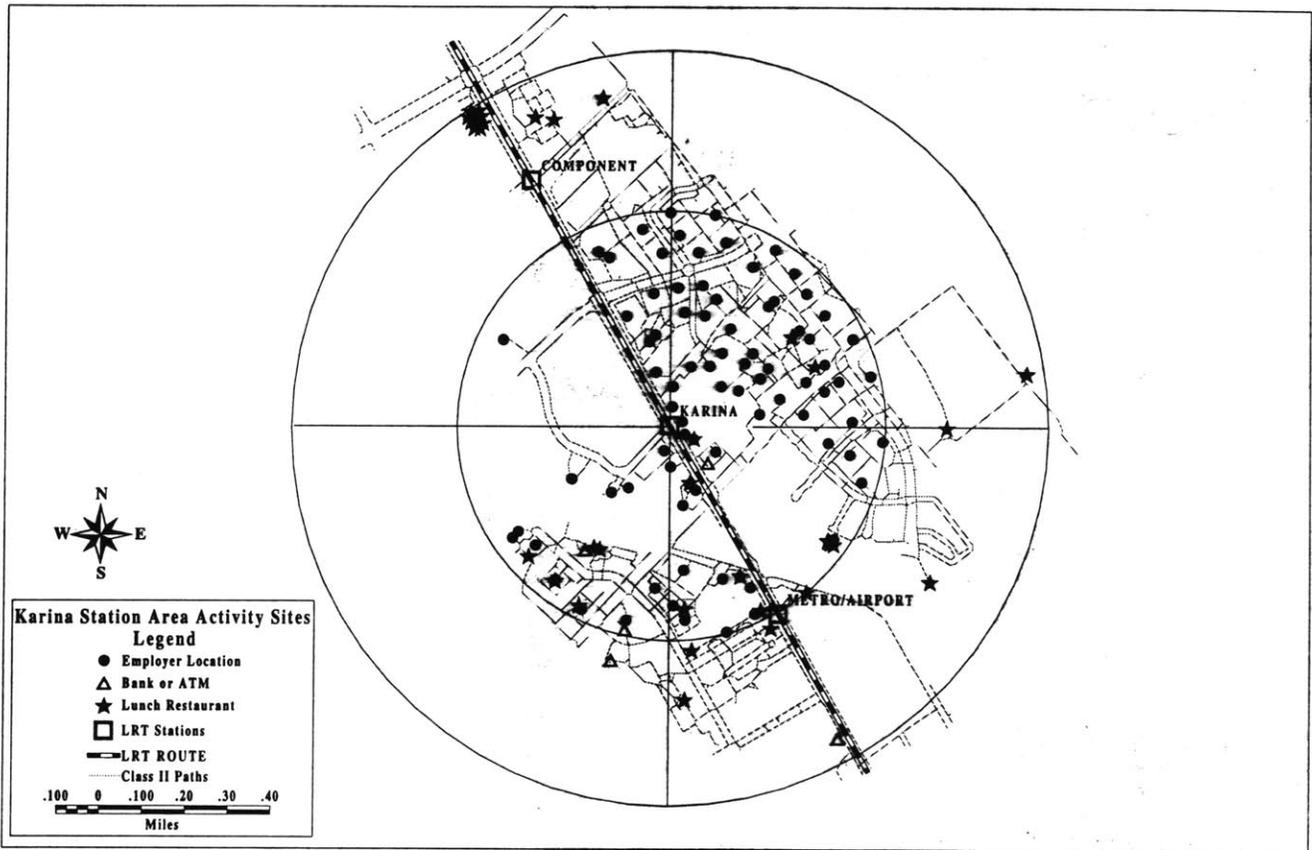


Figure 6.8



6.6.2 Travel Barriers

Travel barriers include both the “hard” and “soft” variety (see **Appendix E** for explanation). Key hard barriers include the US 101 freeway, numerous chain link fences (particularly in the immediate vicinity of Karina Station), dense hedgerows that separate many properties, and building edges. Among the soft barriers are the arterial streets (Brokaw Road, First Street, Guadalupe Parkway, and Zanker Road), the numerous permeable hedgerows and berms that line the perimeter of many properties, industrial railroad tracks on the east side of the study area, and the light rail tracks in the middle of First Street. The US 101 freeway and the light rail tracks effectively divide the study area into four distinct zones.

6.6.3 Employment Density

The total size of the walk-to-transit zone is 502.66 acres. With total employment equal to approximately 15 thousand, employment density is about 29.8 employees per gross acre. This figure lies toward the low end of the density range that Frank & Pivo (1994) suggest should be associated with moderate rates of non-SOV commuting (see Chapter Two).

6.6.4 Land-Use Mix

As noted earlier, land uses in the study area are relatively well mixed for a suburban work environment. While most land is occupied by office buildings, light industrial buildings, and warehouses, a variety of retail and other land uses are also present. The most unusual of these is a casino (card house), located just west of Crane Court. The most notable land use not present is housing.

Most retail activity is associated with food service. A total of 36 restaurants (sit down, fast food, and cafe) operate in the study area. Slightly more than half of these are located in the

peripheral mid-day trip (PMDT) zone. Ten of the restaurants in the PMDT zone are clustered in a small specialty strip mall located on the southwest corner of First Street and Trimble Road (Figure 6.9). Other concentrations of restaurants include the casino (four restaurants) and a Red Lion Hotel (two restaurants) located on Brokaw Road just south of US 101 (Figure 6.10). The remaining restaurants are distributed somewhat unevenly throughout the rest of the study area. Only a few of the restaurants remain open after 6:00 p.m.

Six full-service banks or ATM machines operate in the study area. Four of these are located south of US 101. A fifth is located near the corner of First Street and Brokaw Road. The sixth is located in the Casino.

Other types of retail activity are concentrated in four locations: (1) the specialty strip mall at the corner of First Street and Trimble Road; (2) the ground floor of a large office complex located on First Street just east of the specialty strip mall; (3) the ground floor of a large office building (“Metro Plaza”) located just south of the Metro/Airport light rail station; and (4) the Red Lion Hotel. Retailers and services in the strip mall include a florist, copy shop, dentist, dry cleaner, convenience store, one-hour photo developer, and stock brokerage. The office complex includes a computer book store and hair salon. Metro Plaza retailers include a dry cleaner and travel agency. Finally, the Red Lion Hotel includes a hair salon and gift shop.

Figure 6.9

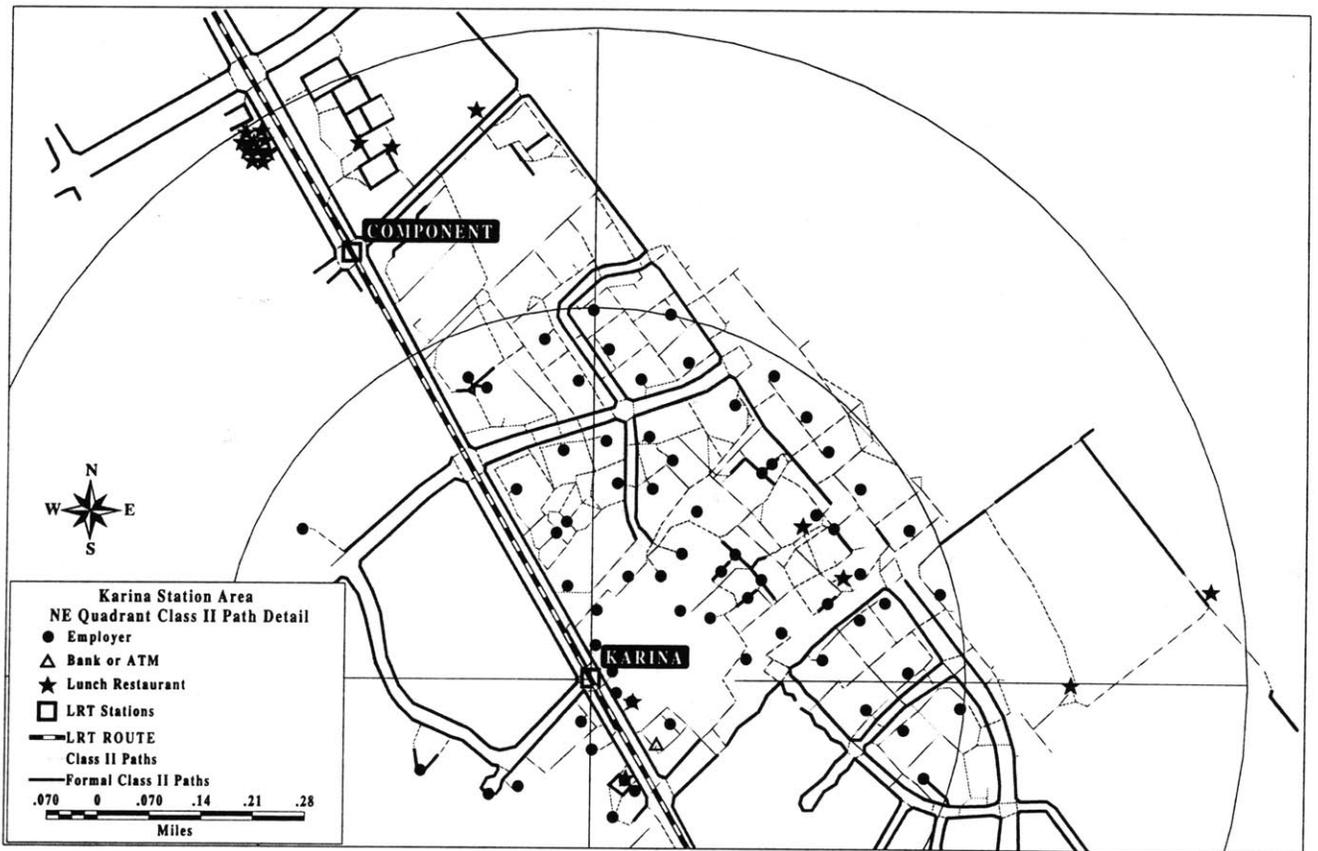
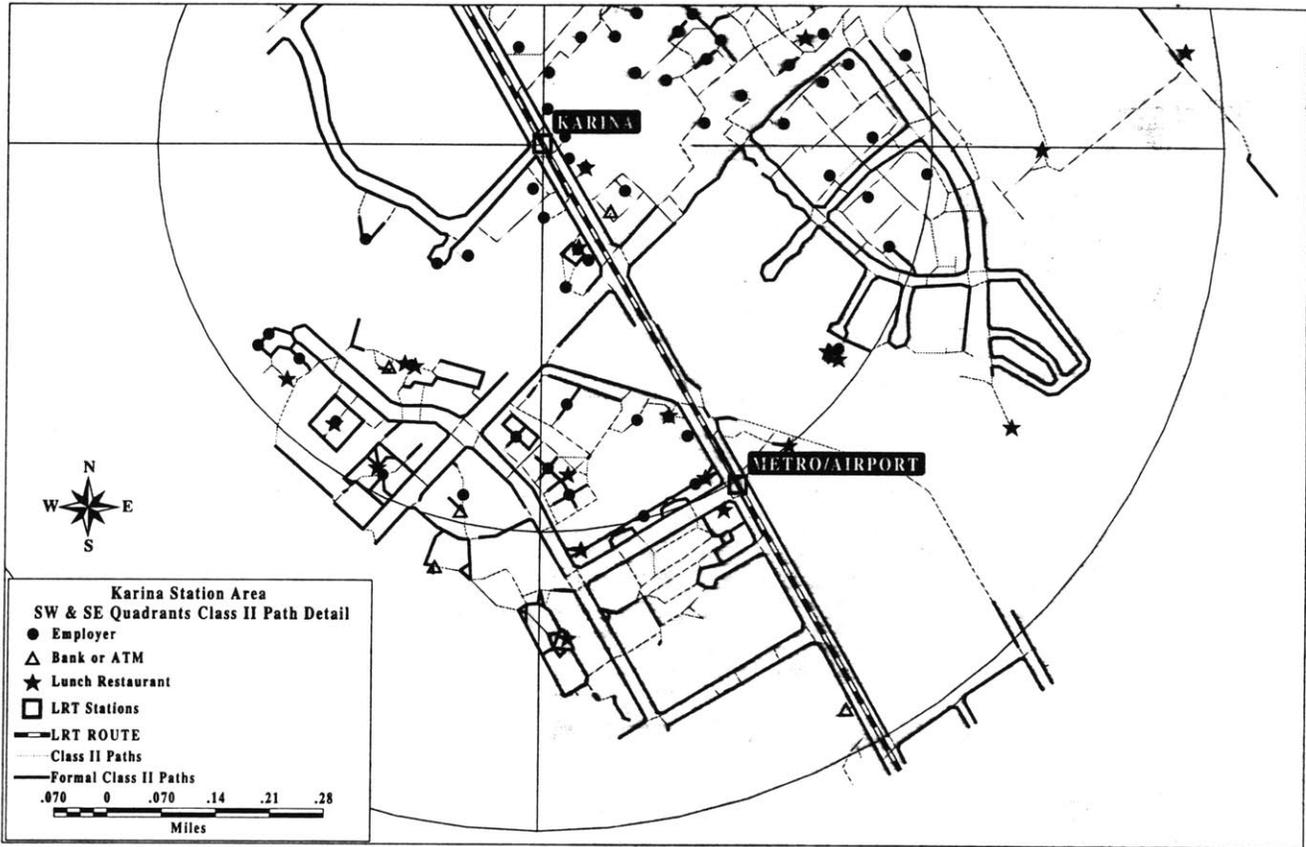


Figure 6.10



6.7 PROFILE OF DIRECT INFLUENCES

6.7.1 Employee Characteristics

While the composition of Karina’s employee population is fairly diverse, persons who work in offices are clearly a majority. Almost 68-percent of the work force falls into this category (Table 6-1). Persons who work in office-industrial and industrial environments also represent large proportions of the employee population.

Women are a large percentage of the office workers. Women also hold large percentages of jobs in the hotel/motel, casino and retail categories. Men, however, still likely compose an overwhelming majority of workers in the office-industrial, industrial and warehouse categories.

Most employees are between 21 and 65 years old. Teenagers, however, compose a large percentage of the retail work force.

Table 6-1: Estimated Employment by Land Use

	Office	Ofc-Ind	Industrial	Warehouse	Hotel/Motel	Casino	Retail
Employment	10403	2891	1081	65	430	200	317
% Total Employment	67.6%	18.8%	7.0%	0.4%	2.8%	1.3%	2.1%

Source: Appendix G

6.7.2 Trip-Specific Factors

Trip-specific factors that influence willingness to use a non-motorized mode include travel distance, trip purpose, travel time-of-day, the availability of trip-chaining opportunities, and the attractiveness of travel by alternate modes.

Pedestrian Travel Distances. The average airline distance separating an employee from the closest LRT station (Karina, Component, or Metro/Airport) is over 1300 feet (Table 6-2). About 11.6-percent of employees work within 500 feet of a station. Just over 26.5-percent of employees

work within 1000 feet, while 87.5-percent of employees work within 2000 feet. The distribution of airline distances is shown in **Figure 6.11**.

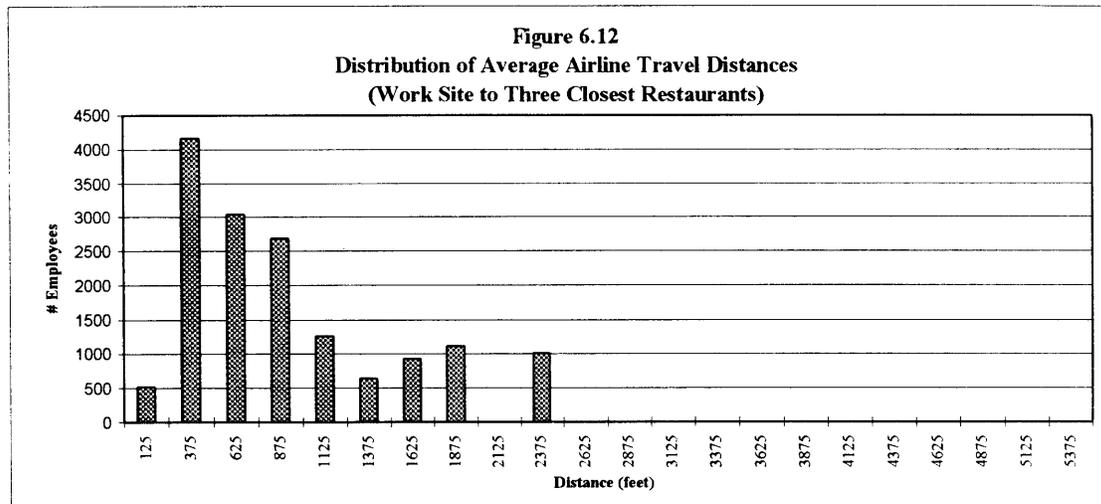
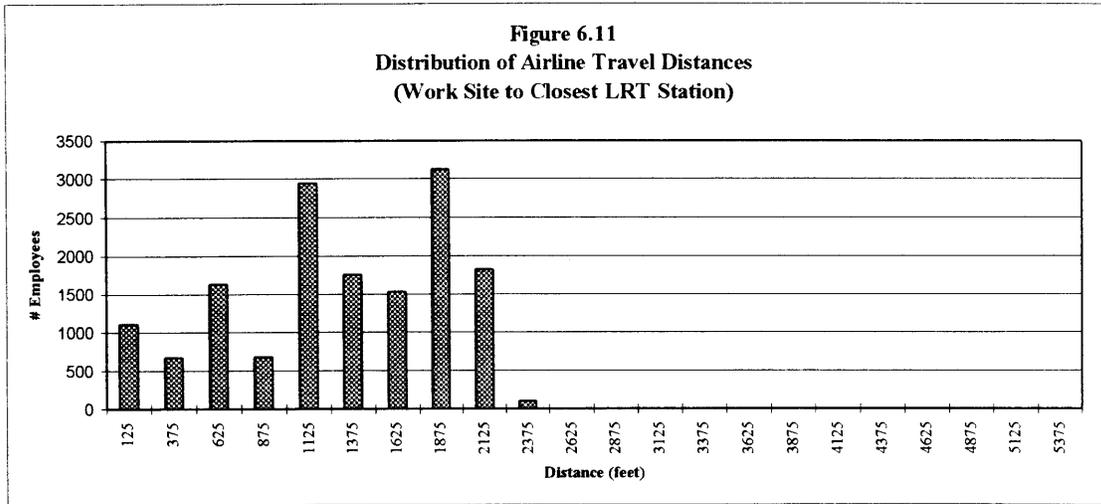
Table 6-2: Employee Travel Distances by Path Type and Trip Category

	Airline Routes		Shortest Paths			
	Walk to Closest LRT Station	Walk to Lunch	Walk to Closest LRT Station			Walk to Lunch
			Non-Stop	One-Stop	Two-Stop	Non-Stop
Mean Distance (feet)	1313.4	922.3	2041.7	2475.4	3351.6	1375.7
Standard Deviation	605.0	605.6	1027.3	1067.8	743.8	823.7
Coefficient of Variation	0.46	0.66	0.50	0.43	0.22	0.60
% Employees 0-to-500 feet	11.6	30.5	9.7	6.9	0.0	16.6
% Employees 0-to-1000 feet	26.7	67.8	21.7	13.9	0.1	39.2
% Employees 0-to-2000 feet	87.5	93.4	47.6	28.8	5.7	74.1

The average airline distance separating an employee from the three restaurants closest to his or her work site is just over 922 feet. About 30.5-percent of employees work within 500 feet average distance to the three closest restaurants. Almost 68-percent work within 1000 feet, while over 93-percent work within 2000 feet. **Figure 6.12** illustrates the distribution of average airline distances to the three closest restaurants.

The average shortest-path distance that an employee in the study area must walk to reach the closest LRT station without stopping is over 2000 feet. For employees who wish to stop at a cafe between the closest station and work, the average distance is almost 2500 feet. Finally, for employees who wish to stop first at a bank or ATM, and second at a cafe before continuing to work, the average distance is over 3350 feet. For lunchtime travel, the average shortest-path distance is over 1375 feet.

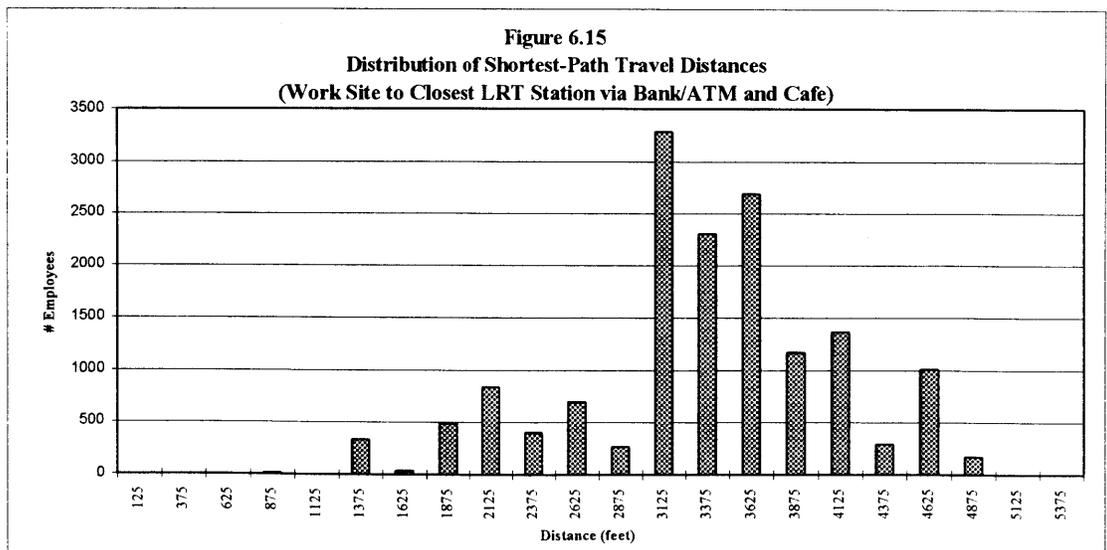
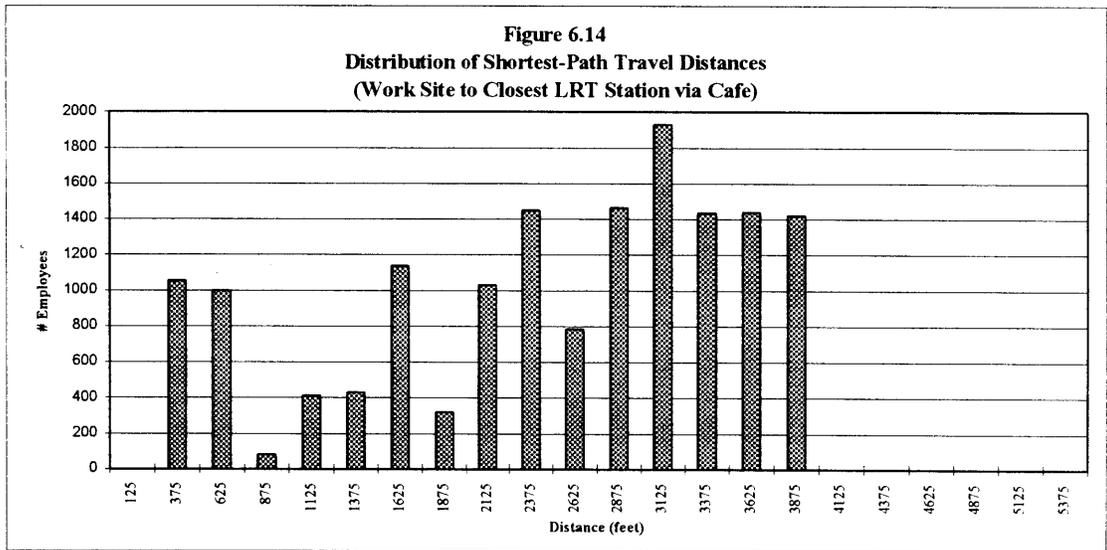
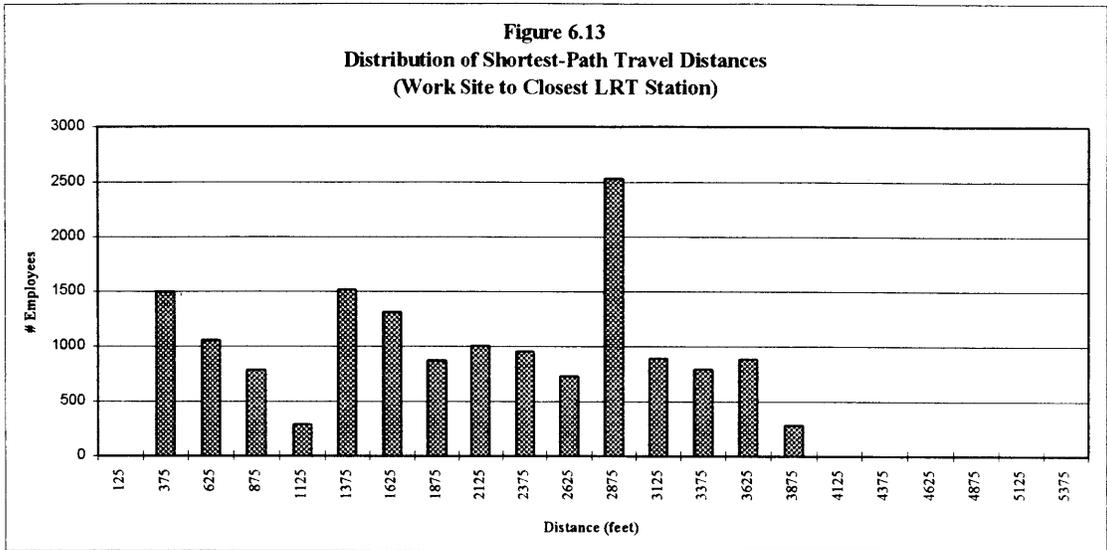
As a percentage of the mean, variation in shortest-path station-to-work travel distances is highest for non-stop and lowest for two-stop trips. For lunch trips, variation for distance is higher



than any of the station-to-work cases. Travel distances for all types of trips are somewhat unevenly distributed, however (see Figures 6.13 through 6.16).

Table 6-3 gives data on the efficiency of the Class II pedestrian path network in the study area.⁹ As the data indicate, shortest paths provide just over 92-percent of the accessibility provided by airline paths for non-stop station-to-work travel. The average detour factor is 1.55, while the actual-to-ideal accessibility ratio is 88-percent.

⁹ The accessibility indices and ratios shown in Table 6-3 are based on impedance functions developed and estimated by Levinson & Kumar (1994).



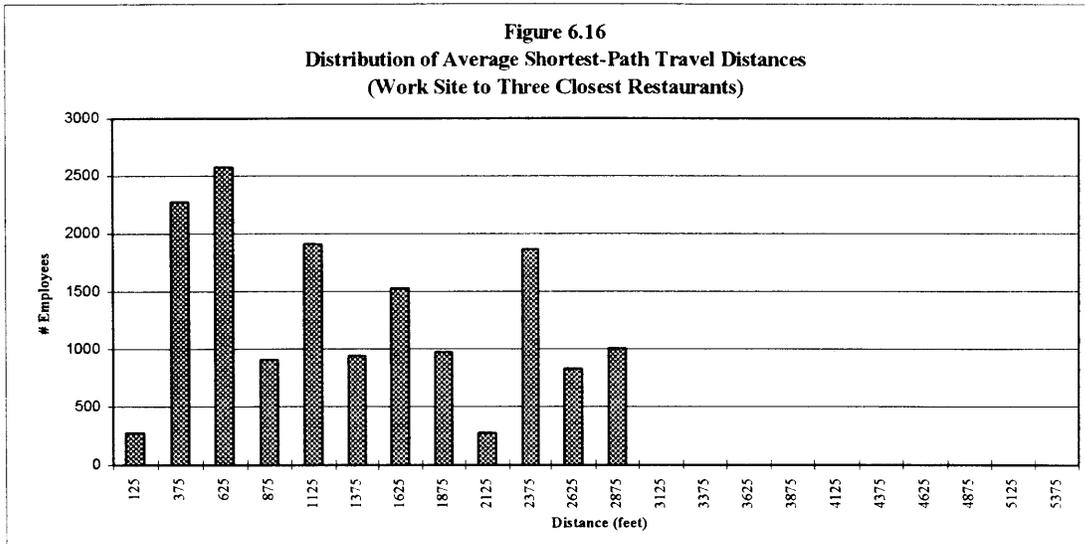


Table 6-3: Current Pedestrian Accessibility Ratio and Detour Factor Statistics

<u>NON-STOP TRIPS</u> (station-worksite)	Shortest-Path Accessibility Index	2500.6
	Airline Accessibility Index	2714.1
	Accessibility Ratio	0.9213
	Total Employment	15386
	Shortest-Path Accessibility per Employee	0.1625
	Average Employee Detour	1.55
	Actual-to-Ideal Accessibility Ratio	0.8813
<u>ONE-STOP TRIPS</u> (station-cafe-worksite)	Shortest-Path Accessibility Index	2372.0
	Airline Accessibility Index	2714.1
	Accessibility Ratio	0.8739
	Total Employment	15386
	Shortest-Path Accessibility per Employee	0.1542
	Average Employee Detour	1.95
	Actual-to-Ideal Accessibility Ratio	0.8359
<u>TWO-STOP TRIPS</u> (station-bank/ATM-cafe-worksite)	Shortest-Path Accessibility Index	2115.8
	Airline Accessibility Index	2714.1
	Accessibility Ratio	0.7796
	Total Employment	15386
	Shortest-Path Accessibility per Employee	0.1375
	Average Employee Detour	3.78
	Actual-to-Ideal Accessibility Ratio	0.7457
<u>LUNCH TRIPS</u> (worksite-restaurant)	Shortest-Path Accessibility Index	44111.3
	Airline Accessibility Index	78290.4
	Accessibility Ratio	0.5634
	“MIN 3” Shortest-Path Accessibility Index	16636.4
	“MIN 3” Airline Accessibility Index	21653.4
	“MIN 3” Accessibility Ratio	0.7683
	Total Employment	15386
	“MIN 3” Shortest-Path Accessibility per Employee	1.0812
	Average Employee Detour	1.45
	“MIN 3” Actual-to-Ideal Accessibility Ratio	0.4358

For one-stop travel, shortest paths give just over 87-percent of the accessibility provided by airline paths. The average detour factor is 1.95, while the actual-to-ideal accessibility ratio is just under 84-percent. For two-stop travel, shortest paths provide just under 78-percent of the accessibility provided by airline paths. The average detour factor is 3.78. The actual-to-ideal accessibility ratio is just under 75-percent.

For lunch trips, shortest paths provide just over 56-percent of the accessibility provided by airline paths when all station-area restaurants are considered, but almost 77-percent when only the closest three restaurants are considered. The average detour factor for trips to the three closest restaurants is 1.45, with an actual-to-ideal accessibility ratio of just under 44-percent.

Bicycle Travel Distances. Transit-to-work and mid-day travel distances for cyclists in the study area tend to exceed distances for pedestrians, but not by much. Most bicycle pathways (informal as well as formal) correspond roughly to pedestrian paths. That is, wherever a pedestrian can travel, a cyclist can as well. For this reason, travel distances for bicycles were not measured.

Trip Purposes and Travel Times-of-Day. Common purposes for non-motorized travel in the study area include commuting to and from work; running work-related and personal shopping errands; attending business meetings; relaxation and stress relief (during work breaks); and accessing restaurants, cafes, hotels, motels, and the casino. Most travel takes place during daylight hours. Very little intra-area travel takes place at night.

Trip-Chaining Opportunities. While a fairly diverse mix of land uses is present within the study area, the uneven distribution of retail and service activities makes trip-chaining difficult. Restaurants and cafes are an exception to this, however. The relatively even distribution of these land uses facilitates trip-chaining for transit-to-work and work-to-transit travel.

Travel by Alternate Modes. Travel in the study area by automobile is generally easy throughout the day and night. While the arterial roads can become congested during peak travel periods (i.e., morning, lunch-time, and evening), this congestion is not sufficient to create a strong disincentive to travel by car for short trips. Moreover, the fact that parking is free and abundant throughout the area means that this factor also does not inhibit use of automobiles. Perhaps the only strong disincentive to using a car comes from the difficulty motorists face when attempting to turn left while traveling on First Street. The presence of the light rail tracks prevents left turns except at street intersections.

Travel by bus or shuttle is an entirely different story. Service frequencies on the conventional bus routes that serve the area are not high enough to provide a practical alternative for short trips. Moreover, while the shuttle service to and from the Metro/Airport LRT station operates several times per hour, its service area is limited.

6.7.3 Use of Public Spaces

Key issues related to use of Karina's public spaces include personal safety, personal security, climate, and institutional support.

Personal Safety. While levels of personal safety for non-motorized travelers in the study area are generally high, significant conflicts between cars, pedestrians, and cyclists exist in three places: (1) points where transit users cross First Street to access light rail stations; (2) the portion of Bering Drive that lacks sidewalks; and (3) surface parking lots. The need for pedestrians and cyclists to cross LRT tracks also poses a moderate threat to personal safety.

Personal Security. Levels of personal security are generally high in the study area. Private security guards routinely patrol many properties, and there seems to be little apparent difficulty with vandalism and graffiti. Some security problems do exist, however. First, travel through the First Street underpass of the US 101 freeway and at various other locations would probably not be considered safe by most travelers. Second, the study area generally lacks good, glare-free pedestrian and cyclist-oriented street lighting. Third, a lack of nighttime retail activity along streets may diminish traveler perceptions of the study area as a secure environment.

Climate. Among North American cities, San Jose has one of the better climates for walking and bicycling. January and July average temperatures are around 48°F and 67°F, respectively. Temperatures are equally mild in the spring and fall. Annual rainfall averages about 14 inches, with most of this amount falling during the winter months.

Institutional Support. Institutional support for alternative (i.e., other than single-occupant vehicle) travel in the study area includes employer trip reduction programs, municipal and transit agency traveler information programs, and educational and information programs of the regional transportation management association. These programs tend to focus on facilitating regional rather than local (i.e., transit-to-work and mid-day) travel.

6.7.4 Environmental Characteristics

Environmental characteristics that enhance the non-motorized travel experience in the study area include comfortable, safe, clean, and well maintained walking and bicycling pathways; level walking and riding surfaces; a generally clean and well-maintained ambient environment; the omnipresence of shade trees; and a multiplicity of route choices. Features that detract from the

experience include a lack of stimulating environmental features; poor network legibility and nighttime illumination; heavy traffic noise; relatively poor air quality; and a lack of resting places and clean public restrooms.

Walking and Bicycling Paths. Paths available to pedestrians in the study area are generally suitable for use by the majority of people who work in the area. Most walkways fall into the Class II category defined in Appendix C. Such paths are comfortably used by all persons except those with disabilities. A large portion of the path network, however, is appropriate for use by the disabled.

Formal pedestrian paths in the study area are generally in good physical condition. Most sidewalks are made of concrete and were constructed relatively recently. Paths are generally free of trash, dirt, and debris.

As discussed previously, bicycle paths include bicycle lanes on portions of Brokaw and Zanker Roads, as well as bicycle routes along local streets. Significant gaps in the bicycle path network exist, however, along First Street and Brokaw Road east of Zanker. Bicycle paths are generally free of dirt and debris.

Topography. There is little variation in topography in the study area. The area is virtually devoid of any slopes that would inhibit or preclude foot or bicycle travel.

Ambient Environment. As in other parts of Silicon Valley, buildings and property in the study area are generally clean and well maintained. As noted previously, there is virtually no graffiti or evidence of vandalism.

Shelter from Intense Sun and Poor Weather. The virtual omnipresence of street trees in the study area makes non-motorized travel reasonably comfortable even on the warmest and wettest days of the year. The few unsheltered areas include the west side of Bering Drive in the vicinity of the casino and the Zanker Road intersection. Portions of the peripheral mid-day trip zone lying south of Brokaw Road and east of First Street also lack shelter. Because most buildings are set far back from streets, the potential for building awnings and arcades to provide shelter is virtually non-existent.

Route Choices. The availability of numerous informal paths in the study area provides many opportunities for choosing between alternative routes when traveling by either foot or bicycle between most origin-destination pairs. Most of these informal paths traverse parking lots.

Environmental Stimuli. Although the study area offers ubiquitous street trees, campus-style landscaping, a scattering of office plaza fountains, and the occasional neon sign, it provides relatively little sense of streetscape continuity, street enclosure, or the stimulus of street-activating retail activities and services. Architecture is strictly utilitarian and designed to be viewed from afar (i.e., from speeding automobiles). Complex facade articulation and public art are virtually non-existent.

Network Legibility and Nighttime Travel Conditions. The legibility of both the pedestrian and bicycle path networks tends to be poor. For people who are unfamiliar with the area, wayfinding proves difficult. There is little clear hierarchy to the paths and few distinct landmarks to guide the way. Signage is oriented to motorists, and no maps of the area exist at any of the LRT stations. At night, poor illumination of paths compounds this problem.

Traffic Noise. Traffic noise tends to be heavy, especially near the US 101 freeway, First Street, and Brokaw Road. Only near the US 101 freeway, however, is traffic noise so heavy that conversation becomes difficult.

Local Air Quality. Relative to other parts of California, air quality in the San Francisco Bay area is reasonably good. The region was designated a “moderate” non-attainment area for ozone in the 1990 Clean Air Act Amendments. Moreover, much of the economic base in the region consists of so-called “clean” industries such as high-technology R&D and manufacturing. In the Karina study area, however, small and medium-size manufacturing firms, auto dealerships, dry cleaners, etc. produce substantial emissions of air toxics. Moreover, the close proximity of the study area to the US 101 freeway means that its air quality is adversely affected by higher than average levels of mobile source emissions.

Rest and Relief Amenities. The availability of rest and relief amenities is generally greater on the south than on the north side of the US 101 freeway. Several office buildings south of US 101 have small plazas and fountains. Moreover, the two hotels on the south side of US 101 have indoor sitting areas and clean, publicly accessible restrooms. South-side restaurants and cafes also provide seating areas and restrooms.

On the north side of US 101, places to sit and use publicly accessible restrooms include McDonald’s and Denny’s restaurants located in the vicinity of First Street and Brokaw Road, the casino, and the small strip mall located at the corner of First Street and Trimble Road. Outdoor resting places consist of a few scattered park benches and some grassy berms.

6.7.5 Bicycling Conditions

Key conditions that may influence willingness to ride a bicycle include the availability of bicycle parking, the availability of showering and changing facilities, bicycle access via the transit system, and bicycle access via the regional bikeways network.

Availability of Bicycle Parking. Relatively little public bicycle parking (bicycle racks, lockers, or standing posts) exists in the study area. As new development occurs, however, this situation will improve in response to the requirements of the Deficiency Plan for North San Jose.

Availability of Showering and Changing Facilities. The lack of a local health club means that showering and changing facilities are not available to many workers, particularly those employed by small firms. Moreover, as new development takes place in the future, only persons employed at the largest employment sites will presumably have access to showering and changing facilities (per Deficiency Plan requirements).

Bicycle Access via the Transit System. Bicycle access to the study area via the transit system is generally quite good. All light rail vehicles on the VTA system will soon be equipped with racks capable of accommodating up to four bicycles at a time. Up to two additional standing bicycles will also be permitted on each train. All buses on the VTA system are equipped with exterior racks capable of accommodating two bicycles.

Bicycle Access via the Regional Bikeways Network. Bicycle access to the study area via the regional bikeways network is currently rather poor. Planned extensions of the bikeways system,

particularly from residential districts north of the study area, should improve this situation somewhat in the future, however.

6.8 IDENTIFICATION OF PRIMARY AND SECONDARY TRAVEL ROUTES

Figures 6.17 and **6.18** show primary and secondary pedestrian and bicycle travel routes, respectively. Primary routes are defined generally as those composing the shortest paths between the closest LRT station and each worksite. Additional primary routes, however, have been identified to connect worksites with restaurants and other retail and service activity locations. Some shortest-path routes have been modified slightly to avoid unseemly areas (e.g., areas behind buildings) and to pass near clusters of retail and service activity.

6.9 EVALUATION OF CURRENT NON-MOTORIZED TRAVEL CONDITIONS

The author's application to the study area of the evaluation criteria developed in Chapter Five is shown in **Figure 6.19**. The criteria are structured as a set of questions. A negative response to any question implies a deficiency or problem in the area to which the criterion refers.

Figure 6.17

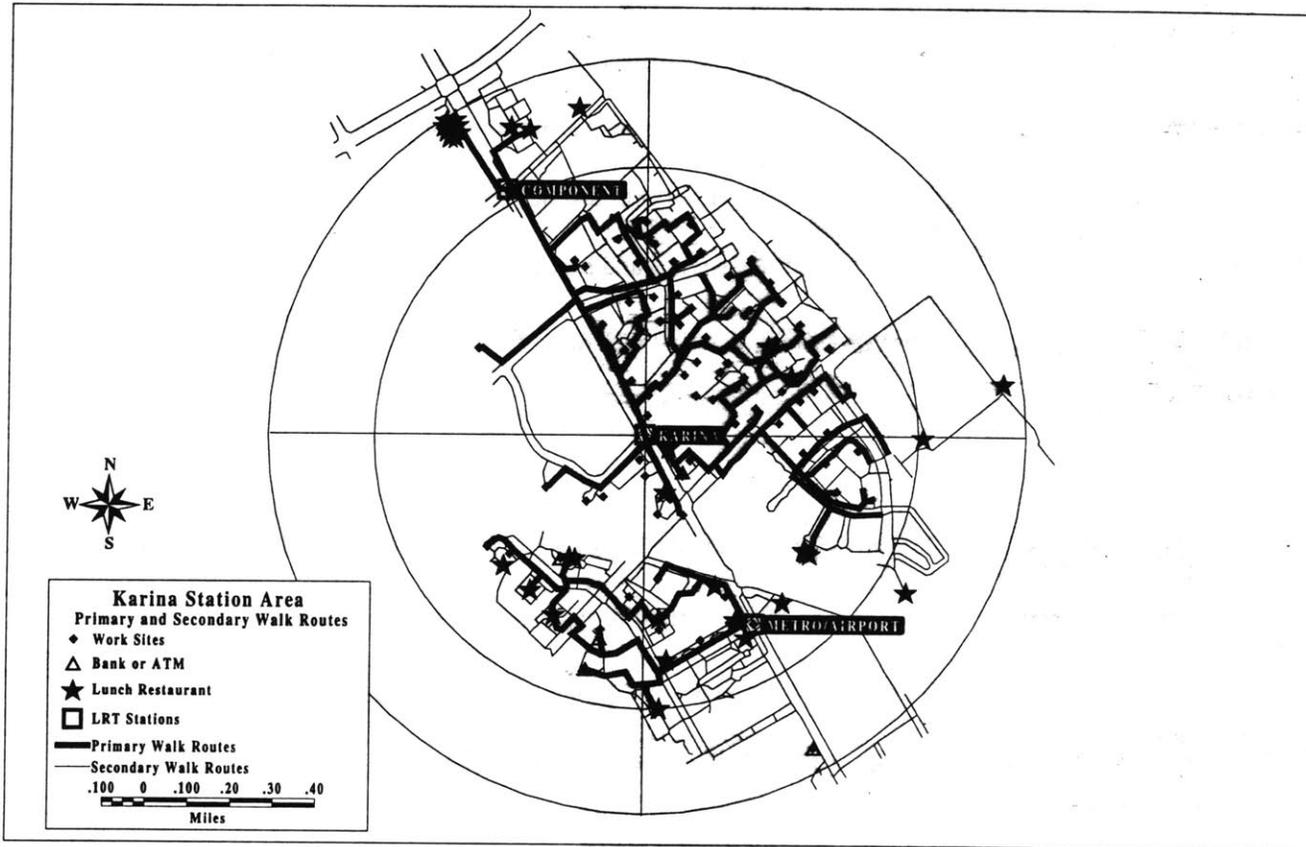


Figure 6.18

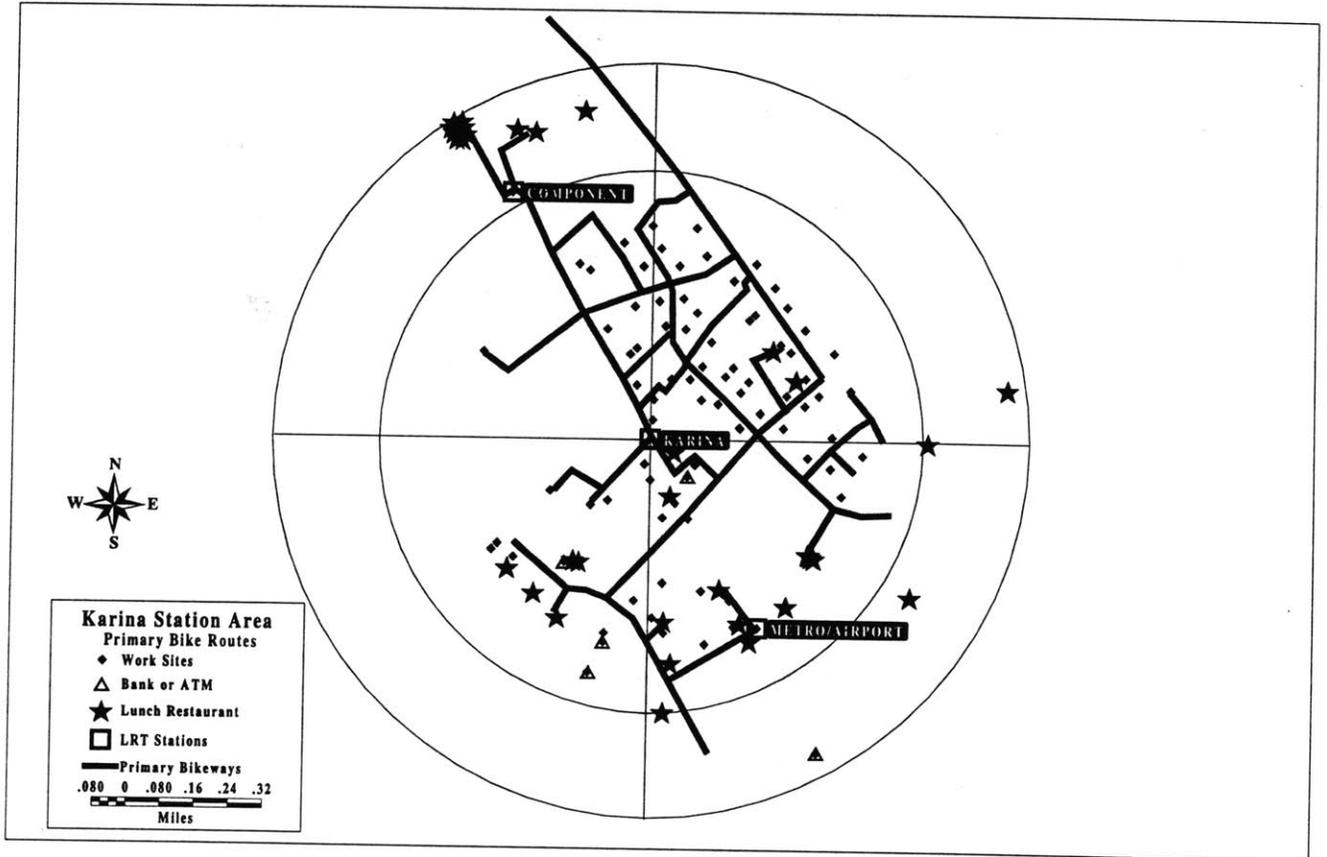


Figure 6.19
Evaluation of Pedestrian and Cycling Conditions
in the Karina Study Area

Base Conditions

1. *Are basic walkway and bikeway networks available for travel between all or most points in the study area?* Yes. Virtually all work, retail, and service activity sites have direct access to the Class II pedestrian and safe bicycle path networks.
2. *Are aggregate population and employment densities great enough to generate continuous pedestrian and cyclist activity throughout the day?* Yes. While no residential land uses exist in the study area, and while employment density lies toward the low end of the range that should be associated with moderate rates of non-SOV travel, sufficient density does exist to generate moderate levels of continuous non-motorized travel activity throughout the work day.
3. *Do study area land uses include a diverse mix of residential, employment, retail, and service activities?* No. While land uses in the study area are relatively well mixed by comparison to other suburban employment areas, land use diversity could be improved. The most conspicuous absence from the mix is housing.
4. *Is the study area generally free of serious crime?* Yes. The sensitive nature of many of the study area's business activities makes security a high priority. Large portions of the study area are guarded by private security services, and there is also a modest police presence.
5. *Is the study area generally free of serious conflicts between pedestrians, cyclists, automobiles, and other traffic?* Yes. Traffic speeds on most streets in the study area remain relatively modest. Moreover, San Jose area motorists tend to obey traffic rules and respect pedestrian and cyclist rights of way. Only two streets in the study area have high traffic volumes, and all intersections along these streets include signalized crosswalks. Conflicts between pedestrians and cyclists are minimized by the existence of dedicated bicycle lanes on streets where cyclists might otherwise be tempted to ride on sidewalks.

Three significant safety-related problems exist in the study area, however. First, some intersections along Brokaw and Zanker Roads include right turn cut-offs. Second, many pedestrian and cyclist travel routes pass through parking lots. Third, pedestrian and cyclist crossings of First Street require special attention to both moving traffic and LRT vehicles. All three of these situations involve some increased hazard to non-motorized travelers.

Figure 6.19 (cont'd)
Evaluation of Pedestrian and Cycling Conditions
in the Karina Study Area

Travel Distances and Impediments

6. *Are travel distances for transit access as short as reasonably possible?*
No. Distances that study area employees must walk to reach a light rail station tend to be long. This is in spite of the fact that three stations are available for LRT access. One reason for this is the poor (airline) spatial distribution of employees relative to the stations. This spatial-distribution problem is compounded by a high average and wide variation in shortest-path distances. Both are due to a relatively inefficient path network structure; there is generally a lack of reasonably direct travel paths between the closest station and each worksite.
 7. *Are travel distances for mid-day travel as short as reasonably possible?*
Yes. Travel distances to restaurants are fairly low. This has much to do with a good spatial distribution of work sites relative to the distribution of food-service establishments. In spite of these favorable conditions, however, distances could be improved by reducing the divergence between shortest-path and airline distances.
 8. *Are opportunities for easy trip-chaining maximized?* No. For transit-to-work trips involving stops at cafes and banks/ATMs, travel distances tend to be very long. Because these land uses represent the predominant and most evenly distributed retail/service activities in the study area, chained trips involving stops at other types of activities must surely be longer.
 9. *Are the path networks without significant gaps?* No. Significant gaps in the sidewalk network are found along (a) most of the north side of Brokaw Road between US 101 and the outer edge of the peripheral mid-day trip zone; (b) a small portion of the west side of Zanker Road just north of its intersection with Brokaw; (c) all of the east side of Zanker Road from Brokaw northward; and (d) both sides of Bering Drive in the area just north of Brokaw. Moreover, the area between First Street and Bering Drive to the northwest of Brokaw Road contains no mid-block passages. Also, paths could be constructed just east of the US 101 on-ramp to connect Brokaw Road to the area around the casino, and between Karina Court and the Red Lion Inn (via an over or underpass of the US 101 freeway) to better integrate the north and south parts of the study area. Finally, a short path could be built east of Zanker Road to connect employment sites in the walk-to-transit zone to the two restaurants located in the northeast quadrant portion of the peripheral mid-day trip zone.
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Figure 6.19 (cont'd)
Evaluation of Pedestrian and Cycling Conditions
in the Karina Study Area

Travel Distances and Impediments (cont'd)

10. *Is the study area generally free of barriers that would inhibit opportunities for taking short cuts using informal paths or building pass-throughs?*
Yes. Opportunities for pedestrians and cyclists to take short-cuts between origin-destination pairs are generally abundant. This abundance has much to do with the fact that most study-area properties are bounded by soft barriers such as permeable hedgerows and berms rather than hard barriers such as fences, walls, and impermeable hedgerows. The ubiquity of surface parking lots often makes property boundaries hardly noticeable. The area between First Street and Bering Drive in the vicinity of the Karina Station is the key exception to the general freedom from barriers. Here, fences block travel in all directions.

 11. *Is the topography of the study area conducive to walking and bicycling?*
Yes. There is very little variation in topography in the study area. The area is virtually flat.

 12. *Do pedestrians and cyclists face minimal waiting times at street crossings?*
Yes. Most streets in the study area do not carry sufficiently high traffic volumes to delay substantially pedestrians and cyclists at crossings. Along the streets with heavy traffic (i.e., First Street, Zanker Road, and Brokaw Road), wide and pleasantly landscaped medians are generally available to assist travelers with crossing. Such medians allow pedestrians to begin crossing the street without having to wait for both directions of traffic to clear. Moreover, all major street intersections have signalized crosswalks that help reduce waiting time. No intersection along a road with heavy traffic is without signals.

 13. *Are street segments and intersections designed to calm traffic and minimize the risk of vehicle-pedestrian, vehicle-bicycle, and bicycle-pedestrian collisions?* No. As a rule, streets in the study area are designed for free flow of automobiles. In particular, problems exist at the following intersections: Brokaw Road and Technology Drive, Brokaw Road and First Street, Brokaw Road and Zanker Road, and Zanker Road and Charcot Avenue. Right turn cut-offs at these intersections pose significant hazards to pedestrians and cyclists. Also, the absence of a street median along Technology Drive increases the risk of accidents. Finally, when crossing First Street, pedestrians and cyclists face a dual problem of crossing both busy automobile travel lanes and the bi-directional light rail tracks.
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Figure 6.19 (cont'd)
Evaluation of Pedestrian and Cycling Conditions
in the Karina Study Area

Urban Environmental Characteristics

14. *Are walking and cycling surfaces along primary travel routes safe and comfortable to use?* No. For non-motorized travel, formal paths offer the highest levels of safety and comfort. Such paths, however, represent only a modest proportion of primary pedestrian and bicycle travel routes. Informal paths compose the remainder. Many of these informal paths traverse parking lots. The presence of potholes, spilled motor oil, curbing, etc. makes walking and cycling through parking lots neither entirely safe nor very comfortable. The unpaved surfaces of other informal paths also reduce the safety and comfort of non-motorized travel.
 15. *Are primary walkways and bikeways generally clean and well maintained?* Yes. In keeping with the study area as a whole, walkways and bikeways are generally clean and well maintained.
 16. *Are buildings and other property along walkways and bikeways generally clean and well maintained?* Yes. Most of the buildings and infrastructure in the study area were constructed in the last three decades and are in very good physical condition. Moreover, litter is collected on a regular basis.
 17. *Are primary travel routes sheltered from intense sun and poor weather?* Yes. While awnings, arcades and other building shelters are generally absent from the area, mature trees line many study area streets. Important exceptions include parts of First Street north of the US 101 freeway, and Brokaw Road between the US 101 freeway and Bering Drive.
 18. *Do primary travel routes offer pleasant visual, acoustic and other sensory stimuli to pedestrians and cyclists?* No. As in many suburban work environments, there is a sterile and placeless quality to the study area. This lack of animation and distinctiveness stems from a variety of sources. These include featureless architecture, a dearth of creative public art, lack of sidewalk-oriented retail and service activities, lack of a strong sense of street enclosure, homogeneity of building tenants and employees, lack of influence by area “inhabitants” (i.e., employees) over their surroundings, strict control over nature, and a seemingly endless expanse of paved surfaces.
 19. *Do pedestrians and cyclists generally benefit from a choice of travel routes between origin-destination pairs?* Yes. An abundance of informal paths ensures that multiple routes are available for travel between most origin-destination pairs.
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Figure 6.19 (cont'd)
Evaluation of Pedestrian and Cycling Conditions
in the Karina Study Area

Urban Environmental Characteristics (cont'd)

20. *Is the study area free from any specific locations where pedestrians or cyclists might feel personally threatened by crime while traveling during daylight hours?* No. The east side of First Street in the immediate vicinity of the Karina light rail station could be perceived by many study area employees as somewhat dangerous. A super budget motel at this location tends to attract a clientele that many area employees may regard with suspicion. Two other areas that may be perceived as dangerous are the First Street underpass of the US 101 freeway, and the area along Fourth Street.

 21. *Are night-time travel conditions along primary travel routes safe, secure and comfortable?* No. After approximately 6:00 p.m., few people other than hotel and motel guests remain in the study area. The local and collector streets become virtually deserted and retail activity ceases. Street lighting is poor.

 22. *Do traffic noise levels along primary pedestrian and bicycle travel routes generally permit pleasant and easy conversation?* No. Significant noise levels exist along First Street, Brokaw Road, and in close proximity to the US 101 freeway. Only near the US 101 freeway are continuous levels of noise substantial enough to inhibit conversation severely. The sound of planes taking off and landing at San Jose International Airport also inhibits conversation severely, particularly in the part of the study area south of the US 101 freeway.

 23. *Is local air quality conducive to walking and cycling?* No. Air toxics emitted by local stationary sources (i.e., small manufacturing firms, auto dealerships, dry cleaners, etc.), together with higher than average levels of ground level ozone and other automobile-related pollutants, make walking and cycling less comfortable and healthy than if the air were cleaner.
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Figure 6.19 (cont'd)
Evaluation of Pedestrian and Cycling Conditions
in the Karina Study Area

Traveler Support Features

24. *Do primary travel routes include “rest and relief” amenities?* No. The south side of the US 101 freeway is generally better equipped with rest and relief amenities than the north side. Yet even the amenities on the south side of the freeway are privately oriented, and few and far between.
25. *Are the networks of primary walkways and bikeways generally “legible” to (i.e., easily navigated by) travelers?* No. Lack of path hierarchy, distinct landmarks, good signage, area maps and adequate street lighting in the study area make wayfinding difficult for travelers.
26. *Are adequate bicycle parking facilities generally available in close proximity to travel origins and destinations?* No. Relatively little publicly accessible and conspicuous bicycle parking is available in the study area.
27. *Does local transit offer convenient and adequate bicycle portage services?* Yes. With the exception of the Metro/Airport shuttle, Valley Transportation Authority provides bicycle carrying capacity on all transit vehicles used to serve the area. While low service frequencies make the local bus routes inconvenient, the light rail service operates with reasonably attractive headways. Once new racks have been installed in the light rail vehicles, there will be no time-of-day restrictions on bicycle portage.
28. *Do study-area transit services provide a reasonable substitute means of travel at night, when the weather is poor, or under other special circumstances?* No. In most parts of the study area, local transit services operate too infrequently to be a viable substitute to walking or cycling. The single exception to this is the shuttle that serves the area south of the US 101 freeway. Even this shuttle, however, does not operate at night. Travelers must instead rely on taxicabs for transportation.
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Figure 6.19 (cont'd)
Evaluation of Pedestrian and Cycling Conditions
in the Karina Study Area

Traveler Support Features (cont'd)

29. *Are showering and changing facilities conveniently available to bicycle commuters?* No. While new large development projects in the study area are required to include showering and changing facilities, many work sites developed before implementation of the Deficiency Plan for North San Jose, as well as smaller employment sites, do not have them. Moreover, no health club operates in the study area.
30. *Does strong institutional support for walking and cycling exist in the study area?* Yes. The existence of a trip reduction ordinance and an active regional transportation management association provide a strong base of institutional support for walking and bicycling in the study area. Moreover, the planning and information distribution efforts of the City of San Jose and the Valley Transportation Authority also contribute strongly to efforts to increase rates of non-motorized travel.
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6.10 EVALUATION SUMMARY

The evaluation conducted in Section 6.9 indicates a wide scope for improving non-motorized travel conditions in the Karina study area. Table 6-4 summarizes positive and negative responses to the evaluation questions.

Table 6-4: Summary of Evaluation Responses

	Positive	Negative
<u>BASE CONDITIONS</u>		
Path Network Availability	X	
Population and Employment Density	X	
Aggregate Land Use Mix		X
Overall Level of Crime	X	
Serious Conflicts between Pedestrians, Cyclists and Autos	X	
<u>TRAVEL DISTANCES AND IMPEDIMENTS</u>		
Travel Distances for Transit Access		X
Travel Distances for Mid-day Trips	X	
Trip-Chaining Opportunities		X
Path Network Gaps		X
Short-Cut Opportunities	X	
Topography	X	
Street Crossing Wait Times	X	
Traffic Calming		X
<u>URBAN ENVIRONMENTAL CHARACTERISTICS</u>		
Comfort and Safety of Path Surfaces		X
Cleanliness and Maintenance of Pathways	X	
Cleanliness and Maintenance of Buildings and Property	X	
Shelter from Intense Sun and Poor Weather	X	
Pleasant Visual, Acoustic, and Other Sensory Stimuli		X
Route Choice	X	
Insecure Locations		X
Nighttime Travel Conditions		X
Noise Levels		X
Local Air Quality		X
<u>TRAVELER SUPPORT</u>		
Rest and Relief Amenities		X
Network Legibility		X
Adequate Bicycle Parking		X
Bicycles on Transit	X	
Transit for Substitute Travel		X
Showering and Changing Facilities		X
Institutional Support	X	

6.11 OUTLINE OF STUDY AREA IMPROVEMENT OPTIONS

The final task of the evaluation is to outline possible means of improving travel conditions in the Karina study area.

6.11.1 Conditions Meeting the Evaluation Criteria

Fourteen conditions meet the evaluation criteria. Table 6-5 differentiates these conditions on the basis of their openness to improvement.

Table 6-5: Differentiation of Conditions on the Basis of Openness to Improvement

Conditions Open to Improvement	Conditions Not Open to Improvement
Population and Employment Density Overall Level of Crime Serious Conflicts between Pedestrians, Cyclists, Automobiles, and Other Traffic Travel Distances for Mid-Day Trips Short-Cut Opportunities Street Crossing Wait Times Shelter from Intense Sun and Poor Weather	Path Network Availability Topography Cleanliness and Maintenance of Pathways Cleanliness and Maintenance of Buildings and Property Route Choice Bicycles on Transit Institutional Support

6.11.1.1 Conditions Open to Improvement

Population and Employment Density. While residential land uses are non-existent in the study area, a reasonably large employment base supports moderate levels of pedestrian and cyclist activity. The trip-generation effects of current employment density, however, are exhibited only during daylight hours, at peak commuting periods and lunch time. At night, few land uses generate much outdoor activity. Increasing employment density and adding residential land uses to the study area would augment daytime activity and enliven streets and public spaces at night.

Employment density should rise particularly in close proximity to light rail access points. Potential locations for residential development include the west side of First Street in the vicinity of the Karina Station, the area near the southwest corner of the intersection of Brokaw Road and Bering

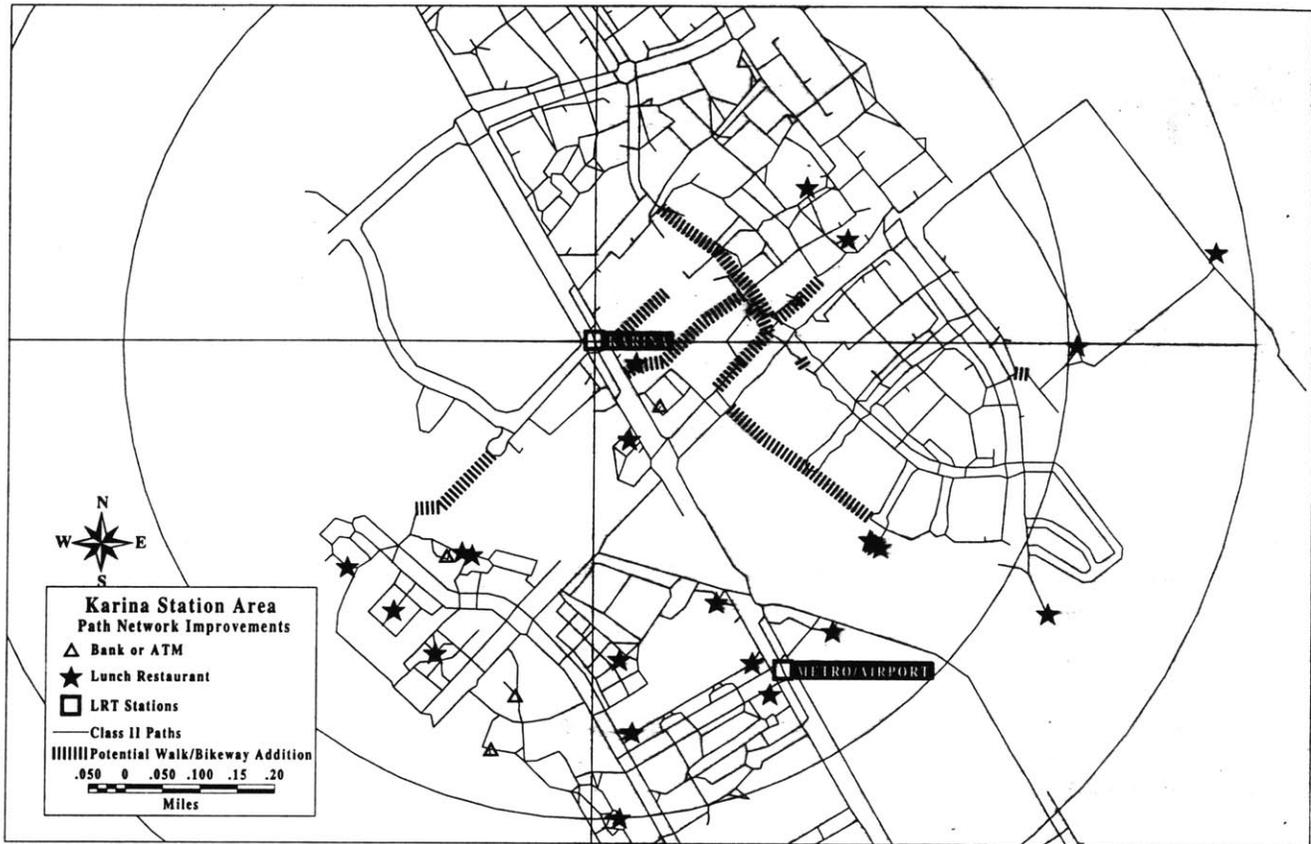
Drive, and in vacant or re-developable parcels along the east side of First Street south of the US 101 freeway.

Overall Level of Crime. The prevailing absence of serious crime lends a generally relaxed and casual atmosphere to walking and cycling. This does not mean, however, that exercising caution is unnecessary. Enhancing traveler education and awareness of crime issues could reduce the risk of crime even further.

Travel Distances for Mid-Day Trips. Travel distances for mid-day trips to eating establishments are surprisingly short, and the spatial distribution of these establishments relative to worksites is good. The divergence between worksite-to-restaurant airline and shortest path distances, however, could be reduced, as could travel distances between worksites and other types of retail and service land uses. This could be accomplished either through adding segments to the path networks, or by incorporating additional retail and service activities into the study area in advantageous locations. **Figure 6.20** shows locations in the study area where pedestrian and bicycle paths could be added to improve worksite-to-restaurant travel distances.

Street Crossing Wait Times. By comparison to many suburban places, crossing streets in the Karina study area is not especially difficult. While several arterial streets carry heavy traffic volumes, wide medians tend to reduce delay associated with crossing. This is because such medians allow pedestrians to begin crossing the street without having to wait for both directions of traffic to clear. In spite of this, however, the need to wait for traffic at crossings does create some inconvenience to pedestrians and cyclists. Increasing the frequency of traffic signal crossing

Figure 6.20



phases, coupled with decreases in traffic volumes along arterial streets in the study area could help to improve this situation.

Conflicts between Pedestrians, Cyclists, Automobiles, and Other Traffic. Conflicts between pedestrians, cyclists, automobiles, and other traffic are currently kept in check by the generally good behavior and alertness of area travelers, but could easily worsen. Continued area-wide efforts to moderate traffic speeds and erratic driver behavior, together with pedestrian and cyclist safety educational programs, should keep conflicts to a minimum.

Short-Cut Opportunities. Over most of the study area, opportunities for taking short cuts are abundant. Extensive barriers in the immediate vicinity of the Karina LRT station, however, severely inhibit pedestrians and cyclists from cutting distances short. A solution to this problem might involve selective installation of fence gates in this area.

Shelter from Intense Sun and Poor Weather. The mature trees that cover much of the study area shelter large portions of the pedestrian and cyclist path networks from intense sun and inclement weather. Significant gaps in this coverage exist, however, particularly along parts of First Street and Brokaw Road. The City of San Jose might seek to remedy this problem with a tree planting program. Also, a small potential for incorporating shelters into buildings has not been realized to the fullest extent.

6.11.1.2 Conditions Not Open to Improvement

Path Network Availability. Solid basic pedestrian and bicycle path networks ensure that most study area employees have the option to travel by foot or bicycle between any origin-destination pair in the study area.

Topography. Flat topography enables pedestrians and cyclists to enjoy minimal physical strain while traveling.

Cleanliness and Maintenance of Pathways. Exceptionally clean and well-maintained paths help to enhance personal safety and security, elevate traveler status, and alleviate the burden of travel.

Cleanliness and Maintenance of Buildings and Property. Clean and well-maintained buildings and other property along travel routes also contributes to increased personal safety, security, and traveler status, and reduces the perceived burden of travel.

Route Choice. Pedestrians and cyclists have abundant opportunities to choose alternate routes between most origin-destination pairs in the study area.

Bicycles on Transit. The Valley Transportation Authority's generous bikes-on-transit policies give bicyclists excellent opportunities to extend travel throughout the metropolitan region.

Institutional Support. The strong support of civic, employer, and other institutions enable study area employees and others to discover the advantages of walking and cycling, and assist them in finding the best possible ways to travel by these modes.

6.11.2 Conditions Failing to Meet the Evaluation Criteria

Sixteen conditions fail to meet the evaluation criteria. **Table 6-6** differentiates these conditions on the basis of the ease with which they may be improved.

Table 6-6: Differentiation of Conditions on the Basis of Ease of Improvement

Conditions Easily Improved	Conditions Not Easily Improved
<p style="text-align: center;"> Path Network Gaps Traffic Calming Comfort and Safety of Path Surfaces Pleasant Visual, Acoustic, and Other Sensory Stimuli Rest and Relief Amenities Network Legibility Adequate Bicycle Parking Transit for Substitute Travel </p>	<p style="text-align: center;"> Aggregate Land Use Mix Travel Distances for Transit Access Trip-Chaining Opportunities Insecure Locations Nighttime Travel Conditions Noise Levels Local Air Quality Showering and Changing Facilities </p>

6.11.2.1 Conditions Easily Improved

Path Network Gaps. Gaps in the pedestrian path network fall into two categories: gaps in sidewalks, and other gaps caused by large street block sizes and the presence of travel barriers. Sidewalk gaps exist along portions of Brokaw Road, Zanker Road, and Bering Drive. The other types of gaps exist between First Street and Bering Drive, Brokaw Road and the casino, Karina Court and the south side of the US 101 freeway, and near the intersection of Zanker Road and Devcon Drive. The path additions shown in Figure 6.20 would close these gaps.

Traffic Calming. The absence of traffic calming along streets and at intersections suggests to motorists that street spaces are for cars only, and that pedestrians and cyclists do not have right of way. Traffic pacification on study area local and collector streets could substantially improve non-motorized travel safety without significantly delaying motor vehicles. Potential opposition to implementation of such a strategy would likely come from fire and police officials concerned about response times. Such opposition could possibly be assuaged by maintaining select routes for public safety access.

Comfort and Safety of Path Surfaces. The problem of uncomfortable and somewhat unsafe path surfaces derives from the fact that many travel routes traverse parking lots, or consist of short sections of informal and unpaved paths that cross landscaped areas or vacant land. Solving this problem would involve selectively upgrading paths across parking lots (i.e., by adding curbs to separate the paths from parked cars, better paving materials, landscaping, and shade trees), and paving the numerous short informal paths (particularly those traversing planting strips separating study area parcels).

Pleasant Visual, Acoustic, and Other Sensory Stimuli. The lack of sensory stimuli may inhibit rates of non-motorized travel in the study area. Solving this problem could involve incorporation of creative public art along travel routes and in publicly accessible outdoor sitting areas; addition of retail activities along and in close proximity to primary travel routes; enlivening of ground floor retail (or even office) windows with artwork, merchandise displays, etc.; building facade enhancement; variegation of pathway pavement styles; and the addition of creative and variegated landscaping along primary travel routes.

Rest and Relief Amenities. The inadequacy and poor distribution of rest and relief amenities may deter non-motorized travel, particularly in the area to the north of the US 101 freeway. Addition of park benches, together with greater availability of clean, publicly accessible restrooms, would help to solve this problem. Benches might be added especially along primary travel routes in the vicinity of the light rail stations, while restrooms might be made available more generally throughout the study area.

Network Legibility. Poor network legibility may be a source of substantial confusion among travelers in the study area. Means of improving legibility include clarifying the difference between

primary and secondary travel routes; placing study-area maps and axonometric diagrams at key locations (e.g., LRT stops, major path intersections, major office complexes, etc.); and incorporating distinctive landmarks at major pathway intersections and other critical points.

Adequate Bicycle Parking. The inadequacy of bicycle parking in the study area makes the use of bicycles for short-distance trips generally unfeasible. Enabling such trips would involve simply placing conspicuous bicycle ribbons near entrances to all retail and service activities.

Transit for Substitute Travel. Public transit in the study area does not adequately substitute for non-motorized travel when the weather is poor, at night, or under other special circumstances. Ideal characteristics of a good substitute mode of travel include ease-of-use, flexibility, and affordability. While the Metro/Airport shuttle serves the substitute need reasonably well during the day, its service area is limited to the south side of the US 101 freeway, and it does not operate after about 7 p.m. Institution of a north-side shuttle, as well as a demand responsive nighttime “safe ride” service to connect LRT stops with employment sites, hotels and motels, and (future) residential activity, might help to assuage concerns of non-motorized travelers who fear becoming stranded at work or elsewhere.

6.11.2.2 Conditions Not Easily Improved

Aggregate Land Use Mix. Housing is conspicuously absent from the land use mix in the Karina study area. Were residential development to occur, opportunities for home-to-work non-motorized travel would increase substantially, the area retail base could be strengthened and enlarged, and streets and public spaces enlivened at night. Potential good locations for housing were noted under the discussion of improvements to employment and residential density.

Travel Distances for Transit Access. For the average study area employee, transit-to-work travel distances for pedestrians and cyclists exceed levels that would normally be associated with high rates of transit use. Two changes to station-area conditions would improve this situation: first, intensification of activity in close proximity to LRT stations; and, second, path network restructuring. The intensification of activity should involve high density development or redevelopment of parcels, and clustering of a diverse mix of retail and service activities within 750 to 1000 feet of the LRT stations. The path network restructuring might involve addition of the path segments shown in Figure 6.20 and removal of barriers near the Karina station.

Trip-Chaining Opportunities. Trip-chaining opportunities enable travelers to satisfy diverse needs in the most efficient manner possible. Such opportunities, however, are extremely limited in the study area. Solving this problem would require either (a) greater co-location of transit, employment, retail, and service activities; (b) addition of more retail and service activities throughout the study area; or both.

Insecure Locations. Insecure locations include the east side of First Street in the immediate vicinity of the Karina LRT station, the First Street underpass of the US 101 freeway, and the area along north Fourth Street. While none of these locations poses a particularly strong threat to travelers, their existence may prompt some travelers to select inconvenient routes, or to avoid walking and cycling altogether. Redevelopment of parcels offers the best long-term solution to the problems near the Karina Station and along Fourth Street. In the short term, however, the area near the Karina LRT station could be made to appear less threatening if the motel facade and street frontage were renovated. A solution to the problem of the First Street underpass might involve

eliminating columns, niches, and other hiding places, and widening the underpass to increase natural lighting.

Nighttime Travel Conditions. Poor nighttime travel conditions are both a cause and a consequence of the little pedestrian and cyclist activity that takes place in the study area after about 7:00 p.m. The addition of a strong street-oriented residential land use base to the area would help to improve these conditions substantially. Improvement might also involve the addition of sidewalk-oriented retail and other activity in the evening, addition of better glare-free lighting along primary travel routes, and enhancement of a non-aggressive police presence.

Noise Levels. High noise levels near the US 101 freeway could be alleviated by constructing sound walls along this roadway. Traffic noise generated by other streets could be reduced by slowing traffic and installing “quiet” types of pavement.

Local Air Quality. Local air quality could be improved by stricter regulation of study area point sources of toxic pollutants. Also, continued efforts to promote non-SOV travel in the study area would contribute to a reduction in mobile-source emissions.

Showering and Changing Facilities. The inadequacy of showering and changing facilities may deter many potential bicycle commuters. This problem that could be solved by the addition of a health club to the study area., possibly in the vicinity of the Karina Station. Such an addition, however, is not likely to occur in the absence of residential development.

CHAPTER SEVEN:

Conclusion

7.1 REVIEW OF THE PURPOSE AND SCOPE OF THE THESIS

The purpose of this thesis has been to develop a framework for evaluating current non-motorized travel conditions in suburban work environments served by high-capacity transit. The need for such a framework arises from concern that the planning and design fields lack robust, paradigm-neutral tools for identifying non-motorized strengths and weaknesses, and for highlighting conditions that are most in need of improvement.

The underlying approach of the thesis is to consider walking and cycling conditions from the perspective of individual travelers. Thus, a solid theoretical and empirical understanding of the numerous and diverse factors that motivate individuals to travel (or not to travel) by foot and bicycle grounds the work. These factors work both directly and indirectly. The consideration of indirect factors in Chapter Two involved investigation of scholarly literature on associations between non-motorized mode use and three broad environmental characteristics: (1) network structure and travel barriers, (2) population and employment density, and (3) land use mix. The consideration of direct factors in Chapter Three emphasized links between travel behavior and more specific personal, environmental, and institutional characteristics. In both cases, the intent was to provide planners and designers with comprehensive insight into why people might choose to walk or ride a bicycle.

One factor that plays a particularly important role in non-motorized mode choice is distance. Longer travel distances mean fewer trips by foot and bicycle. Thus, minimization of travel distances should be a key goal of any non-motorized planning and design effort. Enhancing the efficiency of pedestrian and bicycle path networks to provide non-circuitous travel routes between origin-destination pairs represents one way to help realize this goal. Detour factors may assist planners and designers in gauging the degree to which actions they propose may enhance network efficiency. Yet these simple measures fail to account for (a) the spatial distribution and sizes of travel destinations (i.e., activity sites), and (b) the decay in willingness to travel between origin-destination pairs as travel distances increase. Chapter Four sought to remedy this problem by introducing a set of “accessibility ratio” measures. These measures were based on accessibility indices commonly used in transportation research and practice.

Chapter Five brought together the material of the three previous chapters into a systematic approach to evaluating pedestrian and cyclist travel conditions in small, carefully defined study areas. The purposes of the approach were threefold: (1) to characterize the overall potential for the non-motorized modes to satisfy commuting, shopping, and other travel needs; (2) to identify specific problem areas; and (3) to outline potential problem solutions. The heart of the approach was a set of structured evaluation criteria. A set of guidelines were offered to aid application of these criteria.

Chapter Six demonstrated the evaluation approach developed in Chapter Five with a case study of non-motorized travel conditions in an area surrounding a light rail transit station in San Jose, California. The case study described these conditions in detail, applied the evaluation criteria, and outlined potential ways of improving non-motorized travel in the area.

7.2 THE USEFULNESS OF THE EVALUATION FRAMEWORK

The work of the thesis was intended to fill a need for tools to assess how existing physical and institutional conditions in small geographic areas served by high-capacity transit may support or deter walking and cycling. Such assessment is a critical first step to creating and maintaining urban environments that truly support non-motorized travel.

It is important to recognize, however, that for any tool to be useful to and accepted by planners and designers, it must be easily understood, reasonably simple, and flexible enough to be applied under a variety of different circumstances. Of the three primary tools developed in this thesis, only two (the evaluation criteria, and the coding and classification systems contained in Appendices C, D, E and F) can be said to satisfy these conditions. The third tool (the accessibility ratios developed in Chapter Four) does not.

7.2.1 The Usefulness of the Evaluation Criteria

The evaluation criteria were written as directly, simply, and with as much generality as possible. The questions cover a wide range of travel influences, highlight important areas of concern, and enable easy identification of potential improvements. Their application in the case study demonstrates their usefulness and practical feasibility by showing that (1) they are answerable; (2) their answers can reveal key non-motorized strengths and weaknesses in a typical study area; (3) their answers can greatly facilitate identification of improvement options; and (4) they can be applied with a reasonable investment of time and effort.

7.2.2 The Usefulness of the Coding and Classification Systems

An important tool developed to support application of the evaluation criteria was the set of coding and classification systems developed for mapping and analyzing pedestrian and bicycle path networks and travel barriers. This tool provides a means of (1) organizing vast quantities of data

on the location and characteristics of paths and barriers; (2) performing network analysis (i.e., finding airline and shortest-path distances) using a geographic information system; and (3) producing high-quality maps of study areas.

7.2.3 The Usefulness of the Accessibility Ratios

The one tool developed in the thesis that proved to be somewhat problematic was the “accessibility ratio” network efficiency measure. When applied in practice, this tool requires considerable time, effort, and data to compute. Also, in order to be generally reliable as an indicator of relative spatial attraction, the measure should be based on a case-specific impedance function. Such a function, however, is itself not especially easy to construct. For these reasons, future applications of the evaluation framework could possibly exclude use of this measure.

7.3 RESOURCE DEMANDS OF THE FRAMEWORK

Initial application of the evaluation framework developed in this thesis clearly requires travel up a learning curve, and expenditure of some time and effort. Subsequent application by experienced professionals, however, would likely require fewer hours and less effort.

Not only does application of the framework require much initial effort to become familiar with background materials, the evaluation criteria, and the evaluation guidelines, it also involves collecting much detailed data. Such data is necessary, however, for careful investigation and analysis of how physical and institutional conditions affect non-motorized travel choices. Manifestations of these effects tend to be rather subtle. This is because low travel speeds, the physical burden of non-motorized travel, and potential threats of exposure to the elements, speeding cars, and crime make pedestrians and cyclists very sensitive to small variations in their

travel environment. In sum, collecting and analyzing detailed data enables evaluators to understand the complexity associated with understanding non-motorized travel behavior.

7.4 POSSIBLE FRAMEWORK ENHANCEMENTS

Room exists for improving the framework. More and better input from planners, designers, real estate developers, employers and employees in a study area could be gained, and the framework tested with their cooperation. Better input might include, for example, restructuring the evaluation criteria as an employee survey. Such a survey might help to give insight into where employees feel threatened by crime, are afraid to cross streets, desire rest and relief amenities, etc.

More and better input from planners, designers, and others could also generate much additional numeric data related to study-area physical conditions. Such data might enable development of more and better measures for insight into how these conditions may influence non-motorized travel decisions.

Constructing such measures, in turn, might enable development and incorporation of a predictive (e.g., a discrete choice) model of non-motorized travel behavior into the evaluation framework. A model to predict walking and bicycling traffic volumes would permit extending the evaluation framework to include more explicit specification, as well as ranking, of improvement alternatives. Development of this type of model, however, would not be easy. The current state of the modeling art is simply not yet up to the task (nor may it ever be). The eventual development of even an imperfect discrete-choice or other predictive model, however, could at least help to elucidate the relative impacts of changing the quantity or character of different influences on non-motorized travel.

Finally, better data would enable development of case specific impedance functions that could be used to construct accessibility measures (assuming these were retained for use).

7.5 THE GENERALIZABILITY OF THE CASE STUDY FINDINGS

While the primary purpose of the case study was to demonstrate the planning framework developed in the rest of the thesis, it also offers at least one important and more generalizable insight into the nature of suburban pedestrian and bicycle travel conditions. This is that shortest-path travel distances in suburban work environments characterized by automobile orientation and dispersed activity-site distributions tend to be very long relative to airline distances. Primary reasons for this include (1) the presence of significant barriers (particularly freeways, fences, and wide buildings) to pedestrian and cyclist movement, and (2) the existence of path network gaps at critical locations. Ironically, however, the presence of vast quantities of surface parking often facilitates non-motorized travel by providing numerous shortcut opportunities.

As noted in Chapter Six, less than half of all employees in the study area work within reasonable walking distance (i.e., 2000 feet) of high-quality transit service. Less than one quarter work at sites that most planners would consider to have “excellent” walk-to-transit conditions (i.e., walking distances of no more than 1000 feet).

For trips involving stopovers the situation is much worse. Very few employees have the option of simply stopping for breakfast when walking between a transit station and a work site. Virtually none have the option of both stopping to get cash at an ATM or bank, stopping to get breakfast, and then continuing on to work. Both types of trips are common among workers in suburban employment centers.

For lunch-time travel, relatively more employees are well connected to likely destinations (i.e., restaurants) than in the walk-to-transit case. Almost three-quarters of all employees work within 2000 feet average distance of at least three restaurants. Many planners would likely view such conditions as entirely acceptable. Yet, because time is so valuable for most employees at

lunch-time, 2000 feet is surely not perceived as a short travel distance. The true “reasonable” distance for lunch-time trips is probably about half this amount.

Since proximity to transit, easy ability to chain trips, and proximity to potential lunch-time destinations are important determinants of personal willingness to choose not to solo drive, these distance-related findings are not very encouraging to those who seek to reduce dependence on the auto for travel to and within suburban employment centers.

APPENDICES

Appendix A: Environmental Attribute Definitions

Path Availability: Continuous path suitable for travel between a given origin-destination pair by a given class of travelers.

Availability of Route Choices: Two or more suitable paths available for travel between the same origin-destination pair.

Path Topography: Rise or fall of path in response to changes in elevation.

Legibility of Path Network: Ease or difficulty of way-finding for persons unfamiliar with path network.

Path Type and Condition: Construction materials, age, and maintenance level of path.

Nighttime Visibility: Ability of pedestrians and cyclists to see paths well enough for easy nighttime travel.

Variety, Interest, Attractiveness, and Level of Complexity: Visual, acoustic and other sensory stimuli available to pedestrians and cyclists along travel routes.

Climate Moderation Elements: Street trees, fountains, walkway coverings, etc. that moderate (actually or perceptually) heat, humidity, cold, wind, etc.

Protection from Weather Extremes: Awnings, shelters, etc. that provide refuge from inclement weather.

Local-Area Traffic Noise: Noise generated by motor vehicles operating near pedestrian and bicycle travel routes.

Local Air Quality: Air pollution generated primarily by motor vehicles near pedestrian and bicycle travel routes.

Resting and Relief Points: Public places available to pedestrians and cyclists to relax, use restrooms, etc.

Physical Elements Affecting Personal Safety: Street crossings, fast-moving traffic, etc. which pose threats to pedestrian or cyclist safety.

Physical Elements Affecting Personal Security: Dark alleys, dilapidated buildings, graffiti, etc. located along or within view of travel routes which cause pedestrians and cyclists to feel personally threatened by crime.

Cleanliness and Condition of Public Spaces and Buildings:

Amount of trash, graffiti, dilapidated buildings, etc. along or within site of pedestrian and bicycle routes.

Cleanliness of Bicycle Riding Surfaces:

Amount of dirt, gravel, overgrowth, and trash on bicycle paths, lanes or routes.

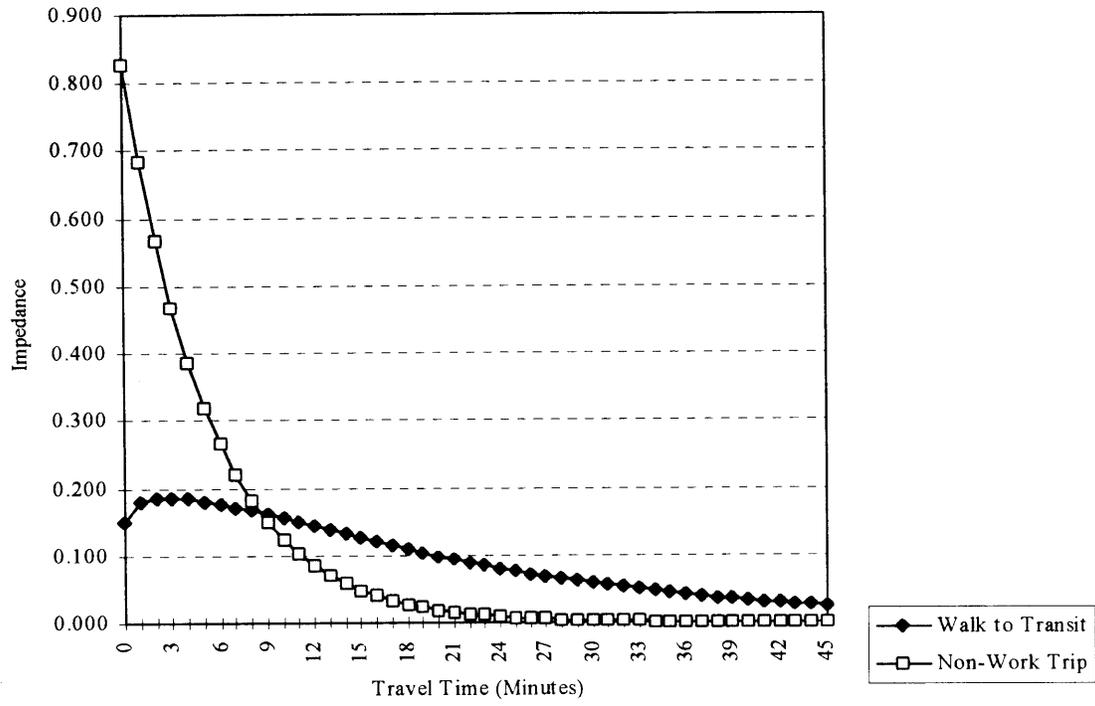
Appendix B

Values of Levinson & Kumar (1994) Travel-Time Impedance Functions

Distance (feet)	Time	Walk to Transit	Non-Work Trip
0	0	0.148	0.827
262	1	0.178	0.684
524	2	0.184	0.566
786	3	0.184	0.468
1048	4	0.183	0.387
1310	5	0.180	0.320
1572	6	0.175	0.264
1834	7	0.171	0.219
2096	8	0.165	0.181
2358	9	0.160	0.150
2620	10	0.154	0.124
2882	11	0.148	0.102
3144	12	0.142	0.085
3406	13	0.136	0.070
3668	14	0.130	0.058
3930	15	0.124	0.048
4192	16	0.119	0.040
4454	17	0.113	0.033
4716	18	0.108	0.027
4978	19	0.103	0.022
5240	20	0.098	0.018
5502	21	0.093	0.015
5764	22	0.088	0.013
6026	23	0.084	0.010
6288	24	0.080	0.009
6550	25	0.075	0.007
6812	26	0.071	0.006
7074	27	0.068	0.005
7336	28	0.064	0.004
7598	29	0.061	0.003
7860	30	0.057	0.003
8122	31	0.054	0.002
8384	32	0.051	0.002
8646	33	0.048	0.002
8908	34	0.046	0.001
9170	35	0.043	0.001
9432	36	0.041	0.001
9694	37	0.038	0.001
9956	38	0.036	0.001
10218	39	0.034	0.001
10480	40	0.032	0.000
10742	41	0.030	0.000
11004	42	0.029	0.000
11266	43	0.027	0.000
11528	44	0.025	0.000
11790	45	0.024	0.000

Impedance Values

[Source: Levinson & Kumar (1994)]



Pedestrian Path Classification System

	Class I	Class II	Class III
<u>Linear Walkways</u>	1001	1002	1003
	1004	1005	1006
	1007	1008	1009
	1010	1011	1012
	1013	1014	1015
	1016	1017	1018
	1019	1020	1021
	1022	1023	1024
	1025	1026	1027
	1028	1029	1030
	1031	1032	1033
	1035	1036	1034
	1043		1037
	1044		1038
			1039
		1040	
		1041	
		1042	
<u>Walk Areas</u>	1101	1102	1104
		1103	1105
		1107	1106
			1108
			1109
<u>Means of Gaining Elevation</u>	1200	1201	1202
	1203	1204	
	1206	1205	
	1209	1207	
	1210		
<u>Road Medians</u>	1300	1301	1304
		1302	1305
		1303	1306
			1307
<u>Traffic Islands</u>	1400	1401	
<u>Bridges</u>	1500	1501	1502
	1503	1504	1505
	1506	1507	1508
	1510	1509	1512
	1513	1511	1515
		1514	1516

Pedestrian Path Class Networks

Class I Network: Includes paths that meet all requirements of the Americans with Disabilities Act (ADA) and are intended for use by all types of travelers.

Class II Network: Includes all paths in the Class I category, as well as some paths that do not meet ADA standards. They are intended for all types of travelers other than travelers with special needs (such as the elderly or disabled).

Class III Network: Includes all Class I and II paths, as well as informal paths used by travelers with high tolerance for poor path conditions (e.g., high school students, construction workers, etc.).

Pedestrian Path Definitions

Linear Walkways

Sidewalk, Types 1-3: An outdoor paved walking surface parallel to a motor-vehicle roadway (or parking lot). Type 1 meets all provisions of §4.3 of the ADA Guidelines (United States Access Board, 1994). Type 2 may fail to meet one or more of the provisions of §4.3 (with the exception of §4.3.5 and §4.3.7), and is characterized by the following clear (w) and point-passage (p) widths:

- $32 \leq w < 36$ inches
- $28 \leq p < 32$ inches

Type 3 may fail to meet one or more of the provisions of §4.3 (with the exception of §4.3.5 and §4.3.7), and is characterized by the following clear (w) and point-passage (p) widths:

- $w < 32$ inches
- $p < 28$ inches

Raised-Curb Shoulder Separation, Types 1-3:

Gassaway (1992) defines this type of walkway as an extension of the surface of a roadway on which a raised and “secure” barrier curb at least six inches in height separates pedestrians from moving traffic. For coding and analysis, Types 1 through 3 are differentiated by width as follows:

- Type 1: ≥ 6 feet
- Type 2: ≥ 4 feet but < 6 feet
- Type 3: < 4 feet

Edgeline Shoulder Separation, Types 1-3:

Gassaway (1992) defines this type of walkway as an extension of the surface of a roadway on which a longitudinal painted line separates pedestrians from moving traffic. For coding and analysis, Types 1 through 3 are differentiated by width as follows:

- Type 1: ≥ 6 feet
- Type 2: ≥ 4 feet but < 6 feet
- Type 3: < 4 feet

Edgeline Shoulder Separation with Implanted Reflectors, Types 1-3:

Gassaway (1992) defines this type of walkway as an extension of the surface of a roadway on which a longitudinal painted line with reflectors implanted at fixed intervals separates pedestrians from moving traffic. For coding and analysis, Types 1 through 3 are differentiated by width as follows:

- Type 1: ≥ 6 feet
- Type 2: ≥ 4 feet but < 6 feet
- Type 3: < 4 feet

Edgeline Shoulder Separation with Rumble Strip, Types 1-3:

This type of walking way is equivalent to the Edgeline Shoulder Separation, but with indentations stamped into the road pavement at narrow, fixed intervals alongside and perpendicular to the painted line. For coding and analysis, Types 1 through 3 are differentiated by width as follows:

- Type 1: ≥ 6 feet
- Type 2: ≥ 4 feet but < 6 feet
- Type 3: < 4 feet

Constructed Exclusive Path (hard surface), Types 1-3:

Hard-surface path (other than a sidewalk) constructed for the exclusive use of pedestrians. Type 1 meets all provisions of §4.3 of the ADA Guidelines. Type 2 may fail to meet one or more provisions of §4.3 (with the exception of §4.3.5 and §4.3.7), and is characterized by the following clear (w) and point-passage (p) widths:

- $32 \leq w < 36$ inches
- $28 \leq p < 32$ inches

Type 3 may fail to meet one or more provisions of §4.3 (with the exception of §4.3.5 and §4.3.7), and is characterized by the following clear (w) and point-passage (p) widths:

- $w < 32$ inches
- $p < 28$ inches

Constructed Exclusive Path (compacted surface), Types 1-3:

Compacted-surface path constructed for the exclusive use of pedestrians. Types defined as in the case of hard-surface exclusive path.

Constructed Exclusive Path (soft surface), Types 1-3:

Soft-surface path constructed for the exclusive use of pedestrians. Types defined as in the case of hard-surface exclusive path.

Constructed Shared Path (hard surface), Types 1-3:

Hard-surface path (other than a sidewalk) constructed for shared use by pedestrians and cyclists. Type 1 is at least 10 feet in width and meets §4.3 of the ADA Guidelines. Type 2 is between eight and 10 feet in width and meets §4.3. Type 3 path is less than 8 feet in width or fails to meet one or more provisions of §4.3 (with the exception of §4.3.5 and §4.3.7).

Constructed Shared Path (compacted surface), Types 1-3:

Compacted-surface path constructed for shared use by pedestrians and cyclists. Types defined as in the case of hard-surface shared path.

Constructed Shared Path (soft surface), Types 1-3:

Soft-surface path constructed for shared use by pedestrians and cyclists. Types defined as in the case of hard-surface shared path.

Informal Path: Path created by the regular movement of persons over a non-paved surface.

Woonerf: Short section of traffic-calmed street designed for shared use by pedestrians, cyclists, children, and very slow moving motor vehicles.

Local Street (low speed, hard surface):

Hard-surface street over which traffic typically moves at no more than 25 miles per hour.

Local Street (low speed, compacted surface):

Compacted-surface street over which traffic typically moves at no more than 25 miles per hour.

Top of Levee (unpaved): Maintenance road atop levee.

Gravel, Grass and Dirt Shoulders:
All self-explanatory.

Asphalt Shoulder: Asphalt roadway shoulder at least 4 feet wide, and with no painted stripe or other means of separation between traffic and pedestrians.

Walkway Painted on Paved Surface (in parking lot, etc.):
Self-explanatory.

Walk Areas

All self-explanatory.

Means of Gaining Elevation

Ramp, Types 1-3: Type 1 meets all provisions of §4.8 of the ADA Guidelines. Type 2 meets the slope requirements of §4.8 (i.e. slope of 1:12 to < 1:20), but fails to comply with one or more other §4.8 provisions. Type 3 has a slope greater than 1:12 and may fail any §4.8 provision.

Elevator, Types 1 and 2: Type 1 meets all provisions of §4.10 of the ADA Guidelines. Type 2 fails to comply with one or more provisions of §4.10, but meets all other applicable local, state and federal regulations for passenger elevators.

Escalator: Self-explanatory.

Stairs, Types 1-3: Type 1 meets all provisions of §4.9 of the ADA Guidelines. Type 2 fails to comply with one or more provisions of §4.9, but meets all other applicable local, state and federal regulations. Type 3 fails to comply with one or more provisions of §4.9, and fails to meet at least one other applicable local, state or federal regulation.

Curb Cut (flared or returned, other than crosswalk): Defined by ADA Guidelines, §4.7.

Curb Cut (built-up, other than crosswalk): Defined by ADA Guidelines, §4.7.

Road Medians

All self-explanatory.

Traffic Islands

Large: Traffic island large enough to enclose fully a circle of 60 inches in diameter (unobstructed).

Small: Traffic island large enough to enclose fully a circle of at least 48 inches, but less than 60 inches in diameter (unobstructed).

Bridges

Pedestrian Exclusive, Types 1-3:

Bridge designed for the exclusive use of pedestrians. Type 1 meets all provisions of §4.3 of the ADA Guidelines. Type 2 fails to meet one or more provisions of §4.3 of the ADA Guidelines (with the exception of §4.3.5), but does have a width of at least 32 inches (continuous) and 28 inches (point). Type 3 fails to meet one or more of the ADA Guidelines, and has a width of less than 32 inches (continuous) or 28 inches (point).

Pedestrian/Bicycle Shared, Types 1-3:

Bridge designed for shared use by pedestrians and cyclists. Type 1 is at least 10 feet in width and meets §4.3 of the ADA Guidelines. Type 2 is between eight and 10 feet in width and meets §4.3 of the ADA Guidelines. Type 3 is less than 8 feet in width or fails to meet one or more provisions of §4.3 of the ADA Guidelines.

Low-Speed Road (with sidewalk), Types 1-3:

Bridge designed to carry motorized and non-motorized traffic typically moving at speeds of no more than 25 miles per hour. Type 1 has a Type 1 sidewalk. Type 2 has a type 2 sidewalk. Type 3 has a type 3 sidewalk.

Low-Speed Road (no sidewalk):

Bridge designed to carry motorized and non-motorized traffic typically moving at speeds of no more than 25 miles per hour.

Other Road (with sidewalk and barrier), Types 1-3:

Bridge designed to carry motorized traffic at speeds above 25 miles per hour, and having a concrete or other barrier to separate traffic from sidewalk. Type 1 has a Type 1 sidewalk. Type 2 has a type 2 sidewalk. Type 3 has a type 3 sidewalk.

Other Road (with sidewalk, no barrier), Types 1-3:

Bridge designed to carry motorized traffic at speeds above 25 miles per hour, with no barrier to separate traffic from sidewalk. Type 1 has a Type 1 sidewalk. Type 2 has a type 2 sidewalk. Type 3 has a type 3 sidewalk.

Other Road (no sidewalk):

Bridge designed to carry motorized traffic at speeds above 25 miles per hour, and having no sidewalk.

Appendix D

Crosswalk Typology and Coding System

Intersection Crosswalk (“local” street)

	<u>Code</u>
Change of Pavement (ST, SP, 0), Types 1 and 2	2000, 2001
Change of Pavement (ST/SS, 0, 0), Types 1 and 2	2002, 2003
Change of Pavement (0, 0, WD), Types 1 and 2	2004, 2005
Change of Pavement (0, 0, 0), Types 1 and 2	2006, 2007
Painted Stripe (ST, SP, 0), Types 1 and 2	2008, 2009
Painted Stripe (ST/SS, 0, 0), Types 1 and 2	2010, 2011
Painted Stripe (0, 0, WD), Types 1 and 2	2012, 2013
Painted Stripe (0, 0, 0), Types 1 and 2	2014, 2015
No Stripe (ST, SP, 0), Types 1 and 2	2024, 2025
No Stripe (ST/SS, 0, 0), Types 1 and 2	2026, 2027
No Stripe (0, 0, WD), Types 1 and 2	2028, 2029
No Stripe (0, 0, 0), Types 1 and 2	2030, 2031

Intersection Crosswalk (“arterial”)

	<u>Code</u>
Change of Pavement (ST, SP, 0), Types 1 and 2	2200, 2201
Change of Pavement (ST/SS, 0, 0), Types 1 and 2	2202, 2203
Change of Pavement (0, 0, WD), Types 1 and 2	2204, 2205
Change of Pavement (0, 0, 0), Types 1 and 2	2206, 2207
Painted Stripe (ST, SP, 0), Types 1 and 2	2208, 2209
Painted Stripe (ST/SS, 0, 0), Types 1 and 2	2210, 2211
Painted Stripe (0, 0, WD), Types 1 and 2	2212, 2213
Painted Stripe (0, 0, 0), Types 1 and 2	2214, 2215
No Stripe (ST, SP, 0), Types 1 and 2	2224, 2225
No Stripe (ST/SS, 0, 0), Types 1 and 2	2226, 2227
No Stripe (0, 0, WD), Types 1 and 2	2228, 2229
No Stripe (0, 0, 0), Types 1 and 2	2230, 2231

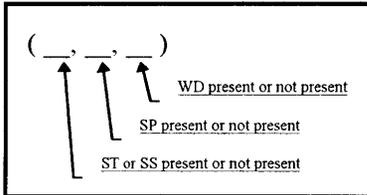
Intersection Crosswalk (“collector”)

	<u>Code</u>
Change of Pavement (ST, SP, 0), Types 1 and 2	2100, 2101
Change of Pavement (ST/SS, 0, 0), Types 1 and 2	2102, 2103
Change of Pavement (0, 0, WD), Types 1 and 2	2104, 2105
Change of Pavement (0, 0, 0), Types 1 and 2	2106, 2107
Painted Stripe (ST, SP, 0), Types 1 and 2	2108, 2109
Painted Stripe (ST/SS, 0, 0), Types 1 and 2	2110, 2111
Painted Stripe (0, 0, WD), Types 1 and 2	2112, 2113
Painted Stripe (0, 0, 0), Types 1 and 2	2114, 2115
Painted Stripe (0, 0, 0), Types 1 and 2	2122, 2123
No Stripe (ST, SP, 0), Types 1 and 2	2124, 2125
No Stripe (ST/SS, 0, 0), Types 1 and 2	2126, 2127
No Stripe (0, 0, WD), Types 1 and 2	2128, 2129
No Stripe (0, 0, 0), Types 1 and 2	2130, 2131

KEY:

ST: Signal for Traffic	WD: Flashing Device for Warning Motorists to Watch for Pedestrians
SS: Stop Sign for Traffic	0: No signal, stop sign or warning device present
SP: Signal for Pedestrians	

Type 1: Meets §4.7 of the ADA Guidelines (United States Access Board, 1994)
Type 2: Does not meet §4.7 of the ADA Guidelines



Crosswalk Typology and Coding System (cont.)

Mid-Block Crosswalk (local street)

Change of Pavement (ST, SP, 0), Types 1 and 2	2300, 2301
Change of Pavement (SS, 0, 0), Types 1 and 2	2302, 2303
Change of Pavement (0, 0, WD), Types 1 and 2	2304, 2305
Change of Pavement (0, 0, 0), Types 1 and 2	2306, 2307
Painted Stripe (ST, SP, 0), Types 1 and 2	2308, 2309
Painted Stripe (SS, 0, 0), Types 1 and 2	2310, 2311
Painted Stripe (0, 0, WD), Types 1 and 2	2312, 2313
Painted Stripe (0, 0, 0), Types 1 and 2	2314, 2315
No Stripe (ST, SP, 0), Types 1 and 2	2324, 2325
No Stripe (SS, 0, 0), Types 1 and 2	2326, 2327
No Stripe (0, 0, WD), Types 1 and 2	2328, 2329
No Stripe (0, 0, 0), Types 1 and 2	2330, 2331

Mid-Block Crosswalk (collector)

Change of Pavement (ST, SP, 0), Types 1 and 2	2400, 2401
Change of Pavement (SS, 0, 0), Types 1 and 2	2402, 2403
Change of Pavement (0, 0, WD), Types 1 and 2	2404, 2405
Change of Pavement (0, 0, 0), Types 1 and 2	2406, 2407
Painted Stripe (ST, SP, 0), Types 1 and 2	2408, 2409
Painted Stripe (SS, 0, 0), Types 1 and 2	2410, 2411
Painted Stripe (0, 0, WD), Types 1 and 2	2412, 2413
Painted Stripe (0, 0, 0), Types 1 and 2	2414, 2415
No Stripe (ST, SP, 0), Types 1 and 2	2424, 2425
No Stripe (SS, 0, 0), Types 1 and 2	2426, 2427
No Stripe (0, 0, WD), Types 1 and 2	2428, 2429
No Stripe (0, 0, 0), Types 1 and 2	2430, 2431

Mid-Block Crosswalk (arterial)

Change of Pavement (ST, SP, 0), Types 1 and 2	2500, 2501
Change of Pavement (SS, 0, 0), Types 1 and 2	2502, 2503
Change of Pavement (0, 0, WD), Types 1 and 2	2504, 2505
Change of Pavement (0, 0, 0), Types 1 and 2	2506, 2507
Painted Stripe (ST, SP, 0), Types 1 and 2	2508, 2509
Painted Stripe (SS, 0, 0), Types 1 and 2	2510, 2511
Painted Stripe (0, 0, WD), Types 1 and 2	2512, 2513
Painted Stripe (0, 0, 0), Types 1 and 2	2514, 2515
No Stripe (ST, SP, 0), Types 1 and 2	2524, 2525
No Stripe (SS, 0, 0), Types 1 and 2	2526, 2527
No Stripe (0, 0, WD), Types 1 and 2	2528, 2529
No Stripe (0, 0, 0), Types 1 and 2	2530, 2531

Right-Turn Cutoff/ On- and Off-Ramp Crosswalk

Change of Pavement (0, 0, WD), Types 1 and 2	2600, 2601
Change of Pavement (0, 0, 0), Types 1 and 2	2602, 2603
Painted Stripe (0, 0, WD), Types 1 and 2	2604, 2605
Painted Stripe (0, 0, 0), Types 1 and 2	2606, 2607
Painted Stripe (0, 0, WD), Types 1 and 2	2608, 2609
Painted Stripe (0, 0, 0), Types 1 and 2	2610, 2611
No Stripe (0, 0, WD), Types 1 and 2	2612, 2613
No Stripe (0, 0, 0), Types 1 and 2	2614, 2615

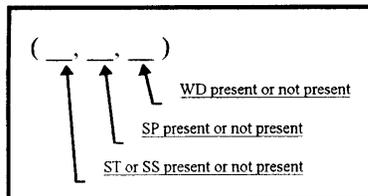
Special Cases

[Types not otherwise identified]	<u>Code</u> 2700 [plus verbal description]
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KEY:

ST: Signal for Traffic WD: Flashing Device for Warning Motorists to Watch for Pedestrians
 SS: Stop Sign for Traffic 0: No signal, stop sign or warning device present
 SP: Signal for Pedestrians

Type 1: Meets §4.7 of the ADA Guidelines
 Type 2: Does not meet §4.7 of the ADA Guidelines



Appendix E

Bikeway Typology and Coding System

<u>Linear Bikeways</u>	<u>Code</u>	<u>Bike Areas</u>	<u>Code</u>
Constructed Shared Path (hard surface), Types 1-3	1025, 1026, 1027	Parking Lot (paved)	1103
Constructed Shared Path (compacted surface), Types 1-3	1028, 1029, 1030	Parking Lot (gravel)	1104
Constructed Shared Path (soft surface), Types 1-3	1031, 1032, 1033	Parking Lot (other)	1105
Marked Bicycle Lane (local street)	3001		
Marked Bicycle Lane (collector)	3002		
Marked Bicycle Lane (arterial)	3003		
Raised-Curb Shoulder Separation, Types 1-3	1004, 1005, 1006		
Edgeline Shoulder Separation, Types 1-3	1007, 1008, 1009		
Edgeline Shoulder Separation with Implanted Reflectors, Types 1-3	1010, 1011, 1012		
Edgeline Shoulder Separation with Rumble Strip, Types 1-3	1013, 1014, 1015		
Marked Bicycle Route (local street)	3004		
Marked Bicycle Route (collector)	3005		
Marked Bicycle Route (arterial)	3006		
Wide Curb Lane (i.e., curb lane \geq 14 feet in width)	3007		
Informal Path	1034		
Woonerf	1035		
Local Street (low speed, hard surface)	1036		
Local Street (low speed, compacted surface)	1037		
Top of Levee (unpaved)	1038		
Gravel Shoulder	1039		
Grass Shoulder	1040		
Dirt Shoulder	1041		
Asphalt Shoulder	1042		
		<u>Means of Gaining Elevation</u>	<u>Code</u>
		Ramp, Types 1-3	1200, 1201, 1202
		Elevator, Type 1	1204
		Curb Cut (flared or returned, other than crosswalk)	1209
		Curb Ramp (built-up, other than crosswalk)	1210
		<u>Bridges</u>	<u>Code</u>
		Pedestrian/Bicycle Shared, Types 1-3	1503, 1504, 1505
		Low-Speed Road (with sidewalk), Types 1-3	1506, 1507, 1508
		Low-Speed Road (no sidewalk)	1509
		Other Road (with sidewalk and Barrier), Types 1-3	1510, 1511, 1512
		Other Road (with sidewalk, no barrier), Types 1-3	1513, 1514, 1515
		Other Road (no sidewalk)	1516
		<u>Special Cases</u>	<u>Code</u>
		[Types not otherwise identified]	3100 [plus verbal description]

Note:

1. Paths shared with pedestrians defined in Appendix C.
2. All other paths are self-explanatory.

Appendix F

Barrier Typology and Coding System

“Hard” Barriers	Code	“Soft” Barriers	Code
Limited Access Roadway	4000	Auto Travel Lane (major arterial street)	4100
River, Canal or Stream	4001	Auto Travel Lane (minor arterial street)	4101
Lake, Pond, or Marsh	4002	Auto Travel Lane (collector street)	4102
Fence or Wall	4003	Right-Turn Cutoff/ Off or On-Ramp	4103
Building Edge	4004	Parking Lane	4104
Dense Hedge Row	4005	Left-Turn Lane (uni-directional)	4105
Hill Side, Steep Slope ($\geq 15\%$)	4006	Left-Turn Lane (bi-directional)	4106
Abrupt Change in Elevation	4007	Permeable Fence	4107
Railroad Yard	4008	Permeable Hedge Row	4108
High Speed Rail Line	4009	Berm	4109
Rail Line with 3rd Rail Electric Power	4010	Hill Side, Moderate Slope (between 4% and 15%)	4110
		Exaggerated-Height Curb	4111
		Active Railroad Track (primary)	4112
		Active Railroad Track (secondary)	4113
		Active Railroad Track (spur)	4114
		Abandoned Railroad Track	4115
		LRT Track	4116
		Chain Festooned Across Road	4117
		Speed Bump	4118

Appendix G

Karina Study Area Site Data

Site ID	Zone	AL Distance to Karina Sta.	Azimuth	Primary Activity	Services	# Eating Establ.	# B-fast Eating Establ.	# ATM/Banks	# Floors	Bldg. Footprint (square feet)	Assumed Sqft per Emp.	# Primary Employees	# Service Employees	Total Employees
2	PMDT	4224	327.0	N/A	Eating Estab.	10	5	0	N/A	N/A	N/A	0	0	0
23	PMDT	4013	336.0	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	0	0
27	PMDT	3907	339.0	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	0	0
42	PMDT	4066	348.0	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	0	0
56	PMDT	3326	330.0	LRT Station	N/A	0	0	0	N/A	N/A	N/A	0	0	0
122	WTT	2587	0.0	Office	N/A	0	0	0	1	25480	300	85	0	85
151	WTT	2587	11.5	Office	N/A	0	0	0	1	25872	300	86	0	86
161	WTT	2323	16.0	Office	N/A	0	0	0	1	30576	300	102	0	102
167	WTT	2323	2.5	Office	N/A	0	0	0	1	25872	300	86	0	86
180	WTT	2112	8.5	Office	N/A	0	0	0	1	25480	300	85	0	85
198	WTT	2112	27.0	R&D Office	N/A	0	0	0	1	43904	350	125	0	125
203	WTT	2376	30.5	Industrial	N/A	0	0	0	1	41160	400	103	0	103
211	WTT	2112	357.0	Office	N/A	0	0	0	1	39200	300	131	0	131
215	WTT	2429	352.0	Office	N/A	0	0	0	1	32144	300	107	0	107
219	WTT	2270	337.0	Office	N/A	0	0	0	2	51744	300	345	0	345
220	WTT	2165	340.0	Office	N/A	0	0	0	2	58016	300	387	0	387
240	WTT	1637	353.0	R&D Office	N/A	0	0	0	1	27440	350	78	0	78
243	WTT	1690	2.5	R&D Office	N/A	0	0	0	1	26264	350	75	0	75
249	WTT	1109	351.0	R&D Office	N/A	0	0	0	1	16464	350	47	0	47
254	WTT	1056	346.0	R&D Office	N/A	0	0	0	1	27440	350	78	0	78
275	WTT	1426	339.0	Office	N/A	0	0	0	3	38416	300	384	0	384
279	WTT	1373	6.5	R&D Office	N/A	0	0	0	1	20384	350	58	0	58
285	WTT	1742	12.5	R&D Office	N/A	0	0	0	1	42336	350	121	0	121
289	WTT	1584	19.5	R&D Office	N/A	0	0	0	1	32928	350	94	0	94
305	WTT	1320	31.5	Warehouse	N/A	0	0	0	1	54880	850	65	0	65
309	WTT	1003	34.0	Industrial	N/A	0	0	0	1	24696	400	62	0	62
310	WTT	845	33.0	Industrial	N/A	0	0	0	1	21168	400	53	0	53
312	WTT	739	18.5	Industrial	N/A	0	0	0	1	17640	400	44	0	44
317	WTT	686	346.0	Office	N/A	0	0	0	6	20384	300	408	0	408
321	WTT	1954	297.5	R&D Office	N/A	0	0	0	3	117600	350	1008	0	1008
333	WTT	0	N/A	LRT Station	N/A	0	0	0	0	0	0	0	0	0
337	WTT	211	7.0	N/A	Auto Parts	0	0	0	1	N/A	N/A	0	8	8
344	WTT	475	5.0	Industrial	N/A	0	0	0	1	17640	400	44	0	44
347	WTT	528	178.5	N/A	Auto Rental	0	0	0	1	N/A	N/A	0	0	0
351	WTT	317	189.0	Office	N/A	0	0	0	6	19208	300	384	0	384
354	WTT	106	64.0	N/A	Car Dealer	0	0	0	1	N/A	N/A	0	40	40

Site ID	Zone	AL Distance to Karina Sta.	Azimuth	Primary Activity	Services	# Eating Establ.	# B-fast Eating Establ.	# ATM/Banks	# Floors	Bldg. Footprint (square feet)	Assumed Sqft per Emp.	# Primary Employees	# Service Employees	Total Employees
355	WTT	158	119.0	N/A	Motel	0	0	0	1	N/A	N/A	0	10	10
358	WTT	264	119.0	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	20	20
359	WTT	1162	242.5	Office	N/A	0	0	0	2	112112	300	747	0	747
364	WTT	1003	222.0	Industrial	N/A	0	0	0	1	5880	400	15	0	15
365	WTT	845	214.0	Industrial	N/A	0	0	0	1	21560	400	54	0	54
370	WTT	739	160.0	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	20	20
374	WTT	845	157.5	N/A	Gas Station	0	0	0	1	N/A	N/A	0	5	5
376	WTT	1003	170.0	N/A	Motel	0	0	0	1	N/A	N/A	0	10	10
389	WTT	634	133.5	N/A	Full Svc Bank	0	0	1	N/A	N/A	N/A	0	12	12
390	WTT	528	119.0	Office	N/A	0	0	0	5	18424	300	307	0	307
400	WTT	1056	157.0	Office	N/A	0	0	0	2	10976	300	73	0	73
410	WTT	2006	154.5	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	20	20
412	WTT	1954	160.5	N/A	Motel	0	0	0	1	N/A	N/A	0	10	10
418	WTT	1795	174.0	Office	N/A	0	0	0	1	85456	300	285	0	285
423	WTT	2006	185.0	Office	N/A	0	0	0	2	31360	300	209	0	209
449	WTT	1690	210.5	Hotel	Eating Estab.	2	1	0	1	40000	200	200	40	240
450	WTT	1742	214.0	N/A	ATM	0	0	1	N/A	N/A	N/A	0	0	0
453	WTT	2218	216.5	Office	Eating Estab.	1	1	0	4	42728	300	570	5	575
466	WTT	2059	75.5	Office	N/A	0	0	0	1	34496	300	115	0	115
491	WTT	1584	95.5	R&D Office	N/A	0	0	0	1	50176	350	143	0	143
497	WTT	1109	75.5	R&D Office	N/A	0	0	0	1	38024	350	109	0	109
498	WTT	898	82.5	Office	N/A	0	0	0	3	23520	300	235	0	235
504	WTT	792	62.5	Industrial	N/A	0	0	0	1	41160	400	103	0	103
508	WTT	686	51.0	Industrial	N/A	0	0	0	1	30576	400	76	0	76
510	WTT	1056	49.5	Office	N/A	0	0	0	1	20384	300	68	0	68
511	WTT	1214	48.0	Office	N/A	0	0	0	1	23520	300	78	0	78
513	WTT	1162	59.0	Office	N/A	0	0	0	1	23520	300	78	0	78
515	WTT	1056	62.5	Office	N/A	0	0	0	1	21168	300	71	0	71
520	WTT	1426	71.5	Industrial	N/A	0	0	0	1	20384	400	51	0	51
527	WTT	1690	68.0	R&D Office	N/A	0	0	0	1	17640	350	50	0	50
528	WTT	1584	67.5	N/A	Eating Estab.	1	1	0	1	N/A	N/A	0	5	5
542	WTT	1742	74.5	R&D Office	N/A	0	0	0	1	29400	350	84	0	84
544	WTT	1584	77.0	Industrial	N/A	0	0	0	1	9408	400	24	0	24
546	WTT	1320	84.5	R&D Office	N/A	0	0	0	1	51352	350	147	0	147

Site ID	Zone	AL Distance to Karina Sta.	Azimuth	Primary Activity	Services	# Eating Establ.	# B-fast Eating Establ.	# ATM/Banks	# Floors	Bldg. Footprint (square feet)	Assumed Sqft per Emp.	# Primary Employees	# Service Employees	Total Employees
551	WTT	1795	88.5	R&D Office	N/A	0	0	0	1	35280	350	101	0	101
562	WTT	1795	98.0	R&D Office	N/A	0	0	0	1	45080	350	129	0	129
566	WTT	2112	93.5	R&D Office	N/A	0	0	0	1	46256	350	132	0	132
587	WTT	2006	105.5	R&D Office	N/A	0	0	0	1	40768	350	116	0	116
598	PMDT	2693	90.0	N/A	Eating Estab.	1	0	0	N/A	N/A	N/A	0	0	0
606	WTT	2112	64.0	Industrial	N/A	0	0	0	1	46648	400	117	0	117
615	WTT	2112	45.5	Industrial	N/A	0	0	0	1	31360	400	78	0	78
617	WTT	2218	38.5	Industrial	N/A	0	0	0	1	44296	400	111	0	111
627	WTT	1742	38.5	Office	N/A	0	0	0	1	31752	300	106	0	106
628	WTT	1848	38.5	Office	N/A	0	0	0	1	19600	300	65	0	65
641	WTT	1742	57.0	R&D Office	N/A	0	0	0	1	29400	350	84	0	84
645	WTT	1742	52.5	Office	N/A	0	0	0	1	57624	300	192	0	192
646	WTT	1637	52.5	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	5	5
651	WTT	2006	54.0	Industrial	N/A	0	0	0	1	58800	400	147	0	147
654	PMDT	3538	81.0	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	0	0
663	PMDT	3221	120.5	N/A	Eating Estab.	1	0	0	N/A	N/A	N/A	0	0	0
672	WTT	2165	125.0	Casino	Eating Estab.	4	1	1	1	40000	200	200	80	280
677	WTT	2482	140.5	Hotel	Eating Estab.	1	1	0	1	40000	200	200	20	220
685	WTT	2165	153.0	N/A	Gas Station	0	0	0	N/A	N/A	N/A	0	5	5
689	WTT	2429	153.5	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	5	5
690	WTT	2482	155.0	Office	N/A	0	0	0	7	45000	300	1050	0	1050
696	PMDT	2587	150.0	LRT Station	N/A	0	0	0	N/A	N/A	N/A	0	0	0
705	PMDT	2693	153.0	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	0	0
706	WTT	2587	164.5	Office	N/A	0	0	0	7	31416	300	733	0	733
708	PMDT	2798	174.0	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	0	0
721	WTT	2270	175.0	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	5	5
723	WTT	2429	175.0	Office	N/A	0	0	0	2	34496	300	230	0	230
731	WTT	2218	179.0	Office	N/A	0	0	0	2	31360	300	209	0	209
777	WTT	2534	192.0	N/A	Full Svc Bank	0	0	1	N/A	N/A	N/A	0	12	12
778	WTT	2429	192.5	Office	N/A	0	0	0	6	27048	300	541	0	541
784	PMDT	3379	176.5	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	0	0
815	PMDT	2957	194.0	N/A	Full Svc Bank	0	0	1	N/A	N/A	N/A	0	0	0
823	WTT	2376	206.5	Office	Eating Estab.	1	1	0	7	28224	300	659	5	664
842	WTT	2112	227.5	N/A	Eating Estab.	1	1	0	N/A	N/A	N/A	0	5	5

Site ID	Zone	AL Distance to Karina Sta.	Azimuth	Primary Activity	Services	# Eating Establ.	# B-fast Eating Establ.	# ATM/Banks	# Floors	Bldg. Footprint (square feet)	Assumed Sqft per Emp.	# Primary Employees	# Service Employees	Total Employees
844	WTT	1954	228.5	Office	N/A	0	0	0	7	18816	300	439	0	439
848	WTT	1954	235.5	Office	N/A	0	0	0	7	18816	300	439	0	439
849	WTT	2059	235.0	Office	N/A	0	0	0	5	18816	300	314	0	314
858	PMDT	4224	151.0	N/A	Full Svc Bank	0	0	1	N/A	N/A	N/A	0	0	0
862	WTT	1373	17.0	R&D Office	N/A	0	0	0	1	38416	350	110	0	110

Note: Breakfast eating establishments are restaurants and cafes open by 8:30 a.m.

Key to Shading:

122	Site does not include potential stopover point (i.e., eating establishment or ATM/bank).
2	Site includes potential stopover point.
56	Site of LRT station.

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