IMPROVING ACCESS TO JOBS VIA EFFECTIVE PUBLIC TRANSPORTATION: A PLANNING FRAMEWORK FOR MOBILITY IN SAN JUAN

by

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B.S.E., Civil Engineering Systems
University of Pennsylvania, 1997

Submitted to the Center for Transportation Studies and the Department of Urban Studies and Planning
in Partial Fulfillment of the Requirements for the Degrees of

Master of Science in Transportation
and
Master in City Planning
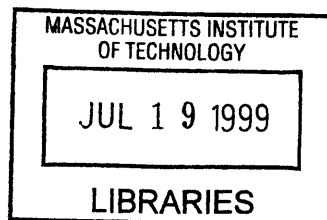
at the
Massachusetts Institute of Technology
June 1999

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ABSTRACT

The research couples accessibility models and demographic analyses to evaluate a modern interpretation of the spatial mismatch hypothesis as it applies to Boston, Massachusetts and San Juan, Puerto Rico. In relation to San Juan's new rapid rail line, *Tren Urbano*, the research evaluates alternative transportation services and land-use policies based on their ability to help welfare recipients and low-income workers reach employment.

Empirical results show that concentrated poverty severely reduces low-income workers' job accessibility by forcing them to compete more intensely with one another for a limited supply of employment. In addition, results from Boston show that some aspect of race contributes very strongly to isolating low-income workers, thereby creating relatively vast areas of highly concentrated poverty. Results from both cities indicate that employment concentrates toward the metropolitan center and that public transportation helps level the economic "playing field" for disadvantaged workers by enabling them to compete more effectively for employment outside low-income enclaves. In Boston, a city-to-suburb residential relocation program would be ineffective and might even reduce low-income families' quality of life by separating them from the social networks, services, densities of opportunity and transportation options available to them within the city. Rather, improving key transportation services seems to have a much greater potential for success.

In San Juan, *Tren Urbano* will improve the physical job accessibility of *all* workers, though its social and geographic distribution of benefits will be inherently uneven. *Tren Urbano* will assist low-income workers living in outlying areas to reach jobs in the central city. Conversely, workers living near major employment centers will experience slight declines in their job accessibility as a result of increased competition. Welfare recipients, meanwhile, will experience an easier time reaching job locations but a slightly harder time gaining employment.

The research identifies five key bus routes in San Juan, recommends adjustments to them, and proposes three specific cross-town services. It also recommends simple extensions of two existing routes, to serve roughly 30% of presently transit-isolated recipient households. Finally, policies that encourage residential relocation to *Tren Urbano* station areas from outlying regions have the greatest potential for improving individual recipients' access to jobs.

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Appreciation

There are several persons without whom the quality of this thesis and my well being would be much less. Joe Coughlin, my advisor, first kindled my interest in welfare-to-work; to him I also owe a significant portion of my understanding of research methodology. Working with him for two years has been a pleasure and I greatly appreciate his support and direction. Qing Shen first introduced me to accessibility modeling in his "Urban Spatial Structures" course and offered excellent critique of my work that I found invaluable to the framing of methodology and final results. Also, Nigel Wilson devoted his time and careful thoughts to my writings, offering precise suggestions and insightful critiques. Other professors or faculty, including Aixa Citron, Joe Sussman, Ken Kruckemeyer and Fred Salvucci offered attentive comments and much background information that helped refine this research's questions and conclusions in context of the larger issues it addresses. Together, these persons took interest in my work, gladly sacrificed many hours and provided a great deal of insight and critique that helped shape nearly all aspects of this thesis. For their contributions, I express my greatest gratitude and appreciation.

No letter of appreciation for this thesis could be complete without acknowledging Jantrue Ting's superb, dedicated work as my research assistant over the past year and a half. Jan's contribution in helping to model transit systems, collect data, review important literature, perform GIS overlays and create map layouts was invaluable to the research that led up to this thesis.

Also, I owe my deep appreciation and gratitude to Julie Robinson, for her unending support and sacrifice on my behalf as I researched and produced this thesis. Because I cared for this work, she did as well, offering assistance however and whenever she could. I thank her gratefully for all her help along the way.

In addition, I would like to acknowledge the influence of Vukan Vuchic, my undergraduate advisor from University of Pennsylvania, who inspired my interest in urban transit and desire to pursue a higher degree in the field.

Finally, I most of all would like to thank my family, who long before I ever entered MIT always believed in me, encouraged me and supported me. To them I express my greatest gratitude for all their love and endless support.

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Chapter 1

Background

Transit systems grant many benefits to society. With complementary land use, transportation and public policy measures, transit can increase mobility, curb urban sprawl, improve equity, reduce air pollution, contribute to economic vitality, redevelop urban neighborhoods, and support the social and cultural life of a city. Overall, transit may improve quality of life greatly for populations of diverse needs and interests. How may we, as planners and engineers and policy-makers, fully evaluate the benefits of new transit service, particularly when the investment is large?

Presently, the transit planning process carefully and precisely evaluates *costs* of major new investment. Engineers project to the last digit how much a multi-billion dollar endeavor will entail, and with National Environmental Policy Act (NEPA), the environmental review process attempts exhaustively to identify all possible negative impacts to society. However, no adequate method exists for evaluating the full *benefits* of transit investment. Presently, as a proxy, engineers apply sophisticated demand models that project ridership and revenue. Since these figures serve as the only available measurement of benefits, most stakeholders use them as a proxy for the magnitude of other, less quantifiable but equally important ones. The consistent optimism of ridership projections makes up in part for their inability to account for other important benefits. When the decision ultimately becomes a political one (as it always will), experts and leaders who at best have a nebulous understanding of how the new investment may help society, debate on its merits. The method's incompleteness has other undesirable effects: it reinforces the idea that benefits from transit extend only so far as its ability to reduce auto congestion and cover 100% of its costs. Postmortem evaluations of systems consistently look at their "performance" on the highway, ironically, and at the fare box, rather than also in neighborhoods, the built environment, and the economy. A full measurement of a new transit investment's benefits would allow policy-makers, planners and engineers to capitalize upon them far more effectively.

One of the most important benefits of transportation is its provision of physical accessibility and enormous role in facilitating improved quality of life. Most current suburban-dwellers could not function without access to the car for which their area was designed. Likewise, public transportation allows many persons to social, cultural and economic opportunities that otherwise might not be available. One of transit's most important effects is its provision of accessibility – the potential for social and economic interaction, for reaching a "multitude of destinations offering a spectrum of opportunities for work and play."[1] In this manner transit also improves social welfare, fosters equity and improves quality of life for transportation-disadvantaged groups. Though physical accessibility and social welfare are two of the most important benefits and primary justifications for transit investment, existing practice does not account for them through any credible analytical framework.

This research attempts to improve the methods available for evaluating the benefits of new transit investment as it affects improved accessibility and social welfare. In doing so it contributes to an investment plan in progress and improves theoretical understandings of the relationship between transportation and job accessibility for low-income families.

The following sections provide greater depth to the context of this study's application, explicitly present the research's goals and objectives, and overview the organization and content of the remainder of this report. By the conclusion of this chapter, the reader should gain a good understanding of this project's motivation, purpose and scope, while becoming familiar with the most significant aspects of its context.

1.1. Focus

This research addresses issues on several levels – practical, methodological and theoretical. As an application, the analysis examines a new rapid rail line of San Juan, Puerto Rico, called *Tren Urbano*, set to open for service in 2001. While San Juan serves as the primary focus of this research, the study also examines metropolitan Boston as well, as a point of comparison. The

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[1] Handy and Niemeier, 1997. p. 1175.

reader may find details of this comparison and its methodological strengths and weaknesses in Chapter 3. Findings from both cases are used to develop recommendations that will help *Tren Urbano* produce the largest possible benefits for society. The results of this research, while making significant contributions both to the literature and to methods of analysis, also could be applied more generally to quantify transit's contribution to the improved accessibility and social welfare of the transportation disadvantaged.

1.1.1. Theoretical

This study examines how transit relates to aspects of the "spatial mismatch" hypothesis of urban economics – the idea that low-income, transit-dependent families have become physically isolated from blue-collar employment as jobs have moved to expanding, auto-oriented suburbs. The research tests the relationship between spatially concentrated poverty and job accessibility in the U.S. *Tren Urbano* and other transit services play a vital role in this regard, because of their ability to help bridge these important spatial gaps. In its theoretical focus, the study addresses important questions that have been left unanswered by the literature, including:

- Do metropolitan areas in which rich and poor are more spatially separated exhibit greater levels of spatial mismatch? Measured by job accessibility, are low-income families worse off in such metropolitan areas?

- Which geographic phenomenon is more prominent in producing poor job accessibility among low-income families: residing in central portions of the metropolitan area, or residing among high concentrations of low-income households?

- What role, if any, does urban density play in facilitating or hampering physical job accessibility for low-income families?

How effectively can transit link low-income households to employment and related opportunities? What role does public transit play in regard to alleviating or augmenting the effects of concentrated poverty?

Answers to these questions apply not only to San Juan but also to most large cities of the U.S. In this sense, the research makes important contributions to the literature, as well as to our understandings of transportation and land use in their effects upon job accessibility and social welfare.

1.1.2. Practical

One of the most recent, major issues of great concern to low-income families in the U.S. has been national welfare reform. This historic legislation sets time limits on recipients' benefits, forcing them to find work and leave welfare rolls or eventually face complete withdrawal of government support. While the policy implicitly assumes that the world of available training, support services and jobs all exist within accessible travel from recipients' homes, only 6% of recipient households actually claim access to an automobile, and many jobs and services exist well beyond the reach of transit. In this context, this research examines the potential for Puerto Rico's new rapid rail system to bridge the possible spatial mismatch of welfare-dependent households and entry-level jobs in metropolitan San Juan. Also, since a major obstacle for low-income families obstacle in reaching and maintaining employment typically is securing adequate child care,[2] this research examines the possible spatial mismatch between residences and day care services.

In this context this study addresses the following set of research questions:

- How will *Tren Urbano* affect job accessibility in San Juan, measured as a function of travel time? How will the benefit of improved accessibility be distributed within the metropolitan area? What populations of workers should we expect *Tren Urbano* to serve most directly?

- What transit services or land use policies should local providers pursue in San Juan, to best meet the needs of low-income families and those moving from public assistance?

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[2] Massachusetts Campaign for Children. "KIDS COUNT Data Reports: Who's Minding the Children?" 1999. http://www.masskids.org/reports.html.

- How well does transit serve the job accessibility needs of those on public assistance in central portions of the Boston metropolitan area? How does San Juan compare to Boston? Based on this comparison of very different metropolitan areas, can we draw any conclusions about how either might benefit from particular policies or transportation services? Does the comparison raise any theoretical questions in regard to spatial mismatch?

Answers to these questions may provide very practical assistance to welfare-dependent families in San Juan, while helping to maximize the new rail line's contribution to the region.

1.1.3. Methodological

Methodologically, this research tests how well existing desktop computers may be used for examining, quantifying and communicating the benefit of improved job accessibility, and identifies how methods might be improved. Different from previous accessibility research, this study examines the possibility of performing sensitivity analysis of individual transit policies and service adjustments upon regional job accessibility. It demonstrates how one may integrate the technique into a traditional transit planning framework and identifies current technological, methodological, and institutional obstacles to applying this potentially powerful method of analysis. In this context the research makes extensive use of geographic information systems, or GIS, a software tool capable of performing rigorous spatial analysis and manipulating large volumes of data.

- How may GIS be used more effectively as a tool for evaluating the effectiveness of transit in providing benefits to society? Specifically, how may GIS facilitate providing improved job access for low-income families?

- What methodological, institutional or technological obstacles exist that hinder GIS from contributing more effectively to transit system evaluation?

- The research examines the relationship between spatially concentrated poverty and job accessibility in the U.S., applies the theoretical questions to a very practical case in San Juan,

and challenges the methodological limits of evaluating transit benefits. In all, the research questions provide a cohesive and valuable framework in which to conduct thorough and cogent analysis.

1.2. Context: *Tren Urbano*, *Públicos* and AMA

San Juan, Puerto Rico, readies itself for the first rapid rail service the island ever has experienced. *Tren Urbano*, as the Puerto Ricans call their new subway-elevated system, will serve a 10.8-mile corridor from San Juan's western suburb, Bayamon, to the capital city's dense Sagrado Corazon neighborhood. The 16 stations will connect residents to the Caribbean's largest medical center, *Centro Medico*, San Juan's emerging financial district (Hato Rey), the island's namesake university, and some of its oldest neighborhoods (Rio Piedras, Bayamon Centro). The full system is eventually planned to span more than 30 miles, to the airport, eastern developing suburbs, densely settled central neighborhoods, a new convention center and historic Old San Juan.

Among one of the least understood aspects of the project is how the city's bus system (AMA) and privately operated *públicos* (public jitneys) will integrate services with one another and *Tren Urbano*. The independent, informal *públicos* have carried San Juan's lion's share of transit riders during the past several decades. However, the system has been suffering from deteriorating vehicles, irregular service (e.g., many drivers abandon their routes for home during the afternoon), and a dearth of young drivers to replenish the system as elders retire. As a result, service and ridership have decreased significantly. In contrast, the city's AMA bus system recently gained significant success with a new service plan that introduced, among other things, printed maps. The system also features several transit center depots, new express and counter-flow routes, and a retained 25-cent fare that commuters find friendly to their pocket books. Though the system does not yet provide schedules, it does guarantee short to medium headways that are known for each route.

With the introduction of *Tren Urbano*, many AMA and público routes inevitably will shift to feed the new system or draw business from it, either via plan or response. These systems

provide an important link between neighborhoods physical and related activity centers. Integrating these services with *Tren Urbano* will be critical to creating a seamless regional transportation system. The shift will lend much opportunity for application of this research's conclusions. By examining the effects of possible service adjustments, the research will address which services or policies would effect the greatest benefits of job accessibility. The conclusions may receive immediate consideration in the redesign of some services.

1.3. Goals and Objectives

The research's goals represent ends toward which its objectives attempt to strive.

Goals of the research are to:

- foster *Tren Urbano*'s ability to improve the job accessibility of low-income families in San Juan;

- improve understanding of current trends of the "spatial mismatch" between jobs, child care and welfare recipient families, in Boston and San Juan;

- better understand the spatial effects of concentrated poverty upon physical job accessibility, and the practical potential for affordable transportation services and land use policies to help overcome any resulting obstacles; and

advance techniques available for evaluating the benefits of both major new transit investments and minor adjustments to existing systems.

The research's more specific objectives are to:

- **develop** methods for evaluating demographic and spatial phenomena related to the job accessibility benefits of transit and *Tren Urbano* in particular (Chapter 3);

- **analyze** how location or relative density of low-income families affects their access to jobs; **examine** the effects of race upon poverty concentration; **postulate** how

transit services affect the geography of job accessibility for low-income workers; **evaluate** the effects of *Tren Urbano* upon job accessibility in the region (Chapter 4);

- **evaluate** the efficacy of transportation services and land use policies in San Juan by their abilities to improve job accessibility; **recommend** new services or policies based on their effectiveness to improve job accessibility (Chapter 5);

- **discuss** the applicability of accessibility analysis to transit planning; and **identify** how existing analytical methods of evaluating transit benefits could become more meaningful or applicable, via either institutional, technological, or methodological improvements (Chapter 6).

1.4. Organization

The remainder of this thesis presents this research's methodology, results, analysis and conclusions, as well as a review of the literature. Chapter 2 begins by reviewing the literature, providing a theoretical basis for the research and highlighting among previous works the inconsistencies or incompleteness that this study seeks to address. Chapter 3 introduces the two case studies (metropolitan Boston and San Juan) and outlines the research's methodological approach and framework of analysis. Chapter 4 presents results of demographic and accessibility analyses of the two regions. Results speak directly to the interaction of race, poverty concentration and the role of transportation in helping low-income families overcome spatial separation from entry-level jobs. Chapter 5 then examines metropolitan San Juan in greater depth, identifying specific transportation services and land use policies that best would help low-income families improve their job accessibility. Finally, Chapter 6 concludes by summarizing the most significant results and highlighting questions raised by the research. The appendices contain technical documentation, including step-by-step delineation of methods used for data processing, tables of employment figures and supplemental maps of the San Juan and Boston metropolitan regions. ∎

Chapter 2

Literature Review

Three bodies of literature provide the theoretical context for this research. The first, by urban economists and sociologists, characterizes the structural forces that historically have separated low-income families from entry-level jobs. A particularly important subset of the urban economics literature is that in which geographic information systems (GIS) have been used as the primary tool for examining spatial issues of job accessibility. Second, the literature provides much discussion about the notion of physical accessibility – based on idea that transportation systems make destinations and opportunities available, rather than solely providing mobility. The research herein makes use of this notion and its important implications. Finally, the literature provides much evidence about the demographic composition of welfare recipient households and the transportation needs of such families. Together these three bodies of literature prepare a broad and solid foundation for the study herein.

2.1. Urban Economics Literature

The prevalence of poverty in U.S. urban centers has attracted much attention from sociologists, economists and policy-makers. Many have posited that the concentration of poor households in central portions of metropolitan areas has intensified a host of social and economic problems, ranging from the inadequate provision of public services to the prominence of violent crime. In these settings, the literature says, poverty begets increasing poverty as residents become increasingly removed from mainstream society – spatially, socially, economically, and culturally (see Katz, 1993a; also Wilson, 1987).[1] In economic terms, the relative isolation is argued to

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[1] Contrary to popular notion, however, John Weicher (1990) observes that over the long-term, populations in "poverty neighborhoods" are relatively transient in terms of their poverty status – with recent immigrants and families new to the poorest income levels replacing those who have moved up the economic ladder. The temporal

have facilitated long-term joblessness, welfare dependency and a widening skills mismatch between inner-city households and the new urban economy (Bartelt, 1993; Kasarda, 1995).

2.1.1. Behavioral versus Structural Models

Two often-competing theories address the nature and causes of long-term poverty, particularly in the context of its disproportionate prevalence among minorities and new arrivals. One theory says poverty and related antisocial behavior arise mostly from innate characteristics of those affected. This "behavioral model" suggests that poverty may be inherited socially or via cultural influence, very similar to the manner in which one would inherit a genetic trait (Lewis, 1961 and 1966; also see Moynihan, 1969). It supports the related notion that if those impoverished had the will to respect mainstream society's values and adopt its work ethic, after some time they no longer would live in poverty. Since some in this group would be unable to overcome the behavioral conditions that lead to social pathologies, either because of strong cultural influence or personal dysfunction, poverty to some extent is an inevitable condition for some of the population. Theorists have extended this model to explain the disproportionate predominance of poverty among racial and ethnic groups.

In contrast, the "structural model" contends that societal institutions create an oppressive environment for a subset of the population, such that those within this group experience great exogenous obstacles to attaining economic mobility (e.g.: Holzer, 1987; Massey and Denton, 1992; see Katz, 1993a; Jenks, 1993; O'Regan and Quigley, 1996). This view cites disparities in housing opportunity, mobility, and economic information among a host of many societal forces acting against the economic and social progress of a disenfranchised group. In this sense, the disparity of prosperity among races and ethnic groups arises mainly from their unequal treatment from society and its institutions.

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extent of any single household's bout with poverty is relatively short (less than two years), especially when compared to popular impressions of endless impoverishment affecting families "trapped" in the ghetto.

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In more recent decades, as mainstream American culture has grown less tolerant of blatant racism (see Massey and Denton, 1992, for empirical documentation) and generally more accepting of cultural pluralism (see Steinberg, 1989), public policy and research have become more partial to structural models of urban poverty than in the past. Recently some scholars even have characterized modern ethnicity, itself, largely as a product of "structural conditions" – such as similar occupational positions, residential locations and dependence upon common institutions and services, that together facilitate "frequent patterns of association and identification with common origins" (Yancey, et al, 1976). While behavioral models still strongly influence modern theory and policy about poverty (e.g., Wilson, 1987; modern welfare reform), the academic community has embraced structural explanations as viable, pernicious in reality, and quite worthy of attention.

2.1.2. The Modern "Underclass"

Within this structural context the fields of economics and sociology have overlapped on the subject of urban poverty. A major portion of the urban economic literature has focused on the widening spatial separation of entry-level jobs and low-income families, particularly with regard to the phenomenon's harmful effects upon minority employment in urban areas. Also, in popular impressions (though not in fact), the color of poverty and the "underclass" is black (Katz, 1993b). Thus, almost any discussion about the formation and endurance of America's "underclass" acknowledges poverty's disproportionate effect upon the country's non-white population. Urban economics literature to date has focused almost exclusively on African Americans and to some extent Hispanics living in northern inner-city areas (e.g.: Kain, 1968; Offner and Saks, 1971; Bell, 1974; Kain and Zax, 1983 and 1996; Ellwood, 1986; Leonard, 1987; Wilson, 1987; Ihlanfeldt and Sjoquist, 1990, 1991a, 1991b; Holzer, 1987; Bartelt, 1993; Ihlanfeldt, 1993; see Katz, 1993a, 1993b; Sugure, 1993; Thomas, 1993; O'Reagan and Quigley, 1995; Freeman and Holzer, 1996; Immergluck, 1998).

According to Sugrue (1993), the extent of urban poverty in these "Rustbelt" cities reflects the magnitude of "great migration" to each of them from the agricultural South during mid-century. Between World War I and 1970, nearly 7 million African Americans migrated North, most to

urban centers (Katz, 1993b).[2] Meanwhile, industrial decentralization moved tremendous numbers of well paying, entry-level manufacturing jobs out of central cities, exerting a disproportionate effect upon youths and recent blue-collar migrants whose numbers continued to grow. Northern whites increasingly moved to new suburban housing or emerging opportunities in the Sunbelt (Kasarda, 1989), leaving a landscape of vacant factories, abandoned dwellings and deterioration as the new symbols of formerly industrial cities.[3]

The trend was particularly ominous for minority families, few of whom were able to keep their jobs when factories moved (Kain and Zax, 1983; Freeman and Holzer, 1986; Zax and Kain, 1996). According to the literature, job loss was particularly evident among blacks, whose residential and personal mobility was constrained. Many were unable to move because of Federal housing policies, discriminatory lending practices, exclusionary zoning and other institutional barriers (see Sugrue, 1993; also see Massey and Denton, 1992, for a thorough review), and most also had inadequate skills or education to meet the labor demands of an emerging post-industrial economy (Katz, 1993b). Nonetheless, blue-collar employment continued to leave central cities, generating structural employment loss among low-income families who remained (Mooney, 1969; Kasarda, 1989; Leonard, 1993).

2.1.3. The "Spatial Mismatch" Debate

John Kain, in his seminal 1968 work, formally proposed these ideas above. He posited that black families experienced poorer levels of employment as a result of the discrimination in the housing market, which forced them to areas of inherently poorer job accessibility. Kain's theory, since termed "spatial mismatch", rested on three formal hypotheses: "that racial segregation in the housing markets (1) affects the distribution of Negro employment and (2) reduces Negro job opportunities, and that (3) postwar suburbanization of employment has seriously aggravated the

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[2] They moved for various reasons, among them: to escape sharecropping, as a result of mechanization, to answer Northern cities' labor demands, to escape racial violence, or to have greater access to ordinary rights (Katz, 1993).
[3] Katz (1993) notes that the association of race with poverty is relatively new – a product of the Great Migration after World War II. However, he writes, "Because racism directed toward African Americans is so powerful, the contemporary fusion of race and poverty remains the most resilient and vicious in American history" (pg. 10-11).

problem."[4] In technical terms, Kain's linear model (see below) assumed that employers' *demand* for black workers was directly related to a neighborhood's proportion of non-white population (R), but that *supply* of black workers was inversely related to straight-line distance, in miles, from the nearest ghetto boundary (d^m). Using these measures to predict non-whites' employment share in Chicago neighborhoods in 1956 (W), Kain's best estimate stated that:

$$W = 9.28 + 0.456\,R - 0.409\,d^m \qquad R^2 = 0.782$$
$$\text{t-stats:} \qquad (10.5) \quad (15.4) \qquad (4.2)$$

The model showed empirically that, controlling for neighborhood racial composition (R), the distance between blue-collar job locations and blacks' residences significantly reduced black workers' propensity to be employed. If his supply assumptions (d^m) were reasonable, then his results indicated that residential segregation significantly reduced blacks' share of employment – by an astounding three to eight percent by Kain's estimate.

Notably, Kain's model did not address the entire set of hypotheses he had proposed. For example, nowhere did the model test empirically whether job decentralization actually raised minorities' unemployment. Much later, researchers showed that when integrated firms moved from the central city to the suburbs, black employees were significantly less likely than whites to follow or keep their jobs (Kain and Zax, 1983; Freeman and Holzer, 1986; Zax and Kain, 1996). Farley (1987) cogently resolved the issue, concluding decisively in support of the hypothesis.[5]

More importantly, Kain's model did not comment on the *mechanism* by which physical isolation from jobs effected lower levels of employment among blacks. His monograph implied Kain believed racial preferences of employers played the primary role, though he supported the idea with no empirical evidence. Cervero and Landis (1990) later documented the particular role of transportation constraints in this context, showing empirically that when firms move from the downtown – in this case San Francisco – the worst off from an individual mobility standpoint

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[4] pg. 176. Kain tested his hypotheses using data from Area Traffic Studies of Detroit (1952) and Chicago (1956) on places of work and residence.
[5] Using the fraction of central city jobs in manufacturing, trade and services to predict black and Hispanic employment rates, Farley concluded that job decentralization raises relative unemployment among these groups. Farley used 1977 Census of Industries data for SMSAs and 1980 Census of Population data for SMSAs.

appear, "to be those whose jobs have suburbanized but [who] have remained in the central city."[6] They noted also that those disadvantaged by employer relocation were composed disproportionately, "of ethnic minorities who . . . had maintained a central city residence."[7] The conclusions highlighted the important role of transportation in the "spatial mismatch" context. If minorities could not reach jobs physically, they certainly could not hold them. Minorities' less ubiquitous mobility played the key role. Ihlanfeldt and Sjoquist (1991a) confirmed from a 1991 study of 43 SMSAs, that job access as measured strictly by commuting time had a significant effect on the probability of youth employment – concluding that 33% to 54% of the racial difference was attributable to travel time. Holzer and Inlanfeldt (1996) further demonstrated by survey of 3,200 employers[8] that proximity to public transit increased their likelihood to receive applications from and hire black workers. Shen (forthcoming) subsequently verified that access to auto is the single largest mobility variable affecting low-income families' job accessibility,[9] and Ong (1995) documented complementarily that large travel time disparities exist between those who have access to a car and those who do not. The evidence clearly shows that transportation constraints may play a significant role in seriously limiting the job accessibility of youths, minorities, and low-income families.

Competing Explanations

In the same context, authorities have shown that many other factors affect minorities' job accessibility significantly. The debate began soon after Kain's 1968 publication. One strong implication of his theory, of course, was that desegregation would improve blacks' employment rate. Offner and Saks (1971) tested this hypothesis by reanalyzing Kain's Chicago data, examining whether blacks fared better in the city's racially mixed areas. They found, as Kain's conclusions had suggested, that employers in all-white neighborhoods hired many whites, while employers in all-black neighborhoods hired many blacks. However, employers in racially mixed neighborhoods acted like those in all-white areas, hiring very few blacks. While the study seemed to contradict some of Kain's conclusions, for several reasons it was arguable whether

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[6] pg. 16
[7] pg. 9-10
[8] 800 each in Atlanta, Boston, Detroit and Los Angeles

this test adequately could address the implications of either desegregation or Kain's hypothesis (see O'Regan and Quigley, 1996). Also, it did not comment on *why* employers in racially mixed neighborhoods hired so few blacks; herein lay the origins of the spatial mismatch debate.

The works' important and competing implications spawned great interest among economists and sociologists who, through a lengthy series of literature, argued the relative effects of numerous structural variables upon disparities in job accessibility. These variables included: job information (Holzer, 1987), racial discrimination (Ellwood, 1987), mobility constraints (Leonard, 1985; Ihlanfeldt and Sjoquist, 1990, 1991a, 1991b; Taylor and Ong, 1995), social effects of economic isolation (Wilson, 1987), residential segregation (Leonard, 1993; O'Reagan and Quigley, 1995 and 1996a), blue-collar job loss (Mooney, 1969; Kasarda, 1989), employment decentralization (Farley, 1987; Kasarda, 1995), and education (Immergluck, 1998), among others.[10] The literature has continued to grow, adapting efficiently to contemporary issues of urban poverty and in numerous cases prominently influencing public policy (see Katz, 1993a; APTA, 1997). However, no clear consensus exists regarding the magnitude or validity of some of the theory's most basic assertions (see reviews by Holzer, 1991, and Kain, 1992).

Significantly, within the literature the formulation of "spatial mismatch" has evolved over time, usually without explicit recognition of having done so. Today, many academics view the argument as including the idea that inner-city *locations* experience inherently poorer physical job accessibility as a result of industrial restructuring (e..g, Kasarda, 1995; also Farley, 1987) and the decentralization of blue-collar employment (Farley, 1987; Leonard, 1987; Rogers, 1997). As a result, some academics support policies that would move low-income households from poverty areas to the suburbs (e.g., Chicago's *Gautreaux* program; see Rosenbaum and Popkin, 1991). Kain has supported this view as well (Kain, 1992). The research herein includes this more recent view in its formulation of the "modern" spatial mismatch hypothesis (see Figure 2.1, next page).

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[9] Shen's study was of the Boston metro area. While one cannot equate low-income families with black workers, it is well documented that African Americans disproportionately comprise low-income households in the U.S.

[10] Authors referenced are those whose works have been most prominent or influential in each regard.

Figure 2.1. Modern Interpretation of the Spatial Mismatch Hypothesis

Massey and Denton, 1992
Bartelt, 1993
Sugrue, 1993
Yinger, 1997

Leonard, 1987
Kasarda, 1995
Coughlin and Rich, 1998

| Racial **Discrimination** in Housing Markets | **Suburbanization** of Employment Opportunities |

Massey and Denton, 1992
Bartelt, 1993
Katz, 1993
Sugrue, 1993
Thomas, 1993

Kain, 1968
Kain and Zax, 1983
Farley, 1987
Cevero and Landis, 1990
Shen, forthcoming
Zax and Kain, 1996

Kain, 1968
Leonard, 1987
Massey and Eggars, 1990
O'Regan and Quigley, 1991
Bartelt, 1993
Katz, 1993
Sugrue, 1993
O'Regan and Quigley, 1996

| **Segregation** of Minorities to Denser Inner-Cities | Inner-cities Experience Inherently Poor Job Accessibility |

Farley, 1987
Kasarda, 1995
Rogers, 1997

Kain, 1968
Kain and Zax, 1983
O'Regan and Quigley, 1995, 1996a, 1996b
Zax and Kain, 1996

Farley, 1987
O'Regan and Quigley, 1991

Kain, 1968
Kain and Zax, 1983
Farley, 1987
Ihlanfeldt and Sjoquist, 1990
O'Regan and Quigley, 1991, 1996b
Ihlanfeldt, 1993
Zax and Kain, 1996

| Minorities Experience Much **Lower Job Accessibility** |

City Core

C

Jobs, services, population

Job Centers

Inner City

C

Suburbs

Manufacturing, retail, unskilled service jobs; Auto-oriented

Highly-skilled service jobs; Transit-oriented

The top figure shows a framework of the structural relationships of the "modern" spatial mismatch hypothesis and the prominent literature that has supported various elements of it. Elements include the existence of each phenomenon (e.g., suburbanization of employment opportunities), as well as the causal relationships between them. While prominent studies have concluded in opposition to the spatial mismatch hypothesis, this figure shows the notable literature that has supported parts of it. Also, most, if not all, of the works cited here encompass subjects of greater scope than shown above.

2.1.4. Questions Raised

1. Existence of Concentration Effects

One question left still unanswered, for example, is whether and in what manner greater geographic stratification of classes may yield poorer physical job accessibility for low-income families. Kain's work strongly would suggest that class segregation would worsen job access.

Clearly, poverty has become more geographically concentrated in recent decades (Massey and Eggers, 1990; Sugrue, 1993), and prominent literature has suggested that the increasing spatial isolation has led to pernicious social effects that have further isolated many low-income families from the mainstream economy (Wilson, 1987). The question herein, however, asks how poverty concentration (as opposed to simple isolation) may effect lower *physical* job accessibility, both via reducing the local ratio of entry-level jobs to low-income workers and by further separating mobility-constrained households from job-rich areas. Alternatively, it is possible that concentration might actually improve physical job accessibility if it happens to occur in locations particularly rich in jobs and affordable transportation options. Given intensifying levels of poverty concentration, the issue of class-related mobility constraints becomes increasingly important.

Some evidence suggests isolation of low-income families may in fact lower job accessibility. If so, geographic patterns of job accessibility (a latent variable) should be observable in spatial variations in both wages and employment levels. For example, one would expect blue-collar wages to be higher in the suburbs because of the high job-to-worker ratio there, but lower in inner-cities, because of the relative dearth of jobs. Recent work by O'Regan and Quigley (1996) confirms that low-income workers' hourly wage increases with distance from the inner-city population. In their study of Detroit and Atlanta teenagers, they found that "a standard deviation increase in firms' distance from blacks (while keeping distance from the Central Business District constant) raises the wages of their black employees by 5 to 10 percent in Atlanta and by

9 to 14 percent in Detroit."[11] O'Regan and Quigley (1995), furthermore, have examined *employment* levels among working-age teenagers, by race:

> Minority youth residing in cities in which minorities are more segregated or in which minorities have less contact with non-poor households have lower employment probabilities than otherwise identical youth living in similar but less segregated metropolitan areas. Simulations suggest that the magnitude of these spatial effects is not small.[12]

Their best models estimate that among major metropolises, "21 to 25 percent of the existing employment gap between white and Hispanic youth is attributable to the spatial isolation of Hispanics," and, "30 to 35 percent of the employment gap between white and black youth arises from the spatial isolation of blacks."[13] These results, which the study asserts are conservative, suggest the existence of significant concentration effects. Similar study of black and white Philadelphia teenagers concludes that 33% to 54% of the racial gap in employment, in fact, can be attributed specifically to households' *distance* to jobs (Ihlanfeldt and Sjoquist 1990). When controlling for school enrollment status, the attributable proportion remains between one-third and one-half (Ihlanfeldt and Sjoquist, 1991a).

Clearly, the pattern of youth employment depends to a large degree upon patterns of spatial isolation, distance to jobs and segregation by race. Notably however, these studies examine wage and employment trends only among teenagers, not the whole of low-income families, and they measure segregation only by race, not household income. Research has confirmed that important characteristics may differentiate minority teens from the whole of low-income families. For example, family social networks are particularly important in facilitating youth access to jobs (O'Regan and Qugley, 1992). Given such informal methods of job search, labor market information decreases steeply with increasing distance from home (Holzer, 1987), creating spatial effects that are not necessarily transportation-related. Also, teens experience greater mobility constraints than their parents (see Ihlanfeldt and Sjoquist, 1990). For these reasons, the studies of teens, while important for providing theoretical foundation for the questions raised herein, do not comment on the whole of low-income families' job accessibility.

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[11] pg. 79.
[12] pg. 2
[13] pg. 15.

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The important question remains as to whether and how spatial stratification of income groups affects physical job accessibility, as measured by travel time, among the whole of low-income families. Furthermore, if such spatial effects prove to be negative and prominent, what transportation policies or services best would help alleviate the problem? Results of teen wage and employment differentials lend strong credibility to the idea of concentration effects. If concentration effects are important, one should expect low-income families in class-integrated cities to fare better than those residing in regions of strictly defined income enclaves.

In this regard, evidence suggests that the geographic distribution of income groups may be quite different in San Juan and Boston. If so, examination of the questions above is possible in context of this research. Research shows that race plays a strong role in geographically separating the residential locations of income classes in the mainland U.S. (Massey and Eggars, 1990), as well as those of Puerto Ricans (Massey and Bitterman, 1985). However, race *in* Puerto Rico does not connote the same meaning or hold the same consequence as in the mainland. Puerto Rican ethnicity is remarkably heterogeneous. As a result, "traditional Puerto Rican culture does not dichotomize the world into blacks and whites and attach a stigma to the former"[14] (see Fitzpatrick, 1971; also Longres, 1974; Rivera-Batiz and Santiago, 1996). While skin color remains somewhat important in that, "light is more highly regarded,"[15] it is not nearly as significant on the island (Burch and Martin, 1998). According to Tumin and Vázquez (1961):[16]

> The evidence urges upon us the conclusion that skin color is considerably less important in Puerto Rico than in the United States; that it is virtually of no significance whatsoever in many important areas of life; that the majority feel that people of darker color are not blocked from major opportunities by their color; that only on job opportunity is there any serious question. . . . [But] by any objective measure, there is only a small and relatively insignificant relationship between skin color and education, income, occupation, or any of the other indices of social and economic position.

Meanwhile, Boston, like other mainland cities, historically and consistently has displayed great spatial dissimilarity of races (Massey and Denton, 1992; Yinger, 1997) and racial or ethnic tensions have marred much of the city's modern history (see Formisano, 1991). It is plausible to

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[14] Quoted from Massey and Bitterman, 1985, pg. 308.
[15] Burch and Martin acknowledge that, although most Puerto Ricans deny the existence of racism in their cultures, skin color remains a very real factor. They and others contend, mostly through anecdotal evidence, that skin color remains an important but overlooked variable in affecting social and economic status.

presume that, as a result of the relative insignificance of race in Puerto Rico, income classes may reside less spatially separate in San Juan than in Boston. Thus, research that examines the significance of race upon poverty concentration may benefit greatly from examining San Juan as a scientific control in a comparative analysis.

2. The Mechanisms of Concentration Effects

A second, related question, asks *how* such poverty concentration may effect lower (or higher) physical job accessibility. In class-stratified cities, do low-income families reside in locations that are inherently "accessibility poor", or alternatively, would the sheer concentration of low-income workers in any location be overwhelming to the labor market? Researchers confirm that jobs continue to decentralize (Kasarda, 1995) and that such dispersion has negative effects upon minority employment (Farley, 1987). Also, a plethora of urban economics literature contends implicitly that central locations experience poorer job accessibility. However, research by Shen (1997, forthcoming) indicates that inner-city areas may actually experience better physical accessibility to the metropolitan area. What is the case in San Juan and Boston? Also, to what extent are such trends of decentralization and poverty concentration present in either city? To date no study has examined both concentration and location effects while simultaneously observing longitudinal labor market trends.

The issue is important in today's world, particularly given modern welfare reform and the political push of some to relocate low-income families to suburban areas as a method of improving their access to jobs (e.g., the *Gautreaux* program, Rosenbaum and Popkin, 1991; see APTA, 1997). The full question asks whether space, and travel in particular, strongly affects job accessibility among the larger set of low-income workers in the same way it does spatially constrained teenagers, and also, *how* geographic class stratification may play an important role. Research that could show whether and how low-income adults experience poorer job accessibility as a result of spatial class-stratification would comment strongly on the spatial mismatch phenomenon and public policy in general.

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[16] Quoted in Rivera-Batiz and Santiago, 1996, pg. 70.

3. Empirical Methods of Measuring Accessibility

Third, much uncertainty exists regarding the validity of some empirical methods of measuring accessibility. Three methods of measuring employment accessibility are most common among the literature: (1) number of jobs within a given radius, (2) jobs-to-workers ratio (called "import ratio") within pre-determined zones, and (3) averaged observed commuting times. Using only the first measure, though simple, ignores labor market competition among workers and ruggedly treats all jobs within the given radius as having an equal level of accessibility. Also, the chosen radius is arbitrary. "Import ratio", while accounting for some worker competition, ignores the market's interaction among zones and ultimately fails to measure or compare the magnitude of job surplus or deficit among zones. After examining these three measures Ellwood (1986) argues that, "the [journey-to-work] travel time measure is particularly appealing because it reflects actual worker behavior. If jobs are found nearby, travel time to work will be short. If particular workers cannot find jobs in the neighborhood, their travel time will be long."[17] Inhlanfeldt and Sjoquist further argue that "both Ellwood's and their experimentation with alternative measures reveal [sic] that travel time is the best predictor of employment probability" and that "travel time conceptually is the most meaningful measure of job access."[18] However, the author of this thesis argues that none of the most prominent measures accurately captures the travel time or distribution of jobs most closely associated with perceived employment potential. Specifically, these measures do not account for the range of travel times to all possible jobs. At best, they account only for the *observed* journey-to-work times, which represent only a subset of those commuting times upon which workers' choose their commutes.

Ellwood's 1986 study of Chicago youth, for which he used observed journey-to-work times, has been one of the most prominent and influential works in the field. In it he concluded pithily, "The problem is space, not race."[19] Ellwood's catchy conclusion provided closure (albeit temporary) to the spatial mismatch debate. For this reason, this report examines his study in greater depth, with particular attention to the empirical methods Ellwood used.

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[17] Quoted in Kawabata, 1997, pg. 15.
[18] Kawabata, 1997. pg. 15.
[19] pg. 149

Ellwood made several notable observations. He confirmed that "low-skilled jobs have been leaving the city faster than low-skilled workers," and that "as a result there are now more low-skilled city residents who work in the suburbs than vice versa." He also made the observation that, "Young and low-skilled blacks in Chicago spend far more time getting to work on the average than comparable whites." However, he contended, "No measure of accessibility proves to have any predictive power in employment equations for young people," citing that labor market outcomes for young blacks in two distinct, Chicago inner-city neighborhoods were remarkably similar, in spite of dramatic differences in proximity to jobs.[20] Likewise he noted, "Black and white teenagers who live in the same neighborhood fare just as differently as blacks and whites who live across town from each other." These conclusions, he said, differed with implications of Kain's theory that space was an important variable in affecting job access.

However, several problems make Ellwood's methods questionable. Importantly, Ellwood's use of journey-to-work travel times does not account for differences in travel modes among races or income groups,[21] nor for the hypothetical commute times of unemployed workers, who are unevenly distributed among races, income groups and geographic areas. How may one measure the effect of journey-to-work travel time upon employment if those persons unemployed experience no commute and therefore may not be included in the data set? Since unemployment differs by race and geographic location, the issue is significant. The implicit assumption that those who are not working, if they had jobs, would experience the same distribution of travel times as those who presently are employed is without basis. This implicit assumption undermines, *a priori*, the hypothesis Ellwood wished to test.

Also, because of these oversights, there is no real indication of which direction journey-to-work times should vary in relation to job accessibility. Since black workers may more often be transit dependent, their job accessibility may depend more significantly on whether the land use and transportation systems bring an adequate supply of jobs to within reasonable travel time. Travel times might be longer, reflecting the greater extent to which blacks must travel to find work

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[20] Works by Inhlanfeldt and Sjoquist (1990, 1991a, 1991b) and O'Regan and Quigley (1995, 1996) clearly refuted this claim.

(Ong, 1995; also Ellwood, 1987), or they could be shorter, in response to the more geographically concentrated nature of *transit-accessible* opportunities (Leonard, 1987). Leonard observed in Chicago that even while the blue-collar job market continued to decentralize in the 1970s, black male employment had been collapsing geographically toward blacks' residential locations.[22] At least in the case of Chicago, *shorter* travel times may be a symptom of the spatial mismatch phenomenon. Again, the issue at hand is adequately accounting for blacks' physical accessibility to all the jobs they did not take – whether by choice or labor market competition, or as a result of transportation constraints.[23] Existing methods that depend on journey-to-work travel times cannot account for this dimension of the job accessibility paradigm.

Taylor and Ong (1995) also observe journey-to-work travel times as a test of Kain's hypothesis. They posit as the fundamental assumption of their study that longer work commutes among blacks would be "the most explicit indicator of the [spatial mismatch] hypothesis."[24] Longer travel times, they assert, would indicate the effects of job dispersal and residential immobility. Ironically, as compared to Ellwood's study, Taylor and Ong make the opposite observation about blacks' commute times – namely, that blacks' commutes are shorter – yet draw the same conclusion regarding Kain's hypothesis!

Both Ellwood (1986) and Taylor and Ong (1995) made the erroneous fundamental assumption that particular variations in journey-to-work times necessarily should indicate something significant about the spatial mismatch hypothesis. If researchers are to make real progress on the issue, and contribute meaningfully to public policy in this regard, they must employ a cogent method for examining the subject. The issue asks for a method that accounts both for mode of travel and also for workers' hypothetical journeys to all job possibilities.

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[21] According to Shen (1997), for example, the approach, "is particularly problematic when the question is about inner-city neighborhoods and low-wager workers, because auto ownership is negatively correlated with income." Quoted in Kawabata, 1997, pg. 8

[22] The geographic collapse of black employment speaks to the interaction of industrial dispersion, residential immobility and the resulting increase in the time and monetary costs of accessing increasingly distant employment.

[23] In this sense, "labor market competition" refers also to possible racial biases of employers that may allow workers of some race to compete more effectively for employment or promotion.

[24] pg. 1543. The study focused on Los Angeles, as opposed to Chicago, where Ellwood's study focused.

4. Geographic Information Systems as a Tool of Analysis

Finally, with increasingly powerful technology, researchers are able to perform more robust and rigorous analyses. Today geographic information systems (GIS) may perform many more complex and extensive analyses than would have been possible otherwise. The technology allows for advances in several respects with regard to the spatial mismatch debate.[25]

Researchers traditionally have analyzed U.S. metropolitan areas at levels of great aggregation. For example, the earliest study, by Kain (1968), sectioned the Chicago and Detroit metropolitan areas each into large "ghetto" and "non-ghetto" zones. Other research has divided metropolises in two "suburb" and "ghetto" areas (Leonard, 1987). More recent analysis has examined groups of census tracts, called "neighborhoods" (Ellwood, 1986), and some still examine spatial phenomena at the county level (Rich and Coughlin, 1998). The most fine-grained analysis to date has used Traffic Analysis Zones (e.g., Shen, 1998a), a much more fine-grained treatment than many previous methods. While such large-scale examination may uncover strong, region-wide trends, it would not provide the fidelity necessary to capture important sub-regional phenomena. Relatively disaggregate data, such as Shen's, surely would prove useful for understanding variations in joblessness among small areas, or for evaluating specific transit alternatives whose services would affect narrow corridors and similarly specific geographic constituencies. Since transportation is a prominent component of the spatial mismatch debate, economists, sociologists and policy-makers may benefit greatly from GIS as a tool that allows more fine-grained analysis.

The need for such a tool was recognized early on by researchers who had completed a thorough review of the spatial mismatch literature. Jencks and Mayer (1990) concluded that:

> We need more fine-grained descriptions of specific cities, including maps that show where workers with specified characteristics earn the most and the least, which neighborhoods have major centers of blue-collar employment, and which neighborhoods have the highest and lowest rates of labor force participation. This is a field where a picture is worth considerably more than a thousand words.[26]

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[25] GIS is a powerful computing tool that will receive more discussion in Chapter 3.
[26] pg. 219.

Modern GIS packages allow much more fine-grained spatial analysis, as well as a visual medium for communication, that could provide the information necessary for implementing transportation-oriented solutions.

In the context of literature that has addressed the transportation issues of urban economics, researchers have used GIS simply to communicate large geographic trends (e.g., Couglin and Rich, 1998) or to perform complex spatial analysis (e.g., Ong, 1995; Shen, 1998b; Zhang, 1998). However, no study to date has employed the tool as a mode of examining the sensitivity of transportation solutions upon the geographic distribution of accessibility. A method that would allow such analysis could be very practical to the research and planning community. A method that would permit the quantification and interpretation of accessibility benefits is currently missing from planning practice.

Finally, much research has focused on distance-based measures of accessibility (e.g., Kain, 1968). Time-based measures, if applied appropriately, surely would be preferable, since they more closely reflect travelers' social construction of urban space. Furthermore, such times should be examined separately by mode (Shen, 1998a) and should account for hypothetical commutes to all possible job opportunities. To date, almost all the literature that rely upon travel time have used either aggregated travel data of observed trips by all modes or the travel times of auto only as a proxy for other modes. Emerging GIS tools may allow one to gather more meaningful trip time data from network simulations, in a manner convenient for tractable usability.

2.2 Accessibility Literature

"Accessibility" has many meanings, depending on its context. Also, researchers have developed various measures to quantify it. This section explores the concept of accessibility and the models available for measuring it. Chapter 3 later evaluates the models in more detail in context of the research herein.

2.2.1. Concept of Accessibility

Traditionally, transportation planning has focused on improving travelers' mobility – their ability to move about the network easily and without experiencing congestion. More recent thought has emphasized the idea of accessibility – that is, travelers' ease of reaching valuable opportunities and destinations using the transportation system. The two ideas are closely related, yet distinct. Good mobility certainly enhances one's accessibility.

The idea of accessibility has many forms. As explained by Hanson (1986), one may categorize academics' attempts to conceptualize the idea into two genres: people or places. Person-based accessibility refers to one's particular social and physical capability to access certain activities (Moseley, 1979), while place-based accessibility refers to the "ease with which one may reach spatially distributed opportunities from a given location using a particular transportation system" (Morris, et al, 1979; also, see Ingram, 1971).[27] The research herein focuses on the latter idea.

In this context, Mosely (1979) argues that accessibility has three components: people, activities and the transportation or communication links between them. Similarly, Burns (1979) characterizes accessibility in terms of personal freedom, arguing that the propensity to participate in certain activities depends on their temporal and geographic availability as well as the procurable transportation and its speed. Ingram (1971), too, defines the accessibility of a place as its inherent advantage of location, "with respect to overcoming some form of spatially operating source of friction, for example, time [or] distance."[28] In all these conceptualizations, transportation or communication bridge the spatial gap that separates opportunities and activities from the individuals who wish to participate in them. Appropriately then, in geographic terms the idea of accessibility strongly involves transportation's interaction with the land use system (Cervero, 1998; Bernick, 1997), including its distributed economic, social, and recreational opportunities.

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[27] Quoted from Lane, 1999.
[28] pg. 101

Finally, academics have posited that accessibility is the central feature of quality of life that metropolitan areas offer (Handy and Niemeier, 1997). According to Handy and Niemeier, accessibility is, "the potential for interaction, both social and economic, the possibility of getting from home to a multitude of destinations offering a spectrum of opportunities for work and play."[29] It is what makes cities attractive. Note that "accessibility" describes the *potential* to access opportunity, not the act. Ramming (1994) recently developed a sophisticated utility model based on this idea, accounting for the set of destinations to which a person could travel, even if such a trip is not made. In this sense, "job accessibility" refers to one's *potential* to access jobs, even those in which he or she does not work.

Several factors could affect one's job accessibility (Lane, 1999) – including social (e.g., familial responsibilities, discrimination, cultural roles), spatial (e.g., access to auto, access to transit, spatial impedance, job information), or skill-wise (e.g., education and experience, supply versus demand for workers). For purposes of this research, "physical job accessibility" narrows the idea to solely spatial dimensions – the product of land use and transportation – while "competitive job accessibility" additionally accounts for competition within the labor market for limited opportunities. This research focuses on the transportation elements of physical and competitive job accessibility, and in doing so assumes land uses remain constant, at least for the short term.

2.2.2. Measures of Accessibility

Most measures of accessibility consist of two components: an element of attractiveness and one other of resistance. The "attractiveness" component accounts for a destination's overall quality or amount of good available, while the "resistance" element characterizes the cost of accessing the opportunity via the transportation system – possibly including out-of-pocket expenses, travel time, distance, discomfort or lost productivity. Three general forms of accessibility measures exist: cumulative opportunity, gravity-based functions, and those measures grounded in random utility theory.

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[29] pg. 1175

Cumulative opportunity measures, referred to also as "isochrone" models (Walker, 1998), are the simplest. These measures of accessibility simply count the number of opportunities within a given travel radius (e.g., Wickstrom, 1971; Wachs and Kumagai, 1973; Sherman et al, 1974; McKenzie, 1984).

Gravity-based measures acknowledge that accessibility deteriorates gradually with increasing distance from the traveler's point of origin and recognize that not all opportunities are equal. These measures weigh destinations by their relative attractiveness – for example, number of jobs, quality of vista, or revenue generated. The attractiveness is weighed against total impedance, which is the sum of costs incurred by moving about the transportation network. One may view gravity-based models as the generalized form of cumulative opportunity measures. In the former, a more complex impedance function replaces the simple binary value, such that opportunities are weighted differently. The use of gravity-based measures has quite a long history (Hansen, 1959; Ingram, 1971; Wilson, 1971; Vickerman, 1974; Patton, 1976).

Two general genres of gravity models exist. The Hansen-type model considers only the "supply side" of accessibility measurement, without acknowledging any capacity constraint of the activities. For example, in terms of job accessibility, a Hansen-type model would account for workers' ability to access employers, but it would neither consider whether enough jobs exist to employ all available job seekers, nor account for the competition among workers for limited employment opportunities. Recognizing this fact, Weibull (1976) and Shen (forthcoming) propose a refined model that divides the traditional Hansen measure by a "demand side". In the example of job accessibility, the "demand side" consists of employers' potential access to workers. The resulting measure's output is quite attractive since an accessibility value of "one" indicates balance between workers and jobs (for proof, see Shen, 1998a).

A final class of accessibility measures is based on random utility theory, in which the probability of an individual choosing to travel to a particular destination depends on the utility of that location relative to the utilities of all other possible destinations (see Ben-Akiva and Lerman, 1977; Koenig, 1980; Ramming, 1994). If one assumes that the traveler assigns a utility to some specified choice set and always selects the alternative which maximizes his or her value, then

accessibility can be defined as the denominator of the multinomial logit model, or logsum (see Ben-Akiva and Lerman, 1985; also, McFadden, 1981). The utility function includes variables that characterize the quality of all possible choices within the set and reflects the impedance that must be overcome to reach the destination. The function also may include socio-economic characteristics that reflect tastes and preferences (Handy and Niemeier, 1997).

Many techniques for measuring accessibility exist, reflecting various realizations of the idea. Chapter 3 will discuss and evaluate the use of these measures and their application to this research in more depth.

2.3   Welfare Reform and Travel Behavior Literature

The subjects of urban economics and physical accessibility converge in modern public policy on the topic of welfare reform (see Community Transportation Association of America, 1996). One may view recipients as one subset of the larger pool of low-income families. In this sense, modern welfare reform is the most significant public policy to affect low-income families in recent time.

2.3.1. Personal Responsibility and Work Opportunity Reconciliation Act of 1996

The reform repealed the Aid to Families with Dependent Children Act and in its place established state block grants with many rules attached. Among them, the Federal government made future funds contingent on each state's ability to move welfare recipients into jobs and reach pre-set benchmarks of reductions in the rolls. Also, the legislation required work in exchange for time-limited assistance (Administration for Children and Families, 1996). The picture looked bleak not only for some low-income families, who would lose their benefits, but more generally for urban areas, which supported the predominance of recipient households. At time of the bill's passage, for example, Los Angeles County alone had over 900,000 AFDC recipients. It was projected that when reforms began, the County would incur net annual costs of

$260 million, and that $1 billion of yearly Federal money inflow would be withdrawn (Wolch, 1998). Other cities faced similar threat. For these reasons, some warned of impending doom from the probable effects of the reform (e.g., Assordino, 1998).

2.3.2. Travel Patterns and Transportation Needs

One particular criticism of the reform has been that it assumes there exist, "adequate mobility alternatives to access the universe of available jobs, training and related support services."[30] Only 6.5% of recipient households claim access to an automobile; yet their travel needs remain among the greatest in society.

Demographic Composition of Recipient Households

One may evaluate the particular transportation needs of welfare-dependent families by comparing their demographic composition to those for whom travel patterns have been well documented. Ninety percent of adult recipients are female, while 65% of all recipients are children — a full half of whom are no more than five years old. Taken together, nearly 70% of recipient families consist of single adult, supporting an average of two children (Coughlin and Rich, 1997). In San Juan, where this research focuses, one may assume the overwhelming majority of recipients are of Hispanic origin. Thus, one may characterize San Juan's recipient families as mostly single adult, Hispanic households, led almost always by a female, with an average of two children, often younger than school-age. From this demographic characterization one may proceed directly to the travel behavior literature to identify their likely transportation needs.

Travel Behavior Literature

Large gender differences in commuting time and travel mode exist and have been documented thoroughly. Overall, women exhibit greater need for more ubiquitous transportation, to care for domestic responsibilities and complete complex trips that chain work, child care, home and

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[30] Coughlin and Rich, 1997.

shopping and service destinations. Paradoxically, though women have shorter average trip lengths than men (Guiliano, 1979; Pickup, 1985; Rosenbloom, 1988, Gordon, et al, 1989, etc.), they make many more trips (Skinner and Borlaug, 1980; Michelson, 1983; Rosenbloom, 1988; Rosenbloom and Burns, 1993). Also, women use public transportation more (Guiliano, 1979; Michelson, 1983; Pickup 1985), yet exhibit much greater attachment to and need for use of the auto mode (Hanson and Pratt, 1990; Rosenbloom, 1993; Rosenbloom and Burns, 1993; Burns, 1998).

In terms of commute time, women work six to seven minutes closer to home, on average (Mauch and Taylor, 1996), and depending on the city, commute half to two-thirds the length of the average man's journey to work (Wachs, 1992). The pattern holds for car, ridesharing and bus modes alike (Hanson and Johnston, 1985). Moreover, when the family consists of a single, Hispanic woman supporting at least one child, household trips are 34% shorter, controlling for travel mode (Mauch and Taylor, 1996). As a result, the physical world of accessible jobs, services and activities is at least 57% smaller, even with access to an auto. Clearly, the literature indicates that recipients exhibit great need for quicker and more frequent mobility, yet they exhibit the lowest rate of car access among any demographic group.

According to Preston, *et. al.* (1993), gender differences in commute time may be attributable to four possible explanations: (1) women's shorter commutes may be an economically rational response to lower wages, (2) the spatial pattern of women's employment may shorten work trips, (3) women may have had limited access to cars, or (4) domestic and child care responsibilities may prompt women to work closer to home. Ong and Blumenberg (1998) confirm that welfare recipients achieve higher wages with increasing commute time, possibly supporting the first explanation above.[31] Study in metropolitan New York City links women's shorter commutes to differences in income, industries and occupations in which women are employed (McLafferty and Preston, 1991) – possibly supporting the first or second explanations.[32] The same study notes that minority women experience longer commutes because of greater transit dependency and the spatial mismatch between homes and work – supporting the second or third possibilities.

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[31] They note, however, that labor markets do not produce compensating wages for the relatively long commutes.
[32] The causal direction is unclear, however.

The strongest evidence, however, supports the fourth notion – that women shoulder a larger share of domestic responsibilities and often value them over work considerations more than men do. Study by Burns and Brinegar (1998) in metropolitan Phoenix confirms strongly that in their travel patterns women respond more sensitively to domestic responsibilities than do men, even among comparable single-parent households. In their longitudinal study of Arizona State University's travel demand management program,[33] they confirm that:

> employed women are more likely than comparable men to drive alone, are less likely to change their travel mode and, when they do change mode, change at the lower rates. Both women and men are less likely to change their travel behavior if they have childcare responsibility, with women more affected than men. . . . [The study] confirms that men are less constrained to driving alone by their domestic responsibilities than women are.[34]

In fact, evidence confirms that as the heads-of-households, single mothers commute longer distances and drive alone more than adults in childless households (England, 1993). Given women's responsibility "to meet competing demands of employment, child care and household management,"[35] few working women can afford the time of commuting by transit, even if it is available (Rosenbloom, 1993). Furthermore, commuting by car better allows for trip chaining between work, shopping and chauffeuring, as well as for attending to emergencies that might involve the home or children (Hanson and Pratt, 1990; Rosenbloom and Burns, 1993). Among the lowest income quartile in particular, women make 3.8 times as many child-serving trips as do men (Mauch and Taylor, 1996). As a result of their need for ubiquity and on-demand service, women are far more likely to drive to work if they have more and younger children (Rosenbloom and Burns, 1993). Clearly, the literature indicates at the very least, that the childcare and domestic responsibilities of single mothers compete very strongly with demands of employment and that the serious transportation constraints of welfare recipients may place great strain upon their job placement and retention. In context of Puerto Rico, the question clearly becomes, "*How may Tren Urbano help support San Juan's population of greatest travel need?*"

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[33] Such programs encourage ridesharing and switching to transit modes, among other strategies to reduce car use.
[34] pg. 2

2.4 Summary

This chapter has observed that the spatial mismatch hypothesis is probably true, though much uncertainty remains regarding the cause or extent of its assertions. The section also has reviewed the theoretical foundation for the concept, measurement and presentation of physical job accessibility, as it relates to this research. Finally it has examined welfare recipients' particular transportation needs and constraints, as well as the public policy impetus to move them into jobs. Together, the discussion herein has established the theoretical motivations and foundation for examining San Juan recipients' job accessibility in context of the spatial mismatch literature.

Chapters 1 and 2 progressively have established the motivation, objectives and theoretical foun\dation for this research. The following chapters will explore how the ideas presented thus far come to bear in study of Boston and San Juan. ■

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[35] Coughlin and Rich, 1997.

Chapter 3

Methodology

This section presents the design of methods and implementation of techniques used for examining the research questions. The section first introduces the two study cases: San Juan and Boston. Next, it presents the measures, tools and framework of analysis that the study uses to examine the research questions and quantify results. Finally, this section defines the data that are used for analysis and details important aspects of their collection and compilation. From this chapter, the reader should become familiar with the two case study areas and gain a thorough understanding of the methods, tools and data that the research uses to analyze them.

The process of collecting and preparing data amounts to a partial test of one important question of the research, which asks how GIS may be a useful tool for the measurement and presentation of user benefits, for use by policy-makers and service designers. Part of Chapter 5 reviews the researcher's experience and highlights what steps might need to be taken for the eventual design of an effective planning framework that accurately incorporates the full range of transit's benefits to society.

3.1. Overview

San Juan is this research's geographic region of primary focus. In this context, an examination of the Boston Metropolitan Area (or simply, "Boston") provides a point of comparison, lending better insight into accessibility and land use phenomena in San Juan while providing a larger scope from which to draw broader, more theoretical conclusions about spatial mismatch phenomena. The chosen cases afford very strong inferences that comment cogently on the nature of accessibility among low-income families in each city. To do so, the study employs unique, quantitative means of measuring spatial, social and economic phenomena. The technical

decisions regarding such measures and the compilation of their data are covered within this chapter.

Boston serves as an excellent case for comparative study for several reasons. First, Boston's geographic form fits the classical spatial mismatch model – with strong focus of transportation and activity on the metropolitan center; relatively smooth contours of increasing density as one approaches the downtown; a large inner-city area;[36] and a ring-shaped, highway-oriented suburban area of office parks and busy retail activity. While such form does not necessarily imply the existence of a spatial mismatch, it is consistent with the forms of cities about which literature regarding the subject has claimed significant evidence of the phenomenon. San Juan shows some elements of this form, but not nearly as strongly. Using comparable measures and tools to study Boston therefore lends very good insight into the existence and extent of spatial phenomena in San Juan.

Second, the social "race factor" seems to be uniquely benign in Puerto Rico (Tumin and Vázquez, 1961; Fitzpatrick, 1971; Longres, 1974; Rivera-Batiz and Santiago, 1996; Burch and Martin, 1998), though very strong in Boston (Formisano, 1991; see Massey and Denton, 1992, for a thorough review). Differences between the two may highlight possible causes for geographic variations of accessibility and certainly will lend insight into the theoretical questions raised by the research.

Third, evidence strongly indicates that San Juan may be developing economically and spatially toward Boston's and other mainland cities' likeness. Boston is larger and more mature in terms of development, and has had much experience with rail transit investment and urban redevelopment. Thus, study of both cities provides insight into San Juan's likely patterns of future growth as well as the consequences of such development. Doing so helps to identify the transportation issues that the region will face in the future.

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[36] In this context, the author refers to the large, contiguous neighborhoods of relatively high poverty rates, that neighbor the most central portions of the metro area.

Finally, much demographic, spatial and transportation data are available for Boston but not for San Juan, even from the nationally standardized U.S. Census. Thus, study of Boston helps to "fill out" results for which from San Juan there are missing or insufficient data. Specifically, study of Boston helps to complete the pictures of (1) race upon low-income households' spatial isolation, (2) child care constraints upon recipients' travel needs, and (3) the general effects of public transit on alleviating or worsening effects of poverty concentration. Completing the stories behind these issues makes both study of San Juan more meaningful and examination of Boston particularly relevant.

Chapter 4 will examine San Juan and Boston comparatively in context of the spatial mismatch hypothesis – testing issues of blue-collar employment decentralization, the spatial isolation of low-income households and the geographic distribution of job accessibility. Chapter 5 then will examine *Tren Urbano*'s impacts in greater depth and evaluate policy and service options for helping the region's lowest-income families reach employment.

3.2. Definition of Study Areas

San Juan and Boston each have important characteristics that deserve overview before studying them in greater depth. This section provides background about each region's economy and urban form – very important components as they relate to the study herein.

3.2.1 San Juan

The San Juan Metropolitan Area (or "San Juan") encompasses a 254.3 square-mile area that includes municipalities (from west to east) of Toa Alta, Toa Baja, Bayamón, Cataño, Guaynabo, San Juan, Trujillo Alto and Carolina, as well as the western portion of Loíza. In 1993, the region had a total population of 1.2 million, and total employment of 390,000 (1990 U.S. Census; Barton-Aschman, 1993). Population concentrated in the region's three largest municipalities – San Juan, Bayamón, and Carolina – while jobs concentrated overwhelmingly in the central city.

Today, the San Juan municipality is home to more than 65% of the region's jobs and 37% of its population, though it comprises only 20% of metropolitan area's land (see Table 3.1, below). San Juan is the densest municipality both in terms of jobs and residences and the only one whose total share of metropolitan employment exceeds it portion of population. Comparing jobs to workers, the term "bedroom community" suits all other nearby municipalities, except perhaps Guaynabo, whose share of metropolitan jobs is more than half its population share – a ratio generally suitable to supporting the region's mean level of employment among local workers.

Table 3.1. Area, Population and Employment of San Juan Municipalities

MUNICIPALITY	AREA	PERCENT	1993 POPULATION[A]	PERCENT[B]	1993 EMPLOYMENT[A]	PERCENT[B]
Bayamón	43.6	17.9	225,338	18.9	46,931	12.0
Carolina	45.2	18.5	185,732	15.6	34,710	8.9
Cataño	5.1	2.1	33,485	2.8	7,072	2.8
Guaynabo	26.8	11.0	97,879	8.2	26,068	6.7
Loiza[c]	10.5	--	N/A	--	N/A	--
San Juan	48.7	20.0	443,372	37.1	256,617	65.7
Toa Alta	29.7	12.2	46,274	3.9	2,702	0.7
Toa Baja	22.4	9.2	94,633	7.9	9,619	2.5
Trujillo Alto	22.3	9.1	66,992	5.6	6,587	1.7
	254.3	100.0	1,193,795[b]	100.0	390,306[b]	100.0

a – Barton-Aschman, 1993
b – Since the study area includes only a portion of Loiza, precise 1993 population and employment figures are not available for this town. Percentiles and totals for land area, population and employment are calculated without Loiza's very small contribution.

Comparing 1990 U.S. Census figures with 1993 data (see Table 3.2, next page), one finds that while municipal San Juan's population has increased slowly, the largest suburban areas all continue to grow at a moderate to fast pace. Except for the region's smallest towns, the smaller the municipality, the faster its rate of growth. In terms of growth *rate*, Trujillo Alto developed most quickly, adding 9.6%, or nearly 5,000 residents. The most notable population growth during the three-year period occurred in Carolina, which added over 9,000 residents, or 5.2%. Planners foresee that the eastern suburbs of Carolina and Trujillo Alto will continue to expand rapidly in the near future. The towns' proximity to San Juan jobs and abundance of open land make them attractive for development. These figures highlight how metropolitan San Juan is following a pattern of population decentralization familiar to many U.S. cities since the 1950's. They also indicate that future extensions of *Tren Urbano* to eastern suburbs may have great potential to influence travel behavior and land use, or possibly to catalyze further residential

decentralization, depending on public policies. In addition, since job openings arise in large part from the establishment of new business locations, future extensions may provide great opportunity for helping low-income families reach entry-level job growth in developing suburbs.

Table 3.2. San Juan Region's Population Change by Municipality, 1990 to 1993

Municipality	Number	Percent[c]
San Juan	5,466	1.2%
Bayamón	5,076	2.3%
Carolina	9,167	5.2%
Guaynabo	5,154	5.6%
Toa Baja	5,179	5.8%
Trujillo Alto	5,872	9.6%
Toa Alta	2,173	4.9%
Cataño	-1,102	-3.2%
	1,193,795	**3.1%**[c]

a – 1990 U.S. Census
b – U.S. Census: http://www.census.gov/ftp/pub/population/estimates/puerto-rico/prest93.txt
c – Since the study area includes only a small portion of Loiza, precise 1993 population figures are not available for this town.

Urban Form

San Juan began developing during the early 16th Century as a dense, defensive settlement at the tip of what today is Old San Juan. In very recent history the city expanded eastward to Santurce, then south through the contemporary neighborhoods of Hato Rey and Rio Piedras. This intensively developed north-south band extends through the modern San Juan municipality to the island's northern coast, while mountainous, rugged terrain constrains development to the south. In the formerly rural areas between this spine and neighboring town centers of Carolina and Bayamón, modern suburban development has filled in. Today the north-south spine forms the central axis of the San Juan region, while the inner-suburbs form an east-west ridge of urbanization stretching between Bayamón Centro and Plaza Carolina. It is along this central spine and east-west ridge that *Tren Urbano* will operate.

Phase 1 of *Tren Urbano* will span from urban portions of Bayamón, through Guaynabo, and into San Juan, terminating just south of densely populated Santurce (see Figures 3.1 and 3.2, next page). A later Phase 1A extension will bring the line further north into the Minillas neighborhood. Future extensions envision an east-west "H" shape, with the north-south spine

Figure 3.1 Central Portions of the San Juan Metropolitan Area

Legend:
— Phases 1 & 1A
+++ Old San Juan Extension
••••• Carolina Extension
--- Airport Extension
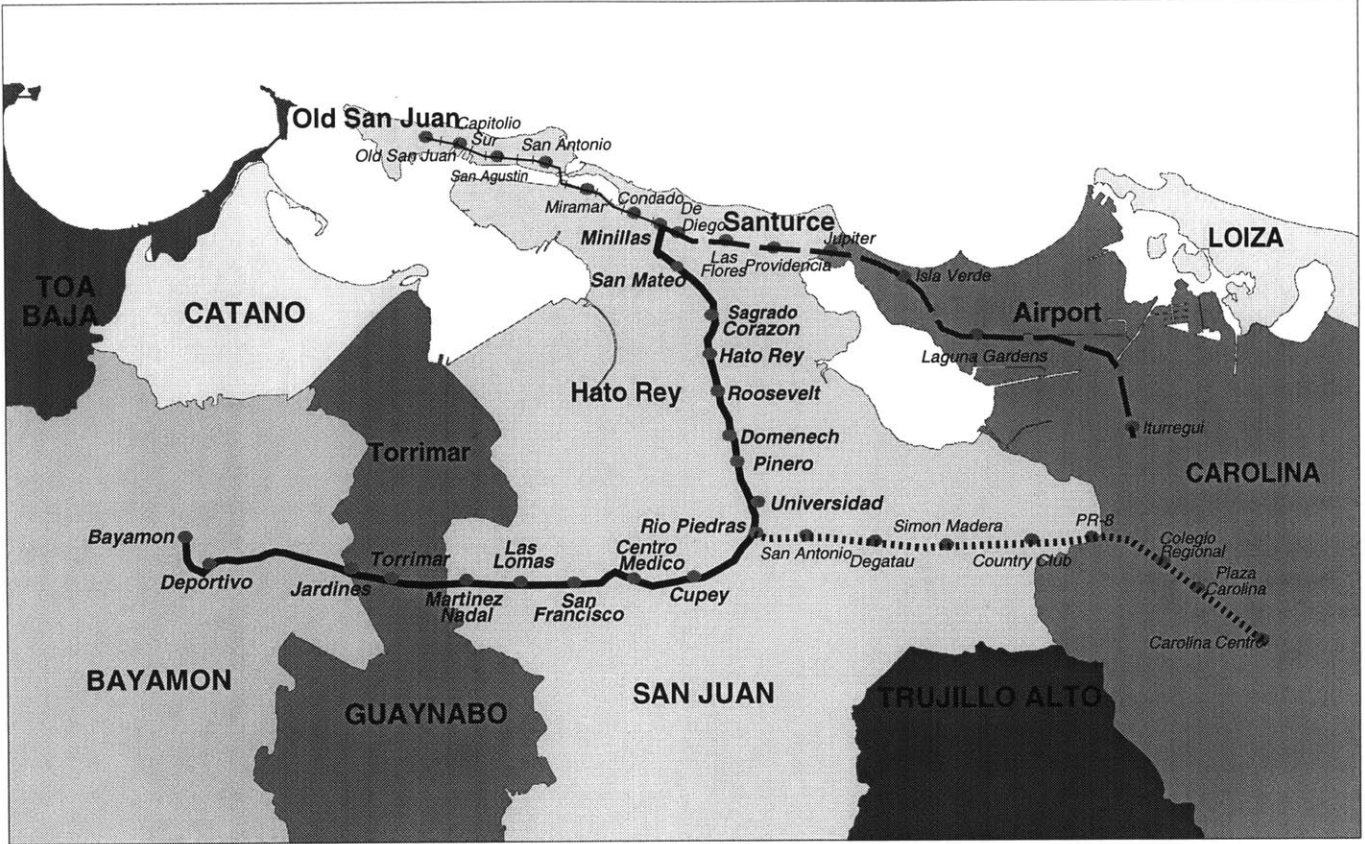
Figure 3.2 San Juan Regional Population Density

Persons per Sq-Mile
18 to 2514
2514 to 8064
8064 to 13187
13187 to 19914
19914 to 147000
Missing Data

1990 Census, by Quintile
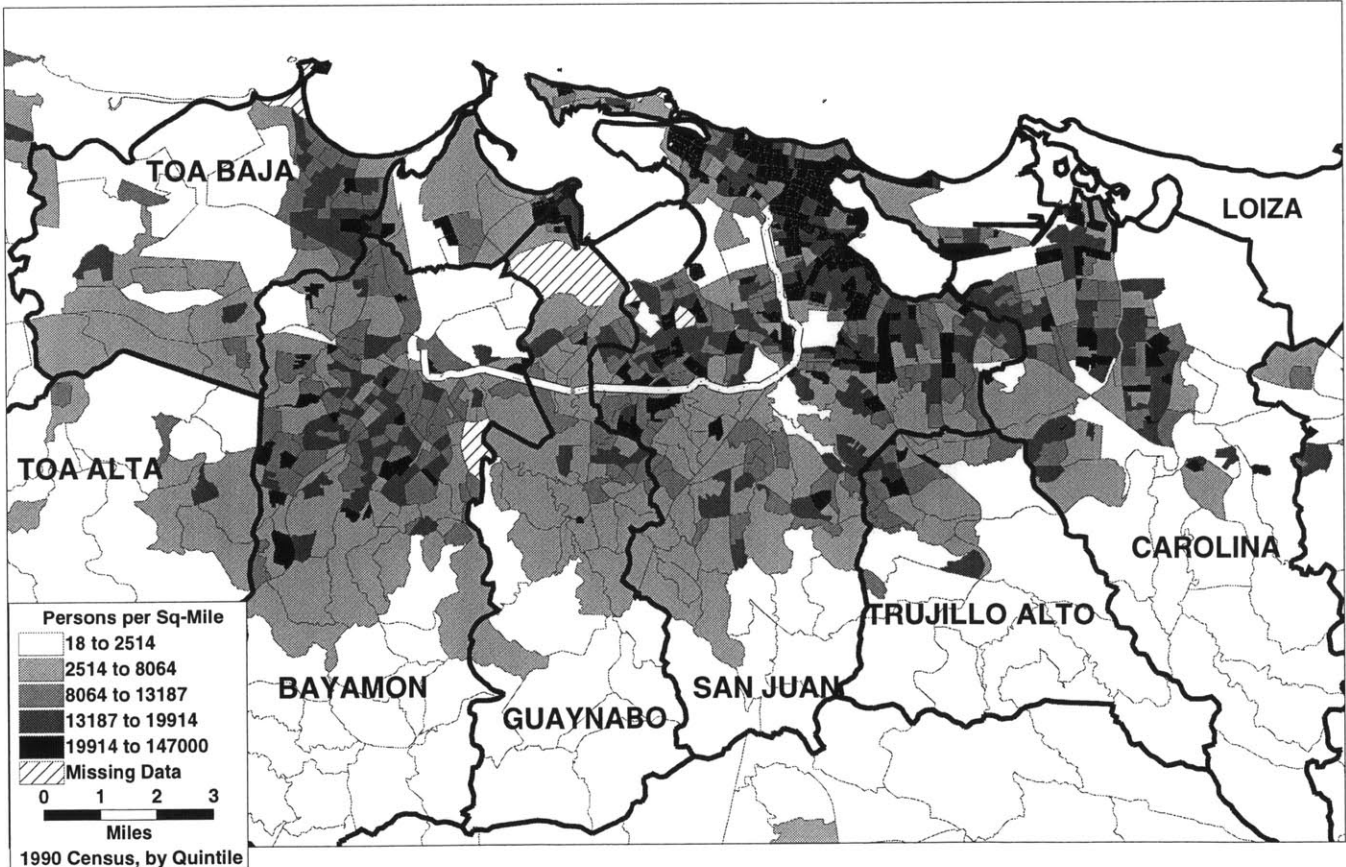
serving central areas, a northern leg serving Old San Juan, the International Airport and developed portions of Carolina, and a southern leg serving developing portions of central and southern Carolina.

Density and Development

San Juan's urban form exhibits strong characteristics of both South and North American cities, with recent development closely resembling the latter. In terms of the region's physical constraints – the Atlantic to the north and mountainous terrain to the south – San Juan resembles many South American cities whose development is spatially restricted and often irregular. In terms of density and character of land use, however, San Juan more closely resembles North American cities, whose development tends to spread over large areas. By far the region's most densely settled areas are in eastern Santurce, where 71,000 people reside in a contiguous 2.2 square-mile area. Twenty-one block groups in this area exceed 35,000 persons per square mile. Though other portions of metropolitan San Juan sporadically approach similar density, the vast majority of urbanized areas accommodate between 5,000 and 12,000 persons per square mile, and many are less densely populated. In comparison to mainland U.S. development, San Juan is far less densely populated than most major cities of the Northeast or Midwest, including Boston, but denser than typical cities of the South or West.[37] Most notably, densities in San Juan's suburban areas are higher than those of most U.S. suburbs – being comparable to development in metropolitan Los Angeles or Miami.

Nonetheless, recent, land-consuming development seems to be following a pattern increasingly similar to mainland U.S. suburbs, complete with gated communities, large tracts of single-family homes, big box retailers, and super-arterials for auto traffic. If present trends continue, the

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[37] Previous literature on *Tren Urbano* has reported misleadingly that San Juan is denser than New York City (Pellot, 1995). If one divides the metropolitan regions' total land area by their respective populations, this statement is accurate. However, New York and other regions encompass vast regions of undeveloped, rural lands, while San Juan does not. Using this measurement of density, for example, makes Miami denser than Chicago. Clearly, such counts are not reliable. If one looks strictly at developed areas, San Juan is less dense than any city of the Northeast. The highest densities of these mainland cities far exceed those of San Juan, and over larger areas, even in comparison to the *barrios* of Santurce. The distinction is important to realize so as not to be disillusioned about *Tren Urbano*'s urban context, or the rail line's true potential.

remainder of San Juan's "developable" areas will fill with single-use, low density, suburban development, most likely of a character similar to developed portions of the region.

Economy

Puerto Rico has one of the most diverse economies in the Caribbean region. Encouraged by tax incentives (Section 936) and duty free access, U.S. firms have invested heavily in Puerto Rico since the 1950's. It is estimated that Section 936 firms supply 10% of the island's employment directly, and another 20% indirectly. As a result of these incentives and low wages on the island, manufacturing long has surpassed agriculture as the primary sector of economic activity. In 1993, manufacturing accounted for 55.5% of the island's Gross Domestic Product, mostly in pharmaceuticals, textiles and electronics, while agriculture accounted for only 1.0%.[38] In terms of GDP, the Puerto Rico government reported the island's fastest growing industries as construction (5% annually) and the already sizable manufacturing sector (15%).[39] Importantly, entry-level jobs tend to concentrate in manufacturing, trade and service industries.

While a large portion of manufacturing jobs in Puerto Rico may require some skill and experience, the industry as a whole supplies many low-skilled positions and its fast growth on the island implies many job openings for low-income workers. Of all industries, Trade provides the highest proportion of entry-level positions – at restaurants, furniture stores, family-owned businesses, supermarkets, shopping plazas and the like. As expected, Trade concentrates predominantly in the island's urban centers, particularly in the San Juan region, where tourism and entertainment are prominent. Though the San Juan metropolitan area supports only 32% of the island's population, it accounts for 44% of Puerto Rico's total wholesale and retail trade employment; over half this figure comes from the San Juan municipality itself.[40]

More detailed examination of employment in San Juan will include the mix, growth and movement of blue-collar jobs in the region, identifying to what extent decentralization may have

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[38] As recently as 1950, agriculture accounted for 37.7% of Puerto Rico's non-public administration employment (Rivera-Batiz and Santiago, 1996). By 1996, this figure has dropped incredibly to 0.1% (County Business Patterns: Puerto Rico, 1996).
[39] Rivera, 1995-1999. "Welcome to Puerto Rico!" http://Welcome.toPuertoRico.org/

been occurring and characterizing the most recent shifts in employment. The reader may refer to Chapter 4 for results of that analysis.

3.2.2. Boston

The Boston region is much larger and geographically focused, encompassing a 3074.1 square-mile area and at least 110 municipalities. In 1997, the region had a total population of 4.0 million and employment of 1.96 million. Population concentrates in the region's ten central municipalities, as well as in outlying towns. Though these central municipalities cover only 3.0% of the region's land area, they account for 26.2% of its population (see Table 3.3, below).

Table 3.3. Area and 1990 Population of Portions of the Boston Region

Region	Area	Population
Central Boston[a]	92.4	1,037,628
Boston	48.4	574,283
Cambridge	6.4	95,802
Somerville	4.1	76,210
Medford	8.1	57,407
Brookline	6.8	54,718
Malden	5.1	53,884
Revere	5.9	42,786
Everett	3.4	35,701
Chelsea	2.2	28,710
Winthrop	2.0	18,127
Inner Suburbs[b]	279.3	1,383,864
Outer Suburbs	2802.4	1,541,889
METRO REGION	**3074.1**	**3,962,681**

Source: 1990 U.S. Census
a – These towns are the ten most central municipalities, that together compose "Central Boston".
b – "Inner Suburbs" include all towns inside the Route 128 beltway but outside the ten central municipalities.

Likewise, the inner suburbs of Boston – those remaining towns inside the Route 128 beltway – comprise another 35.0% of the region's population, while covering only 9.1% of its land (refer to Figure 3.3, next page). This area within the Route 128 beltway most compares to the San Juan region, in terms of both population and size. In terms of employment, however, Boston has a much greater density of and ratio of jobs to population in its central core (see Table 3.4).

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[40] U.S. Economic Census of Outlying Areas: Puerto Rico. 1992.

Figure 3.3 Boston Metropolitan Area
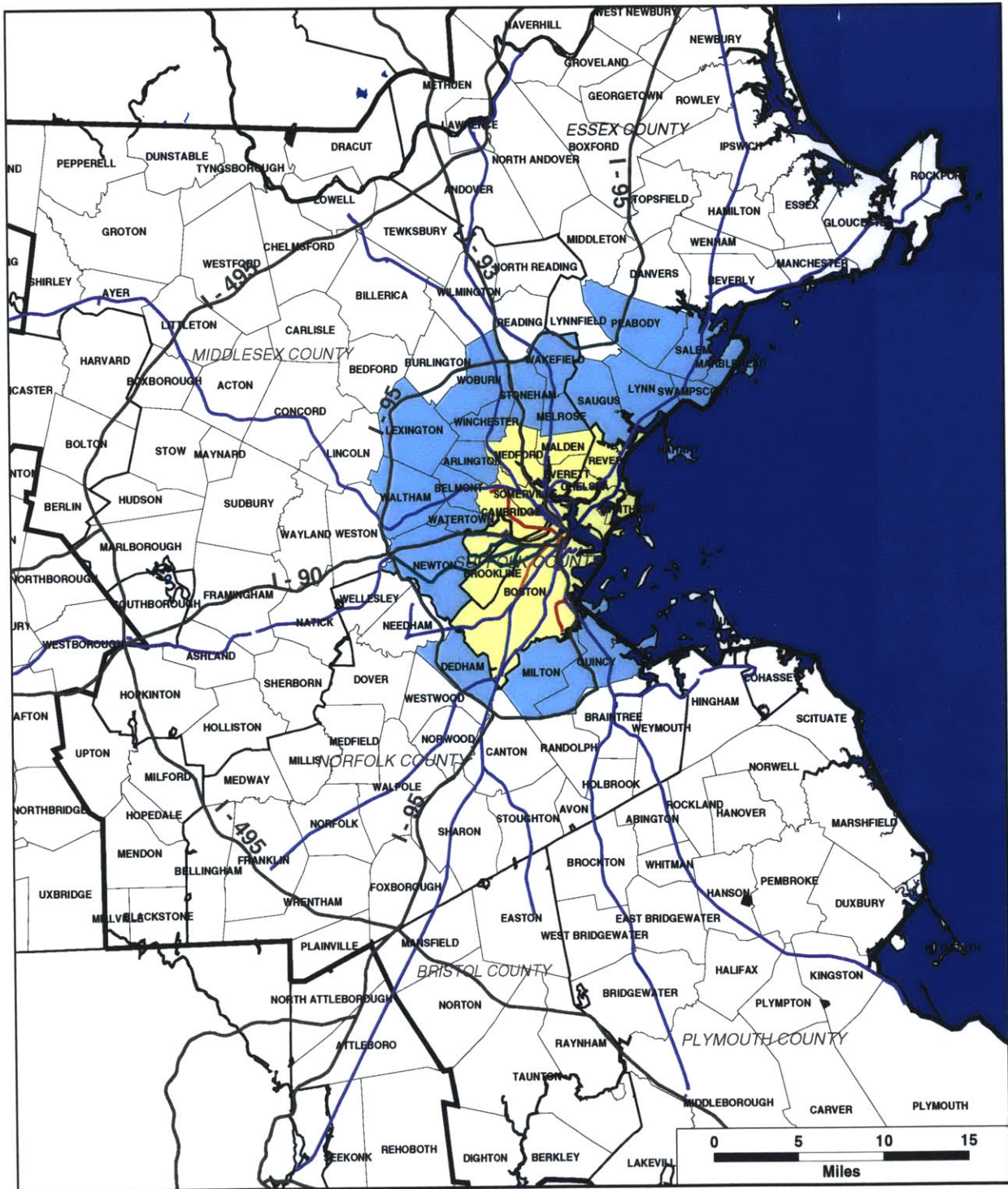
Legend:
- Central 10 Municipalities
- Inner Suburbs
- Outer Suburbs
- Boston MSA Boundary
- County Boundary
- Interstate Highway
- MBTA Rapid Rail
- MBTA Commuter Rail

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Table 3.4. Comparison of San Juan and Boston: Area, Population, Employment

	Boston Metro Area	Boston Inside Rt. 128	San Juan Metro Area	Boston Municipality	San Juan Municipality
Population[a]	3.96 million	2.41 million	1.16 million	574,000	443,000
Employment	1.96 million[b]	--	370,000[c]	520,000[b]	257,000[d]
Area (square miles)	3074.1	371.7	254.3	48.4	48.7

a – Source: 1990 U.S. Census
b – Source: 1997 County Business Patterns: Essex, Middlesex, Norfolk, Plymouth, Suffolk Counties
c – Source: http://www.census.gov/ftp/pub/population/estimates/puerto-rico/prest93.txt
d – Barton-Aschman, 1993

Economy

Metropolitan Boston has a strong, growing economy. A full 44.0% of its jobs are in its rapidly expanding service sector. Retail Trade follows a distant second with 17.4% of all jobs, while Manufacturing accounts for 14.6% of employment and Fire, Insurance and Real Estate another 9.2%. Of the largest sectors, both Services and Finance enjoy the strongest growth rates, while Wholesale Trade and Manufacturing show the weakest (see Table 3.5, below). Overall, the

Table 3.5. Employment in Metropolitan Boston, 1994 and 1996 (thousands)

	1994	1996	2-Year Difference	Annual % Change
Agriculture	6.7	7.1	0.9	6.9%
Mining	0.81	0.82	0.01	0.8%
Construction	52.7	61.1	8.4	7.7%
Manufacturing	280.4	285.3	4.9	0.9%
Transportation	89.8	99.7	9.9	5.4%
Wholesale	121.6	120.6	-0.9	-0.4%
Retail	329.6	341.4	11.9	1.8%
F, I, RE	170.8	181.0	10.2	2.9%
Services	812.6	861.6	49.0	3.0%
TOTAL	**1,865.2**	**1,959.3**	**94.0**	**2.5%**

Source: 1994 and 1996 County Business Patterns: Essex, Middlesex, Norfolk, Plymouth, Suffolk Counties – a close approximation of the Boston metropolitan area.

economy is shifting toward consumer-oriented and high-tech industries, even within the slow-growth manufacturing sector. Chapter 4 will examine in detail the spatial distribution of employment and blue-collar job growth within the region, highlighting geographic shifts in the economy that aggregated regional data do not encompass or communicate.

3.3. Analytical Frame\work

The heart of any methodology rests in the design of its analytical process. This research approaches each form of questions raised by the first two chapters (theoretical, methodological and practical) in a distinct analytical framework. The "theoretical" framework closely resembles the phenomena and interrelationships posited by the spatial mismatch hypothesis, and as such, tests a modern version the theory directly and as a whole.[41] Meanwhile, the study addresses its practical questions by evaluating the effects of *Tren Urbano* upon job accessibility in San Juan and examining alternative transportation services and land use policies.[42] Finally, methodological questions are addressed both as the study proceeds and as part of the conclusions. Figure 3.4, on the next page, shows the general analytical framework for the research, in context of its presentation in this thesis. Chapter 4 presents results of the analysis performed within a "theoretical" framework (discussed below), while Chapter 5 addresses the practical questions related to improving low-income workers' job accessibility in San Juan. Methodological questions are addressed as the research proceeds in parts of Chapters 4, 5 and 6.

3.3.1. Framework for Theoretical Analysis

Chapter 4 systematically tests the spatial mismatch hypothesis, matching empirical evidence to each component of the theory's purported phenomena and set of relationships. Different from previous literature, this research (1) tests all facets of the theory, instead of only one component or a single independent variable related to the hypothesis' implications, and (2) tests the hypothesis as it applies to the larger set of all low-income families, instead of among a single ethnic, racial or age group. In addition, the research performs these tests in the context of the very latest data available for metropolitan Boston and San Juan, thereby evaluating the theory's relevance to modern-day social, spatial and economic reality. The analytical framework for this examination, shown in Figure 3.5 (two pages forward), closely resembles modern interpretations of Kain's original hypothesis (1968).

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[41] This "modern" version reflects a more recent interpretation of Kain's original spatial mismatch hypothesis, that is further modified for the purpose of this research. Details are contained within this chapter.

Figure 3.4. General Analytical Framework

Chapter 4

Theoretical Test (1)
Evaluation of Modern Interpretation of the
Spatial Mismatch Hypothesis: Boston

Methodological Evaluation
Accessibility Models' Applicability to
Transit Planning

Theoretical Test (2)
Evaluation of Tren Urbano's Effects Upon
Job Accessibility in San Juan

Chapter 5

Policy Analysis
Transportation and Land Use Policies
for San Juan

Chapter 6

Conclusions
Theoretical
Methodological
Practical
Future Directions

Three notable differences distinguish this framework from the one originally posited by Kain. First, as mentioned, the research examines low-income, instead of specifically minority, households. Second, and more subtly, the study focuses on race, not race-*ism*, per se. Kain (1968) asserted explicitly that racial discrimination had segregated minorities to inner cities, where in turn they experienced lower job accessibility, in part because of a decentralizing economy. By comparison, the research herein focuses on the effects of any race-related variable upon the spatial isolation of low-income families more generally. Such variables might include: (1) housing discrimination and exclusionary zoning, (2) preference among minorities to reside separately, or (3) remnants of historical patterns of settlement. While the literature strongly

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[42] Originally, the author had intended to employ transit network simulation as a means for estimating job accessibility. The innovative method proved impractical given existing desktop computer tools. Part of Chapter 6 discusses the method's possible, future applicability to transit planning.

Figure 3.5. Analytical Framework for Test of the Spatial Mismatch Hypothesis

```
┌─────────────────────────┐   ┌─────────────────────────┐
│ Race Strongly Affects    │   │ Decentralization of      │
│ Socio-economic           │   │ Blue-Collar Employment   │
│ Residential Patterns     │   │ Opportunities            │
└───────────┬─────────────┘   └───────────┬─────────────┘
            │                             │
            ▼                             ▼
┌─────────────────────────┐   ┌─────────────────────────┐
│ Geographic Isolation of  │   │ Inner-city Locations     │
│ Low-income Families      │   │ Experience Inherently    │
│                          │   │ Poor Job Accessibility   │
└───────────┬─────────────┘   └───────────┬─────────────┘
            └──────────────┬──────────────┘
                           ▼
            ┌─────────────────────────┐
            │ Low-income Families      │
            │ Experience Much Lower    │
            │ Job Accessibility        │
            └─────────────────────────┘
```
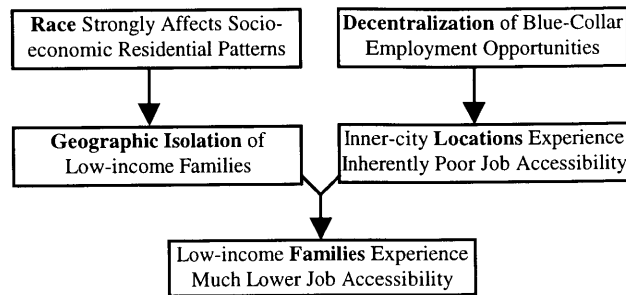
suggests that to this day racial discrimination remains most prominent of these variables (see Massey and Denton, 1992, and Yinger, 1997, for thorough reviews), the research here tests only the effects of any such race-related factors. Finally, the research incorporates a more modern view of Kain's hypothesis, namely that job decentralization and industrial restructuring actually have caused inner-city areas to experience inherently poorer physical job accessibility than suburban areas (e.g., Farley, 1987; Kasarda, 1995; Rogers, 1997).

In context of the theoretical framework, the research first measures the degree to which low-income households are spatially separated from other households in each metro area. For Boston, the research further evaluates empirically the effect of race upon the region's residential pattern of low-income households. Measures for each of these variables are described later.

Second, the research examines whether blue-collar jobs are decentralized and if so, to what extent they continue to move to suburban areas. Using longitudinal County Business pattern data for Puerto Rico and Massachusetts, the study observes and compares the geographic distribution of blue-collar job growth (or decline) throughout the San Juan and Boston regions, from 1990 to 1996, the year for which the most recent data are currently available.

Closely following the analytical framework above, the study then tests the hypothesis that central portions of metropolitan areas experience inherently lower levels of job accessibility by transit. For this part, the study employs a Hanson-type "gravity" accessibility model and inputs both transit travel times and job opportunity estimates to evaluate regional job accessibility in each

region. The application of this model tests whether particular locations of each metro area experience inherently poorer or better job accessibility.

Given those findings, the research then tests the interrelationships of poverty concentration, employment decentralization and job accessibility, by employing a Weibull-type "supply-demand" accessibility model. This model, unlike the traditional gravity model, additionally accounts for both the limited capacity of job opportunities and workers' competition for them, accounting for workers' accessibility to the limited supply of employment. Differences in outputs from the two accessibility models therefore indicate the relative contribution of poverty concentration upon job accessibility (see discussion in Section 3.5.1, Accessibility Indicators).

In addition, the research comments on geographic variations in the availability of subsidized childcare services. Together, the tests above evaluate a popular, modern interpretation of the spatial mismatch hypothesis, within a framework that closely mirrors its purported set of phenomena and relationships. The framework provides a robust test of both the theory and its implications for low-income families in Boston and San Juan. In reflecting upon results from this analysis, the study draws many important theoretical conclusions. In addition, it evaluates the applicability of each accessibility model to the planning of transit services and evaluation of land use policies.

3.3.2. Framework for Policy Analysis in San Juan

To this point, the examination of spatial mismatch in both regions will have provided much information about the distribution of job accessibility within each city and the related effects of *Tren Urbano* in San Juan's regional context. Analysis will proceed to focusing specifically on alternative transportation services and land use policies for San Juan. The study evaluates them by their relative effectiveness in improving physical job accessibility for San Juan's low-income, transit-dependent households. In doing so, the research analyzes the region's distribution of jobs and services, examines existing and planned *público*, AMA and *Tren Urbano* services, and draws upon results from the theoretical analysis. Transit and land use alternatives include:

- serving those recipients presently isolated from all transit services;

- preserving key AMA and *público* services (though not necessarily identical routes);

- implementing more effective AMA service between low-income workers and jobs;

- extending *Tren Urbano* to the airport, southern Carolina or Old San Juan;

- providing PM *público* services comparable to levels provided in the AM; and

- relocating recipients' to locations of better job accessibility.

The study ranks each alternative in terms of its effectiveness and practicality.

3.4. Tools

Since the study requires intensive computation and geographic analysis, it uses geographic information systems, or GIS, as a primary tool. GIS is a computer-based mapping and geographic analysis tool that "layers" geographic features into a single display, from which the program may perform spatial analysis among the strata. This research uses GIS to present thematic maps of demographic phenomena; perform elaborate statistical calculations; process spatial data such as transportation networks or geographic overlays; and visualize complex spatial phenomena, such as accessibility. Importantly, GIS is the primary tool of executing the sensitivity analysis described above.

The research uses TransCAD as the primary GIS tool, because of the program's capability to perform rigorous analysis of large transportation networks, and supplements the work using ArcView. Other tools also are essential for manipulating data and handling large databases – in particular, MS-Excel and a C compiler.

3.5. Measures

Integral to this analysis are measurements of job accessibility, employment growth, and the spatial separation of income groups. Measures should gauge each clearly and convincingly. The following section discusses measures of important accessibility and demographic indicators.

3.5.1. Accessibility Indicators

The study employs three general forms of accessibility indicators: those that measure access to transit services themselves (termed "access"); those that measure the ability of transit to provide access to job locations (physical job accessibility); and those that measure workers' resulting employment potential (competitive job accessibility). If one were to translate these concepts into questions expressed by low-income workers, they would read respectively as follows:

- "Do I have access to transit?"
- "How well does transit allow me to access the locations of entry-level jobs?"
- "How well does transit allow me to compete for entry-level employment, accounting for other workers' job accessibility by transit?"

Access Measures

For Boston and San Juan, identical measures compare the locations and concentrations of recipients and employers and measure their relative access to transit. The research maps the geographic boundary of transit-accessible land and identifies isolated recipient populations and inaccessible employers.[43] The general access measures follow.

Table 3.6. Indictors and Measures of Transit Access

Indicator	Measures
Access of recipients and employers to transit services	• Percent of recipients and employers that do (or do not) have access to transit services – including AMA, *públicos*, *Tren Urbano*, MBTA buses, MBTA light rail, MBTA rapid rail or MBTA commuter rail. Access is defined as being located within ½-mile of a bus line, or rapid, light or commuter rail stop. • Itemized (by mode) and cumulative counts in each region
Concentrations of employers and recipients that are inaccessible by transit; concentrations of recipient households isolated from transit	Number of recipient households and job opportunities per square mile that are outside the envelope of "transit accessible" areas (defined above)

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[43] Displays of these maps are not included in the thesis but were used to help examine each metro area and calculate some of the measures discussed here.

Job Accessibility Measures

Next, the study measures the *quality* of available transit in making jobs accessible, by employing traditional models that use travel times as primary inputs. Chapter 2 introduced these models in their general forms. The following presents an example of each model's output and evaluates their relative usefulness in this research.

Of accessibility models' two main components – attractiveness and resistance – the latter part contains the spatial "impedance" function that characterizes the schedule of costs a traveler perceives as a function of his or her traveled distance. In this study, distance is measured temporally, to best reflect travelers' actual experience. Thus, costs are in terms of travel time. Also, the impedance function as a whole should have behavioral foundations. This study uses the impedance function calibrated by the trip distribution model of the San Juan Regional Transportation Plan (Barton-Aschman & Associates, 1993), which also used travel time as an input for estimating commuters' demand for travel. Finally, in terms of the models' "attractiveness" component, this study uses an estimate of the number of entry-level jobs in each destination zone.

Overall, according to Morris, et al (1979), the measure should be tractable and technically feasible, and for simplicity, it should make use of existing data. In addition, it should be easy to interpret. These characteristics are particularly important in terms of the concept's usefulness among policy-makers. If accessibility is to be incorporated within the benefit analyses of traditional planning processes, policy-makers should be able to understand its meaning, and engineers should have an easy, fluent grasp of its operational applicability. The measure also should (1) provide accuracy with the given data, (2) measure the distribution of benefits, and (3) compare effects across scenarios (Walker, 1997). Example outputs of applicable, conventional accessibility models follow:[44]

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[44] The reader may refer to Chapter 2, Literature Review, for a discussion of each model's significant behavioral attributes.

Table 3.7. Forms and Sample Outputs of Alternative Accessibility Models

Model	General Form	Sample Output
Isochrone	$A_i = \sum\limits_{j,\ Cij < C^*} Oppor_j$	94 jobs lie within 10 minutes. 160 jobs lie within 15 minutes.
Gravity	$A_i = \sum\limits_{j} Oppor_j \times f(Costs_{ij})$	Score for Zone A is 650, or 30% above average. Score for Zone B is 374, or 25.2% below average.
Utility	$A_i = ln\ \sum\limits_{j} e^{\ U\,j}$	Alternative Z produces a net benefit of $560 per workday for Zone A.
Supply-Demand	$A_i = \sum\limits_{i}\left[\dfrac{Oppor_j \times f(Costs_{ij})}{\sum\limits_{j} Demand_j}\right],$ $Demand_j = W_k \times f(Costs_{kj})$	(Average weighted score equals region's total number of jobs divided by its total number of workers. If the amounts are equal, for example, the weighted average equals 1.00.) Job accessibility for Zone A is 1.43. Job accessibility for Zone B is 0.91.

Ai = Accessibility of location i, or accessibility of individual at location i.
Uj = Utility of reaching location j
Oppor$_j$ = Opportunities (jobs) at location j.
f(**Costs$_{ij}$**) = Perceived cost (impedance) of travel from each location i to locations j (from each worker to job opportunities).
f(**Costs$_{kj}$**) = Perceived cost (impedance) of travel from each location j to locations k (from each job opportunity to workers)
Demand$_j$ = Demand of workers for jobs at location j
Wk = Workers at location k

Each type of model has special properties. Isochrone models simply count the number of opportunities within a given travel or geographic radius. The results, then, are strictly in these terms. Gravity models, named for their relation to Netwon's discovery of physical attraction among objects, weight closer opportunities more than those farther away. The function by which distance relates to relative weight is called the "impedance" – a representation of the psychological and physical hindrance one perceives while traveling. Impedance functions sometimes are calibrated empirically from travel surveys or traffic counts as part of the travel demand modeling process, but more often are discretionary. A gravity model in this context sums accessibility to job opportunities in all destination zones, for each zone of origin. Quite differently, utility models sum the net value a hypothetical trip, usually in context of a Logit or other binary-decision model that relates the calculated net utility to the probability of making a trip or taking a particular mode. Finally, supply-demand functions act as multi-dimensioned gravity models. Not only do they weigh closer opportunities more heavily; they also account for all other competitors' accessibility to that same opportunity. For each unique origin-destination pair, the denominator of a supply-demand model represents the *aggregate job accessibility of all*

workers in the whole metro area to the destination zone, while the numerator represents the estimated *job accessibility of any worker within the zone of origin to the destination zone*. The quotient therefore equals the share of regional job accessibility that belongs to any individual worker in the zone of origin. For each origin, the supply-demand model simply sums this proportion for all possible destination zones.

The models' distinct characteristics deserve particular attention when choosing one for application. The table below shows, *in context of this research*, the value and applicability of each type of accessibility measure, in terms of specific attributes and as a whole. For each attribute, models' performances are rated "excellent," "good," "fair," "poor," "very poor" or "impractical."

Table 3.8. Applicability of Various Accessibility Models to the Context of This Research

Attribute	Isochrone	Gravity	Utility	Supply-Demand
Interpretability	Good	Fair	Good	Good
Tractability	Excellent	Good	Very Poor	Poor
Meaningfulness	Very Poor	Fair	Excellent	Excellent
Compares Effects Across Scenarios	Poor	Fair	Excellent	Excellent
Measures Geographic Distribution of Benefits	Poor	Good	Excellent	Excellent
Compatibility With Available Data	Excellent	Excellent	Impractical	Excellent
Presentability in a Format That Provides Accuracy	Very Poor	Excellent	Fair	Excellent
OVERALL	**Poor**	**Good**	**Poor**	**Excellent**

Isochrone models provide excellent ease of use and policy-maker friendliness; however, they have no behavioral foundations and fare poorly in terms of accurately presenting voluminous results. Their results are difficult to display graphically and take on an inherently qualitative nature that makes comparison across scenarios difficult. Also, any delineation of categories (e.g., 15-minute range, 20-minute range) tends toward arbitrariness. The Hanson-type gravity model presents no major technical or theoretical weaknesses, and this attribute sets it apart from the others. Its largest weakness is the interpretability of its output. A "score of 824" does not hold much meaning for a policy-maker or layperson. However, comparison of scores for many zones, across a metropolitan region, may provide very good interpretability and presentation. Utility models have the inherent strength of rigor and thoroughness, based on their root in micro-

economic theory. However, because of their high sensitivity to inputs that oftentimes are uncertain, they are very difficult to compute. Importantly, the types of thorough data that they require simply are not available for San Juan. Finally, supply-demand models provide comparably excellent quality because of their strong relationship to macro-economic theory and their interpretability. Uniquely, they account for the non-uniform distribution of demand for jobs and acknowledge that opportunities have limited capacity (Shen, 1998a). Consequentially, they provide strong reliability when comparing among scenarios or geographic areas; their results also are easy to present. The model's most significant drawback is its complexity, which makes its computation potentially difficult to manage.

In the context of this research, the supply-demand and Hanson-type gravity models, together, are most useful and methodologically appropriate for application. Operationally, use of both is convenient since the Hanson gravity form serves as the supply-demand model's numerator. More importantly, use of both models is methodologically robust. While both account for supply of jobs and spatial impedance, only the supply-demand model recognizes spatially-constrained competition among workers for limited opportunities. Thus, one may interpret the difference between their results as an excellent measure of poverty concentration effects. The supply-demand model offers one other particular methodological advantage: its expected value, expressed as the weighted average of the workers' scores, always equals the ratio of total jobs to total workers – 1.00 when the numbers are equal (see proof in Shen, 1998a). If, for example, the weighted average is 0.97, then at least 3.0% of workers are unemployed.[45] *It is therefore appropriate to interpret a zone's score's proportional difference from the expected value as the relative* "accessibility potential" *of typical workers within that zone.* This property makes differentiating "accessibility rich" from "accessibility poor" locations quite easy. Coupling the gravity and supply-demand models, the research captures the particular interaction of transportation and labor economics, on a sociological issue rich with important policy implications for transit and land use.

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[45] This fact is true only of the aggregate, since all zones are part of a single closed system. One could not make the same interpretation for a single zone, since workers may travel to and from other zones.

Specification of the impedance function is adopted from the San Juan Regional Transportation Plan (Barton-Aschman, 1993), which, for the purpose of predicting trip distributions (i.e., travel demand), calibrated its gravity model using survey data from the region:

$$f(C_{ij}) = \alpha \times C_{ij}^{\beta} \times e^{\gamma \times C_{ij}}$$

In this specification, C_{ij} is the cost of travel from zone i to zone j, measured in minutes of perceived travel, e is the natural logarithm base, and α, β and γ are coefficients, such that for home-based work trips:

$\alpha = 4,106,986$;

$\beta = -1.3924$; and

$\gamma = -0.0132$.

One may eliminate α from the function when applying it to an analysis of accessibility, since job accessibility is a relative concept. Eliminating the coefficient thus does not affect the results but shortens computation.

The impedance function specified here for San Juan has a strong, empirically based, behavioral foundation that substantiates its meaningfulness and ultimately supports the reliability of results that it produces. Barton-Aschman calibrated this function based on empirical data from 1993 travel surveys of metro San Juan residents. The decreasing function characterizes the likeliness for San Juan residents to travel various travel times by any mode. While one conceivably could apply a number of other decreasing functions to characterize local travel behavior, this function most accurately does so, because of its behavioral basis in observed travel patterns.

In addition to accounting for transit travel times, the study also recognizes the ability of transit-dependent workers to commute by foot. The research uses in its models the smaller of perceived travel times by transit or walking. Thus, if for a particular pair of zones travel time by foot is shorter than by transit, the model uses walking time as its estimate of travel time between the locations. The model accounts for this property only among *neighboring* zones, to reflect roughly for travelers' unwillingness to walk very long distances, even when walking times may be shorter than by transit. While this estimate obviously is rough, it nevertheless better accounts

for transit-dependent workers' real travel options. Otherwise, in some cases, neighboring zones might be quite inaccessible either because of transit's circuitous network or from lack of any service at all to one or both of the zones.

For Boston, no recent published study has generated an impedance function or travel time values comparable to those estimated for San Juan. In the absence of a calibrated model specific to Boston, this research applies the same specifications as for San Juan. It is likely that, if an impedance function for Boston were calibrated, it would be somewhat more constraining than a comparable one for San Juan – reflecting San Juan residents' behavior of traveling longer times, on average, and their subsequently lower value of time. While applying the impedance function from San Juan certainly affects the *magnitudes* of resulting scores for Boston, it should not forfeit any capturing of the dominant relative variations that ultimately determine relative job accessibility. An accessibility rich zone remains so, and vice versa, such that one may base conclusions on the results. If any systematic variation in job accessibility exist in Boston, it will show up. While the results' precision is lower than it would be using a function specific to Boston, its accuracy remains consistent and meaningful. Using the same model for both regions affords at least one important benefit – a more experimentally controlled comparison of the two metro areas.

Finally, for executing the supply-demand model, one needs to define the set of workers with whom welfare recipients compete for jobs. These workers' accessibility composes the model's "demand" side. The author defines this set as all those persons between 18 and 64 years of age whose incomes fall below the poverty level, as defined by the 1990 U.S. Census.[46] Welfare recipients comprise a *subset* of this population. To discern the accessibility of welfare recipients, the research, *after computing scores for all zones using the full set of low-income workers*, observes the distribution of recipient households and calculates their relative accessibility level. This average score then is compared to the score calculated for the larger set of all low-income workers.

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[46] These counts are compiled by smaller age ranges by the U.S. Census Bureau.

The specification of accessibility measures herein has provided a strong foundation for meaningful and robust analysis.

3.5.2. Demographic Measures

Examination of demographic characteristics allows for evaluation of *Tren Urbano*'s social distribution of benefits, as well as for identification of neighborhoods of particular transportation need. In addition, particular demographic measures gauge specific phenomena of the modified spatial mismatch hypothesis studied by this research. This section focuses upon the measures.

This research uses demographic measures to gauge social and economic phenomena quantitatively. To address the issues of poverty concentration, the study classifies block groups, census tracts and households by quartile according to average household income. In this sense, annual income is a measure of economic wealth, strictly speaking; it does not attempt nor claim to measure the quality of any neighborhood. The quartile classification controls for major differences in income levels between the two regions, thereby allowing for meaningful comparison between them. However, the technique does not control for all differences that, if unaccounted for, might otherwise skew the results. For example, the meaning of a "quartile" itself may differ between regions, depending on the relative levels of income disparity and the propensity for households of each quartile to reside in tracts of the same classification. The research addresses these issues quantitatively as well in Chapter 4, ultimately supporting the measures' validity and methodological strength. Next, the study measures important socio-spatial phenomena, such as the relative isolation of economically poor neighborhoods and the contribution of race to geographically separating income groups. Then, the study measures purely economic phenomena, such as the relative growth or decline of blue-collar employment in the central city and suburban areas. Chapter 4 discusses the measures in greater depth before applying them to its study of the spatial mismatch hypothesis. Finally, the study examines the geographic distribution of entry-level jobs, low-income workers, and welfare recipients, as well as the employment capacity of zones to accommodate additional low-income workers. These measures are shown in Table 3.9 (next page).

Table 3.9. Demographic Indicators and Measures

Indicator	Measures
Capacity of a zone to support additional low-income workers	• Intensity of entry-level job surplus or deficit, by census tract (jobs minus workers, divided by area). Negative values therefore represent a greater number of low-income workers than entry-level jobs.
Relative concentrations of recipients, low-income workers and entry-level job opportunities	• Number of recipient households per square mile • Number of jobs supported by entry-level employers, per square mile • Point locations of employer locations
Availability of subsidized child care (Boston only)	• Length of subsidized child care waiting list divided by capacity, by municipality

3.6. Data

Clearly, the study requires much social, economic and spatial data. Also, to examine geographic relationships and present information visually, the study requires geographic line and zonal data, such as block groups, street networks and transit networks. The following table lists the data sets and sources this research draws upon.

Table 3.10. Data Sets and Sources

Item	Data Set	Source
Base Demographic Information	• San Juan: 1990 U.S. Census Public Use Samples • Boston: same as for San Juan	• Multisystems, Inc., of Cambridge, MA; also, U.S. Census Bureau • Caliper Corporation, of Newton, MA; also, U.S. Census Bureau
Base Geographic Information	• San Juan: base geographic data, such as streets, highways and block group boundaries • Boston: same as for San Juan	• Multisystems, Inc.; also, U.S. Census Bureau's 1992 and 1995 TIGER/Line Files • Caliper Corporation
Transit Systems	• San Juan: AMA, *público* and *Tren Urbano* geographic data • San Juan: systems' operational data • San Juan: regional origin-destination travel times by transit • Boston: MBTA bus, rapid rail and commuter rail geographic data • Boston: regional origin-destination travel times by transit	• Multisystems, Inc. • Barton-Aschman, 1993; Multisystems, Inc. • Barton-Aschman & Associates • MBTA Planning Department • Central Transportation Planning Staff (CTPS), Boston, MA

Continued on next page…

Welfare Recipients	• San Juan: 1998 point locations of recipient households • Boston: same as for San Juan	• San Juan Socio-economic Development Department • Massachusetts Department of Transitional Assistance
Employment	• San Juan: 1998 addresses of businesses in selected industries rich in entry-level jobs • San Juan: 2010 projections of basic, retail, service and government employment, by TAZ • San Juan: employment by county and industry from 1990 and 1996 • Boston: 1998 log/lat. locations of businesses in the entire region • Boston: Job estimates per employer; also, employment by industry and county from 1988 to 1996	• Dun & Bradstreet Corporation • Multisystems, Inc. • County Business Patterns: PR, published annually by the U.S. Census Bureau • Select Phone Deluxe, by Pro-CD, Inc. • County Business Patterns: MA, published annually by the U.S. Census Bureau
Child Care Availability	• Boston: Spring and Fall 1997 subsidized child care capacities and waiting list lengths, by municipality	• 1998 study by John Lippett of Brandeis University's Heller Graduate School[47]

Data on welfare recipients and employment opportunities required significant preparation. The following reviews the *particularly relevant* aspects of this process.

3.6.1. Welfare Recipient Data

The information's highly sensitive nature about families supported by public assistance, and the relative inexperience of welfare agencies with the data peculiarities of GIS, together made data collection difficult. For Boston, the state's Transitional Assistance agency provided highly tractable latitude/longitude data of recipient residence locations, but only for the metropolitan region's most central portions – specifically, a 65.7 square-mile area covering Boston, Brookline, Cambridge and Somerville. By contrast, for San Juan, the island's Department of Socioeconomic Development enthusiastically provided data for the entire 762.1 square-mile metro area, though in a mailing address format that ultimately proved intractable. The following reviews the preparation of recipient data for each region.

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[47] Mr. Lippett compiled and synthesized the data, while the author in turn performed further calculations so as to relate it most meaningfully to the research herein. One may reach Mr. Lippett by e-mail at lippet@brandeis.edu or by phone at (781) 736-3843.

Boston

Though voluminous, the data available for Boston were sufficient for a full study only of the region's central portions. While a very large portion of Boston-area recipients live in these central cities, a significant number live in the inner suburbs or in dense outlying towns, such as Brockton, Lawrence or Lowell. A more comprehensive data set was desirable for completing the larger job accessibility context and providing a more ample base of information from which to draw conclusions.

To accomplish this objective, the author created a simple model relating 1990 public assistance households, available from the 1990 U.S. Census, to the 1998 density of recipient families within census tracts of the central four cities, for which complete data were available. Then, applying this model to the larger metropolitan region the author estimated densities of recipient households throughout the full study area. The author's best model is below.

$$1998\_RECIPIENTS = -7.9013 + 0.2885 * (HH\_W\_PUBLIC) \qquad R^2 = 0.70$$

t-stats: (−3.02) (20.57) n = 225

1998_RECIPIENTS = 1998 households receiving transitional assistance support in each block group
HH_W_PUBLIC = 1990 households receiving public assistance in each block group (U.S. Census)

This model explains a credible 70% of the variation in 1998_RECIPIENTS. Also, its coefficients hold very strong statistical significance. The remaining variation likely arises from differences in tract population. When one controls for sizes of the census tracts (the model above does not), by dividing both variables by population and then running the regression, the model's standard error is only 0.009 from the actual values of "1998_RECIPIENTS / POPULATION".[48] Only a single tract's estimation varied by more than 3.3 from the "actual" as reported by the Massachusetts Department of Labor. However, while this "second best" model accurately predicted *proportions* of the population who were welfare dependent, it less precisely estimated actual magnitudes. For this reason, the author chose the model displayed in full above for application. The author additionally set to zero any predicted value of 1998_RECIPIENTS

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[48] R^2 for the model was 0.50: $(1998\_RECIPIENTS / POPULATION) = 0.001 + 0.209 * (HH\_W\_PUBLIC / POPULATION)$
t-stats: (1.00) (14.96)

that was negative. These steps allowed for meaningful study of the entire metropolitan area. As expected, poorer outlying towns produced sizeable showings of recipient populations, while other suburbs showed few or sometimes no recipients. Results are displayed in Chapter 4.

San Juan

For San Juan, the island's Department of the Family enthusiastically provided information listing 21,357 address locations of recipient households, but delivered it in a form quite difficult to manage or interpret. Locations were listed as mailing addresses – a format that would require the GIS program to search and match to an inadequate database of Puerto Rico streets. Moreover, the addresses were in no standardized database; rather, they were listed as one might write or read them, each one in a unique format. Converting the data to a set of meaningful column fields (i.e., one column each for city, street address, zip code, etc.), that would allow for mapping with GIS, proved impossible in any reasonable time frame

As a remedy, the author devised a method to parse the zip code from each record, which in turn allowed for 100% precise counts of recipients *by zip code*. These counts were related finally to block groups by assuming a proportional relationship between households living below the poverty level and those receiving public assistance in each block group – a reasonable assumption, given the evidence from Boston.[49]

3.6.2. Employer and Employment Data

Job accessibility may be defined in one of several ways. For instance, the idea may focus on job openings – that is, empty positions created by either turnover or job growth. In this sense, job growth could occur either by expansion of existing businesses or via the establishment of new ones. Alternatively, the idea of job accessibility may focus on the total availability of employment versus full supply of workers to fill the positions. For purposes of this study, job accessibility is studied as the latter concept.

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[49] More descriptive U.S. Census data, such as were used for Boston, were not available for San Juan.

The research approaches job accessibility in the context of existing labor and job markets, trying to balance employers' need for workers with the supply of recipients and others desiring employment. In this sense, both jobs and low-income workers are limited and valuable commodities – each to the other. An accessibility model in this sense requires a "snapshot" of the relative supply and distribution of workers and job opportunities among existing employers. The data requirements therefore comprise information about the availability of entry-level positions among all existing employers at a given point in time.[50] The study weights the quality of employer locations by each one's number of available jobs, and uses travel time as the primary measure of location difference. A more complicated model might also include wage rate, hours of labor or scheduled start time to measure quality (or utility); likewise, one could use out-of-pocket costs as a measure of "distance" (or disutility). For simplicity this study models only the most significant part of employment opportunity: the existence of jobs and the travel time required to reach them. Thus, it examines, other factors being equal, the net effect of transportation services upon job accessibility.

Because of differences in the availability of data describing employer locations in San Juan and Boston, collection methods varied for the two metropolises.

Boston

The method of estimating entry-level jobs in Boston involved three steps: identification of industries particularly rich in entry-level employment; comprehensive point mapping of individual employers; and estimation of positions at each individual establishment.

To identify industries particularly rich in entry-level jobs, the author used 1998 wage and employer information from the Massachusetts Division of Labor and Training,[51] coupled with general literature on the subject (e.g., Holzer, 1995; also see references from Chapter 2). A full list of these "entry-level-rich" industries is included in the appendix of this report.

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[50] A more comprehensive study would include employment projections as well, to capture opportunities created by the establishment of new business locations. Such data were not available for this study.
[51] http://www.detma.org/lmi.htm

Employer locations and types were compiled from a national phonebook on CD-ROM, made available through Pro-CD's Select Phone Deluxe package. Data for every business in the Boston Metropolitan Area were collected, including each establishment's name, longitude/latitude location and 4-digit Standard Industry Classification (SIC) code. Then, the author used a C program and MS-Excel to thoroughly "clean" the data set of duplicate entries and incomplete records. These steps allowed for precise mapping of employer locations for the entire metropolitan area.

Next, the author obtained data describing the average number of jobs at each establishment from the U.S. Census Bureau's 1996 County Business Patterns report for Massachusetts. The Bureau delineates establishments both by 4-digit SIC code and by county, thereby providing refined information about variations in employment by both geographic location and minor industry type. From this point the author estimated jobs for each employer individually, based on its primary SIC. The author tested the sensitivity of three distinct methods upon final accessibility results. The first weighted each and every employer equally. The second estimated employment strictly by assigning jobs based on the average employment level of each employer's location and 3-digit industry.[52] A third method compared aggregated counts of the second technique to published data and accounted for any geographic or industry-related imprecision by appropriately scaling the estimates independently for each of the Boston region's 50 county/major industry groups.[53] This step was taken to insure against any geographic or industry-related bias in the estimation; however, the adjustments were relatively small in nearly all cases, indicating that the second method produced a relatively robust estimation.[54] Sensitivity analysis of the three methods upon accessibility outcomes showed remarkably similar results. The first method, which weighted employers equally, displayed some relative bias toward suburban areas, where establishments are smaller on average, while the second and third methods produced nearly identical results – attributable to their very similar estimates. The last method was chosen as being best, because of its strongest relationship to empirical census counts

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[52] There are approximately 1,000 such industries over five counties – totaling to about 5,000 distinct 3-digit industry groups.
[53] There are ten major industry groups and five counties.
[54] It is important to note that major institutions and very large companies normally show up as several distinct employers in the data set, reflecting their internal organizational partitions. Thus, the methods used here do account well for the unusually large employers.

of employment. This method was used for calculating the job accessibility results displayed in this report.

San Juan

No such comprehensive and precise employer database included data for Puerto Rico; thus, the author had to look elsewhere. For San Juan, the author enlisted Dun & Bradstreet's professional service to create a database of employers in industries richest in entry-level employment. This database included each establishment's name, mailing address, 4-digit SIC code and other information. Of the original records, 47.0% of them were P.O. Box addresses with no geographic location. For the remainder, the GIS program matched business addresses to its geographic database of San Juan streets. This method normally locates 60-75% of addresses. However, since: (1) the address database included unconventional abbreviations, or characters not found in the English language, (2) the GIS database of San Juan street names was less than comprehensive, particularly for rural roads or short streets, and (3) many addresses in San Juan have two or more possible locations because of duplication (e.g., there are four streets named "Calle 3"), the GIS program could locate only 27.6% of the records on its own. From this point, the author referenced a detailed map of the metropolitan area (Metrodata, 1997), to manually pin-map another 23.5% records, bringing the total match rate to over one half. The match rate seemed to be unbiased among industries. However, there existed significant geographical tendency toward central portions of the region, where streets more often had name labels in the GIS database.

To ameliorate the inadequate database, the author chose to use somewhat less precise, but far more accurate, traffic analysis zone (TAZ) employment data from Multisystems, Inc.[55] The database listed counts of basic, service, retail and government employment. Of this set, the author used counts of serve and retail jobs as the best proxy for entry-level employment.

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[55] The 760 TAZs studied in metropolitan San Juan range in size from 0.1 to 1.0 square miles in urbanized areas, which comprised the vast majority of zones, up to about 5.5 square miles in some rural areas.

3.7. Summary

The methods, techniques and tools introduced in this chapter are used to address the primary questions of this research. This chapter introduced the two case study areas and their basic demographic, geographic and economic features. In addition it formally developed measures and specified models that are used to characterize low-income families' accessibility to employment in the two cities, as well as to *Tren Urbano* and other transit services. The chapter also developed measures for examining the research's theoretical hypotheses, particularly in regard to the modified spatial mismatch hypothesis tested herein. Finally, it presented important information about the sources and preparation of data sets used for the research. Evidence from this chapter also will be used also to form conclusions about the readiness of GIS software and available data for meeting the needs of transportation planners and policy-makers who could benefit from more quantifiable methods for measuring the benefits of major transit investment or minor service adjustment. Using the methodology, techniques and data preparation described in this chapter, the research has a strong basis from which to produce meaningful and significant results. ∎

Chapter 4

Evaluation of Spatial Mismatch

Previous chapters have established the motivation, theoretical foundations, objectives and methodology for this research. This section empirically examines the potency of spatial mismatch in affecting job accessibility. It directly and systematically addresses each component of the modified spatial mismatch hypothesis framework, as presented in Figure 5 of Chapter 3, evaluating the existence of its purported phenomena in the context of modern-day urban economics. In this context, this chapter examines the interrelationships of poverty concentration, employment decentralization and job accessibility in the Boston and San Juan metropolitan regions. In addition, for Boston this chapter briefly explores possible land use policy and transportation services for helping low-income families reach entry-level jobs. Elements that separate this analysis from previous literature include its evaluation of all facets of the mismatch hypothesis, its specific examination of welfare recipients, and its focus upon the effects of poverty concentration on job accessibility. Chapter 5 later builds upon results found here to test the efficacy of specific public policies and services upon the job accessibility of low-income households in San Juan.

4.1. Overview

This chapter first examines the geography of poverty in each city, characterizing the geographic patterns and spatial dissimilarity of income classes in the respective regions. For Boston, the study further speculates, via quantitative measurement, about the role of race in separating classes. Second, the chapter uses longitudinal and geographic data to examine the purported decentralization of blue-collar employment in each region. Then it analyzes for each metro area the accessibility (by transit) of locations to entry-level jobs. This step's objective, again, is to evaluate one component of the modified spatial mismatch framework. Finally, this section

directly examines the accessibility of welfare recipients to employment, fully recognizing the competition among workers for limited opportunities by accounting for the "demand side" of job accessibility. The chapter's conclusions evaluate the validity and efficacy of spatial mismatch in affecting the job accessibility of low-income families in Boston and San Juan.

4.2. Geography of Poverty

Urban economics literature has focused often on the "ghettos" of inner-cities – separated physically from mainstream society and isolated socially, politically and economically from upward mobility. Many have hypothesized that race plays an important role in separating income classes; however much debate remains regarding its effects as compared to income in separating classes (see Massey and Denton, 1992).[1] Using new measures, this section quantifies both the separation of income classes in Boston and San Juan and the relative roles of race and income. In the context of the modified spatial mismatch framework, these ideas compose a significant aspect of the hypothesis's argument (see Figure 4.1, below), without which the theory's validity and consequence would be greatly diminished.

Figure 4.1. Class and Race Component of the Modern Spatial Mismatch Framework
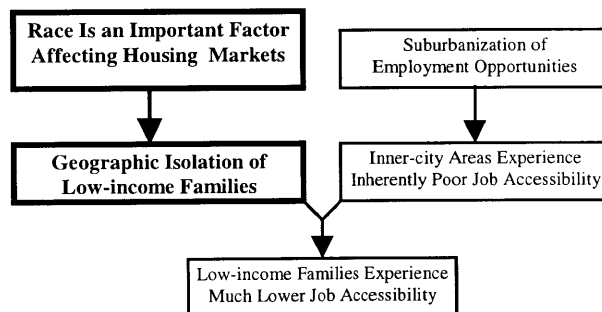
Note: Bold and enlarged components represent those examined in Section 4.2.

To provide fuller meaning to the measures and observations of this section only, the report includes results from a comparable examination of metropolitan Atlanta, Georgia, chosen for its location in a different region of the mainland United States.

4.2.1. Meaningfulness of the Income Quartile

Before examining and comparing income levels and the spatial segregation of income groups in San Juan and Boston, it is important to understand the relative meanings of income in each city. Chapter 3 discussed use of income quartiles for characterizing both households and census tracts. While the use of quartiles statistically controls for differences in income levels between Boston and San Juan, the classification still could be affected adversely by differences in regional income distributions or by differences in the income-group compositions of census tracts. This section accounts for the magnitude and direction of any possible bias in the measure.

Relative Meaning: Comparative Income Inequality

Important distinctions exist with regard to the distribution of median household incomes within the two regions.[2] Residents of metropolitan San Juan on average earn much less than Bostonians ($5,766 compared to $18,570 per capita),[3] though consumer prices and cost of living tend to be comparable. Meanwhile, some Puerto Ricans' incomes remain very high, as reflected in the degree of income inequality on the island. As a result, the distribution of incomes in San Juan "loads" toward the scale's lower end, while incomes span a much wider expanse in the higher ranges. Thus, income quartiles in San Juan distinguish less among "poor" and "lower-middle" classes than in Boston, but differentiate considerably more among "lower-middle", "upper-middle" and "wealthy" classes.

The degree of income inequality in Puerto Rico is striking. In 1989, the poorest 40 percent of all families earned only 7.5 percent of all family income – compared to 15 percent of earnings for the same group in the U.S. as a whole (Rivera-Batiz and Santiago, 1996). Mean per capita income in the island's wealthiest *municipo*,[4] Guaynabo, was 3.8 times higher than that of its

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[1] While Massey and Denton acknowledge in their thorough report that much debate remains, they express with no uncertainty that in their view, a "class-only" view has no foundation in a plethora of credible empirical evidence.
[2] While Puerto Ricans might view class or income differently from Bostonians, it is the purpose of the analysis to capture any relevant effect of such difference in the form of observed spatial dissimilarities among income classes. Thus, perceived differences in the meaning of "class" present no problem for the analysis herein.
[3] The figures here were calculated from 1990 U.S. Census data. According to this source, in 1989 dollars, Puerto Rican's per capita income was $4,099, compared to the U.S. average of $14,052.
[4] A *municipo* is equivalent to both a county and a municipality in Puerto Rico.

poorest, Adjuntas (1990 U.S. Census of Population and Housing). Similarly, within the San Juan metropolitan area, census tracts averaging among the top ten percent of per capita income out-earned the bottom ten percent by an extraordinary factor of 21.3 (see Table 4.1, below). In the Boston region this factor was only 10.4.

Table 4.1. Income Inequality in Boston and San Juan: Per Capita Income as a Factor of the Median

1990 Census Tracts	San Juan Region	Boston Region
Poorest	0.16	0.15
Poorest 10%	0.18	0.25
MEDIAN	**1.00**	**1.00**
Wealthiest 10%	3.84	2.60
Wealthiest	4.19	2.80

Note: The "MEDIAN" figure shown here is by person, for the metro region, while the other factors are by tract.

Mixing of Classes Within Census Tracts

Perhaps the best measure of the relative meaningfulness of income quartiles in each city is the propensity of each income group to live in a tract of its own classification. "Poor" tracts do not comprise only low-income families, after all. Note this research's choice to examine census tracts as opposed to block groups surely creates a more heterogeneous impression of class geography; however, the choice also allows for more meaningful interpretation of data describing regional trends in poverty concentration and vastness (see measurements in the following sections). Since the research focuses upon low-income families, the discussion here examines economically poor households as an example. Focusing upon a single group simplifies the test; also, mathematically one expects the measures for economically poor families to reflect complimentarily those for households of other income groups.

The table below shows evidence that economically poor families are somewhat more likely to live in poor neighborhoods in San Juan than they are in Boston, and comparatively less likely to live in lower-middle or upper-middle income areas. The trend highlights that within small areas of San Juan there exists relatively less diversity of income groups – indicating less mixing of classes within housing developments and small neighborhoods.[5] The data show that among

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[5] The trend cannot be attributable to a general difference between the mainland and Puerto Rico, though, since Atlanta, for example, displays even less mixing of incomes than San Juan.

"poor" tracts in Boston, slightly more than one-third of households earn the lowest one-fourth of incomes; in San Juan the figure is higher: 40 percent. The data highlight that, despite the study's relatively less robust division of poor and lower-middle income classes for San Juan, the *meaningfulness* of such division remains higher than even in Boston simply because the income levels of Puerto Rican households are more homogenous within small neighborhoods. Notably, for all cities in Table 4.2, the portions of poor, lower-middle, upper-middle and wealthy residents decline in respective order. A fairly consistent distribution among all three regions further indicates that the classification holds real meaning.

Table 4.2.   Probability That a Randomly Chosen Poor Household Lives in an Area of Each Income Quartile

	Atlanta	San Juan	Boston
Poor	0.41	0.40	0.34
Low-Middle	0.29	0.24	0.28
Up-Middle	0.15	0.20	0.22
Wealthy	0.16	0.16	0.16

Note that figures are rounded and may not add to 100%.

The figures point to a few important observations: (1) the definition of quartiles is indeed meaningful and therefore useful, (2) their meaning is stronger for San Juan than for Boston, even among the lowest income levels, since less mixing of classes exists within small neighborhoods of the former, and (3) one should remain generally conscious of the fact that the categorization of any tract does not imply that all residents within it fit the classification.[6]

4.2.2. Geographic Income Distribution in Boston and San Juan

Maps on the following page show the average annual per capita income of areas in San Juan and Boston. They group zones by income quartiles, as defined above. Notably, over large geographic areas income groups reside quite separately, though some interspersion is evident –

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[6] Thomas Sugrue (1993) suggests that such classifications of areas have augmented the misconception among Americans that the "underclass" is overwhelmingly black, thereby unwittingly burdening African-American families with an additional social and economic impediment. In fact, the great majority of "poor" households in this country are white in race, though the majority of residents in "underclass areas" are African-American (pg. 85-117). Ken Krukemeyer at MIT gives the practical example that simply identifying someone as "a Roxbury woman" stirs subtle yet powerful images of her character, race, family structure and social status.

Figure 4.2 Per Capita Incomes in the Boston Region

Boston, MA
Census Tract
Water Area
Interstate Highway
Income Per Capita
0 to 12929
12930 to 15909
15910 to 18069
18070 to 22139
22140 to 60000
0 1 2 3
Miles
1990 Census, by Quintile
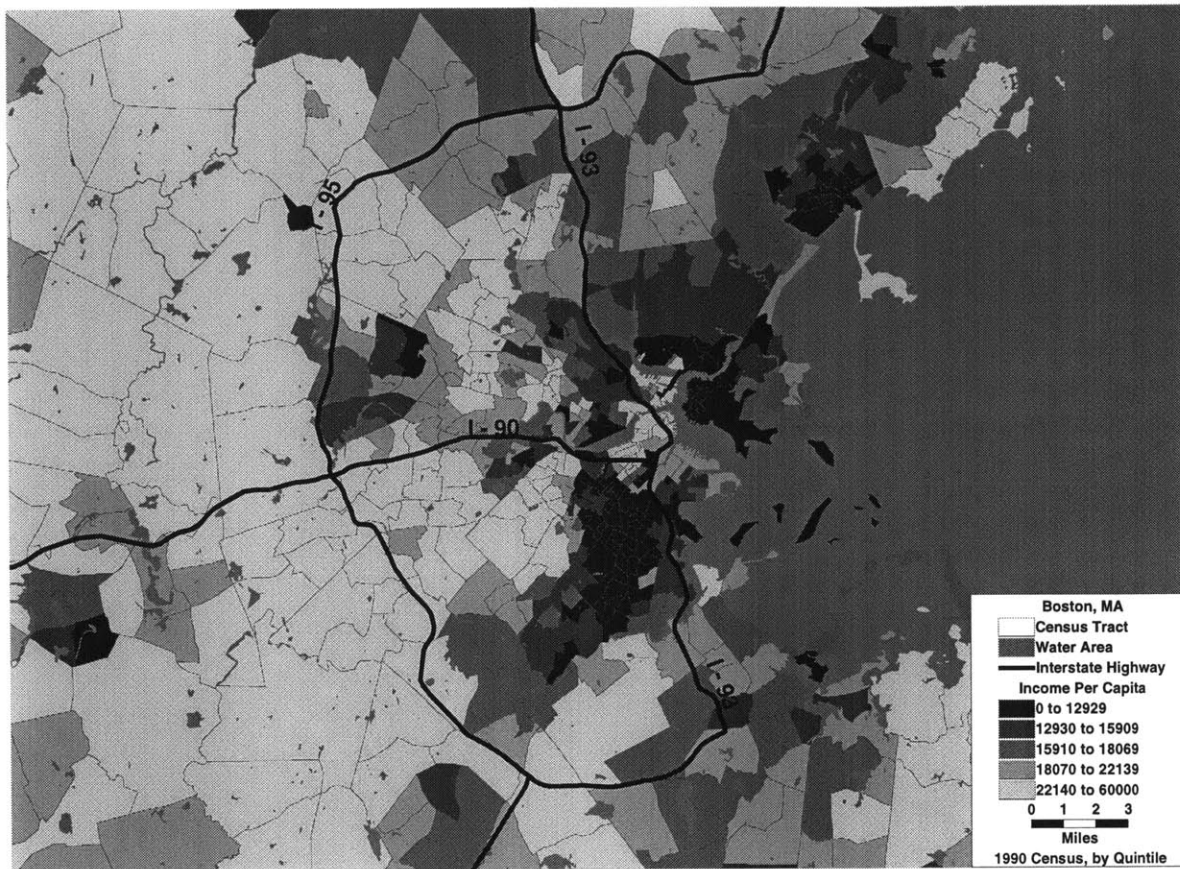
Figure 4.3 Per Capita Incomes in the San Juan Region

N

San Juan, PR
Block Groups
TU Phase 1 Alignment
Income Per Capita
768 to 2887
2888 to 3894
3895 to 5081
5082 to 6980
6981 to 52429
Missing Data
0 .90 1.8 2.7
Miles
1990 Census, by Quintile
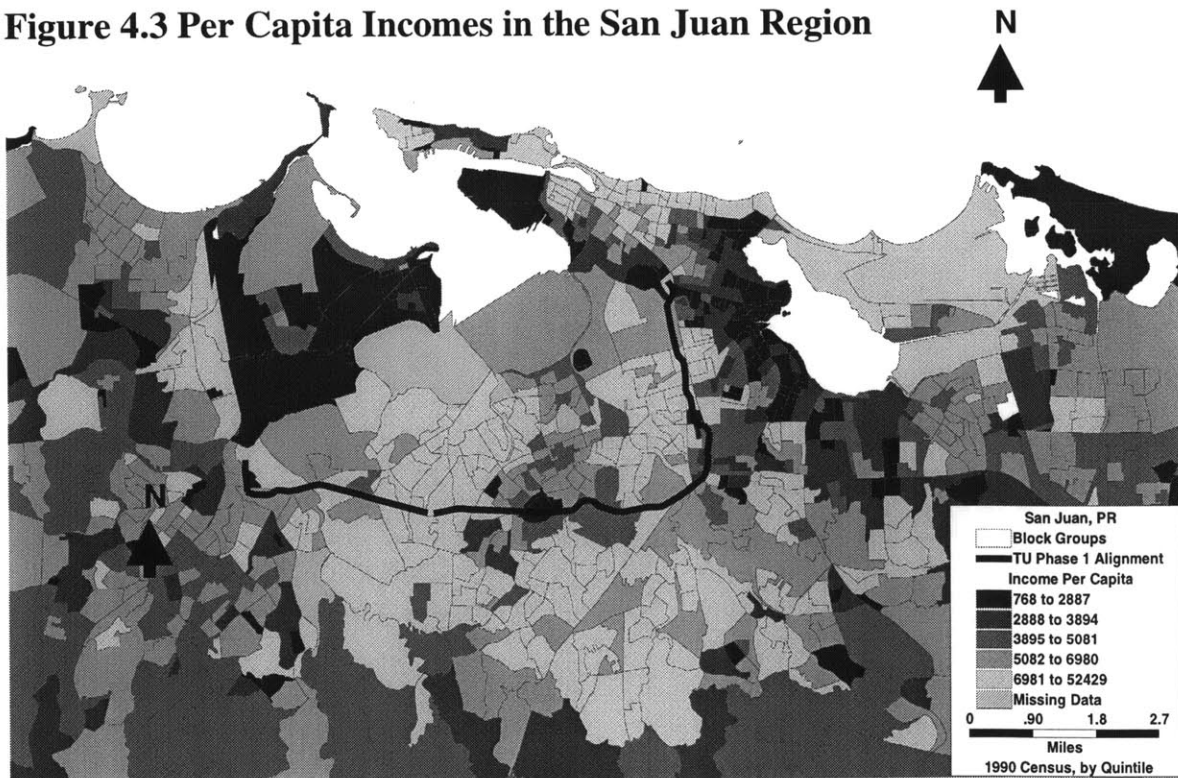
more so in San Juan. One may find a comparable map of Atlanta in the appendix.[7]

In Boston, large inner-city areas south of downtown and in close-in neighborhoods around the west and north support the largest populations of poor households (the poorest zones are shaded darkest). Pockets of low-income areas also concentrate in some outlying towns, such as in Lowell, Lawrence, Waltham and Brockton, as well as along sections of the North Shore. Most striking, vast areas of consistently wealthy tracts comprise a very large, contiguous section of the region's expansive western suburbs.

Examination of San Juan shows greater variation among income levels throughout urbanized portions of the metropolitan area, though again, classes remain quite separate.[8] The poorest households agglomerate in Cataño and Loiza, as well as in eastern portions of Santurce. Low-income areas continue south from there along Laguna San Juan, to the San José neighborhoods. Different from Boston, the Carolina and Bayamón suburbs both exhibit high levels of income heterogeneity. Meanwhile, municipal San Juan has large, contiguous territories of wealthy neighborhoods that ring the central core's south side, extending west into Guaynabo, the island's wealthiest and fastest growing *municipo*. If one were to expand the view, however, one would notice that the mountainous, agricultural areas that ring the urban areas comprise predominantly poor households, while the urbanized city and its somewhat dense suburbs support a wealthier population.

While visual examination of each metro area provides important, qualitative understanding of the general trends, a quantitative measurement of spatial dissimilarity, by census tract, more robustly would gauge the relative levels of spatial class separation.

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[7] Compared to Atlanta, Boston and San Juan both exhibit relatively *less* strict patterns of class separation. San Juan seems to exhibit the most interspersion among classes.

[8] Note that the San Juan map displays block groups, not the larger census tracts. The author chose to display block groups to show in finer detail the much smaller metro area, as well as to highlight with greater differentiation the character of local neighborhoods through which *Tren Urbano* will pass. Quantitative measures in the following section measure geographic dissimilarity in a more precise manner.

4.2.3. Geographic Dissimilarity of Income Classes

The relative vastness of poverty over large areas has been a central theme among urban economic literature (e.g., Kain, 1968; Wilson, 1987; Katz, 1993 and 1999), which has cited spatial isolation as a primary cause for urban decay. Therefore, a cogent measure of the phenomenon would be very desirable.

Vastness of Poverty Areas

Table 4.3, below, shows the most likely neighbors of economically poor census tracts in each city. For example, in San Juan, 52% of the tracts neighboring those classified as "poor" also are from the lowest income quartile. The results show that low-income tracts in San Juan are much more interspersed among upper-middle and wealthy tracts than similar tracts in Boston or Atlanta. Notably, a low-income tract in San Juan has *six times* the chance of neighboring a wealthy tract than does one in Boston (12% versus only 2% of neighbors are wealthy). Trends in Atlanta closely reflect those of Boston.

Table 4.3. Probability that a Poor Tract's Neighbor is of Each Income Class

	San Juan	Boston	Atlanta
Poor	0.52	0.63	0.68
Lower-middle	0.24	0.27	0.21
Upper-middle	0.12	0.09	0.06
Wealthy	0.12	0.02	0.05

Most significant about these results is the relative vastness and contiguous nature of Boston's poor areas. Two-thirds (67%) of poor tracts in Boston neighbor *only* other poor and lower-middle class areas – compared to only about one-third (35%) in San Juan (see Table 4.4, next page). Furthermore, the Boston region encompasses more than twice as many tracts – thereby placing high income tracts even farther away by this measure. Clearly, poverty neighborhoods in Boston are much more vast and geographically isolated. The very close similarity of Boston and Atlanta in this regard confirms that poor tracts in San Juan experience far less spatial isolation than those of typical mainland cities.

Table 4.4. Isolation of Poor Tracts: Probability that the Neighboring Tract Is Also of Low Income

	Neighbors 100% Quartiles 1 and 2	Neighbors 100% Quartile 1	Number of "Poor" Tracts
San Juan	0.35	0.19	88
Boston	0.67	0.28	182
Atlanta	0.68	0.28	573

In examining Table 4.4, one might question to what extent differences in the geography of block groups might affect the observations. One would expect that if census tracts have *more* neighbors on average, they would have a *greater* chance of neighboring tracts of other economic quartiles, and so bias the measure. Thus, San Juan's observed heterogeneity might be a simple product of the fact that its tracts have more neighbors on average. In light of this concern, Table 4.5, below, shows that low-income tracts in San Juan actually have fewer neighbors on average than those of either Boston or Atlanta. This observation highlights that the measurements of Table 4.4 (above) *underestimate* the magnitude of class heterogeneity in San Juan's regional geography. The results emphasize even more strongly that low-income households in San Juan experience far less spatial isolation than those in Boston.

Table 4.5. Number of Neighbors of Low-Income Tracts

	Average Number of Neighbors
San Juan	4.5
Boston	4.8
Atlanta	5.3

4.2.4. Role of Race in Separating Income Classes

One issue of central importance in the spatial mismatch hypothesis is the relative influences of race and class in spatially separating low-income families from the middle- and upper-classes. Sociologists and economists have postulated that race plays an important role in contributing to the creation of income enclaves (see Massey and Denton, 1992); however, some disagree, and the subject draws much debate. If race is *not* a factor, one should expect that economically poor whites, blacks and others would reside at similar rates in each of poor, lower-middle, upper-middle and wealthy tracts. Poor whites, for example, should experience the same propensity to

live in "poor" areas as do poor blacks. Likewise, both should live in wealthy areas at about the same rates. Conversely, if poor households of each race reside disproportionately among tracts of different income quartiles (e.g., if low-income American Indians exhibit much higher propensity to live in wealthy areas than do low-income whites), then one may conclude that race plays an important factor in spatially separating low-income households from others.

San Juan

While Census data on race are not available for San Juan (see Chapters 2 and 3 for details), the literature consistently reports that race "is considerably less important in Puerto Rico than in the United States." As a result, there seems to exist a "relatively insignificant relationship" between skin color and the most prominent social, economic and educational variables that determine class, residential location and well-being (Tumin and Feldman, 1961, pg. 245; also, see Rodríguez, 1989; Rivera-Batiz and Santiago, 1996; Burch and Martin, 1998).[9] Thus, one may assume that, while income classes remain geographically distinct in San Juan, skin color plays relatively little role in contributing to their spatial separation. Unfortunately, no data are available to confirm or deny the validity of this assumption. Therefore, conclusions that compare San Juan and Boston in this regard can be only tentative.

Boston (and Atlanta for Comparison)

In Boston, however, race seems to contribute very strongly to class separation. Table 4.6, on the next page, shows that poor black families have exactly *four times* the propensity of poor white families to live in "poor" tracts of the Boston metro area (0.68 versus 0.17). Blacks seem to be the only race to experience much misfortune. All other poor households exhibit low propensity to live in poor areas (between 0.16 and 0.22). In fact, poor households of all other races exhibit higher propensity to live in *wealthy* neighborhoods than they do poor ones! Poor black families, on the other hand, are *17 times* more likely to live in a poor area than in a wealthy one, and only 11 percent live outside of tracts defined as "poor" or "lower-middle" income class.

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[9] Refer to the literature review for a fuller account of the relative significance of skin color in Puerto Rico and the empirical evidence supporting this conclusion.

Table 4.6. **Propensity for Poor Households of Each Race to Live in Tracts of Each Income Quartile: Boston**

INCOME QUARTILE	Poor Black	Poor White	Poor Hispanic	Poor Asian/ Pacific Island.	Poor Amer. Indian	Poor "Other"
Poor	0.68	0.17	0.22	0.17	0.16	0.28
Lower-middle	0.21	0.35	0.24	0.26	0.41	0.20
Upper-middle	0.07	0.23	0.17	0.28	0.25	0.15
Wealthy	0.04	0.25	0.37	0.28	0.19	0.37
TOTAL	54,873	60,024	1,844	1,378	290	691

Note that Hispanics are not mutually exclusive from the other races shown in this table.

Atlanta also displays patterns of inequity, indicating a similarly significant role of race (see Table 4.7, below). In this Southern city, instead of poor blacks being uniquely disfavored (though, they do experience comparable misfortune as those in Boston), poor whites solely experience particularly better fortune. Data from Atlanta and Boston suggest that, in stark contrast to San Juan, race plays a very significant role in the Eastern United States in separating income classes. One may conclude that differences in perceptions of race between San Juan and the mainland strongly influence the observed variation in isolated poverty concentration among these cities. Clearly, some aspect of race *is the key factor* contributing to Boston's vast areas of highly concentrated poverty.[10]

Table 4.7. **Propensity for Poor Households of Each Race to Live in Tracts of Each Income Quartile: Atlanta**

INCOME QUARTILE	Poor Black	Poor White	Poor Hispanic	Poor Asian/PI	Poor Amer. Indian	Poor "Other"
Poor	0.76	0.27	0.76	0.54	0.52	0.82
Lower-middle	0.10	0.31	0.13	0.16	0.25	0.10
Upper-middle	0.07	0.25	0.06	0.14	0.13	0.05
Wealthy	0.07	0.18	0.04	0.16	0.10	0.03
TOTAL	23,144	215,783	19,075	7,280	803	10,363

Notes: same as Table 4.6.

4.2.5. Summary

Factors related to racial inequity greatly augment the level of concentrated poverty in Boston and contribute strongly to creating relatively vast, isolated territories of low-income neighborhoods

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[10] From a plethora of audit studies, conducted through the present day, the literature cogently indicates that the important aspect in question is the subtle yet pervasive racial discrimination in housing markets, which to this day continues to strongly affect minorities' residential choice.

that one does not find so much in San Juan. Low-income families in Boston thus are highly concentrated into inner-city areas. In comparison, San Juan's poor areas remain many times more likely to neighbor upper-middle and wealthy neighborhoods. Observations about the relative effects of race and income seem to confirm that differences in perceptions about race explain much of the contrast in levels of poverty concentration among the two cities.

To this point, the results support important components of the modified spatial mismatch hypothesis in the Boston context and suggests that, if the theory holds merit, San Juan may experience a lesser degree of physical separation between low-income families and entry-level jobs. The following sections systematically examine remaining components of the theory while presenting valuable demographic and economic information about both Boston and San Juan.

4.3. Spatial and Temporal Examination of Blue-Collar Employment

A second important tenet of the spatial mismatch hypothesis is that blue-collar employment has been decentralizing from central cities, thereby severely affecting central city areas. As a result, scholars say, low-income workers who remain in inner cities experience much lower job accessibility or propensity to be employed. Figure 4.4 (next page) highlights the employment decentralization component of the modified spatial mismatch hypothesis framework. Ultimately, this section investigates the transportation implications of current employment trends for low-income families in each city.

Recent reports confirm that, contrary to the popular notion that U.S. urban areas are now experiencing an "Urban Renaissance",[11] American cities continue to suburbanize at very fast rates. According to results to be published by the Brookings Institute, in nearly every major metropolitan area, suburban counties systematically continue to gain jobs and population faster than central cities (Katz, 1999). Between 1990 and 1997, the District of Columbia lost 50% of its regional share of employment, such that its *outer* suburbs now support more than twice as

Figure 4.4. Suburbanization Component of the Modern Spatial Mismatch Framework
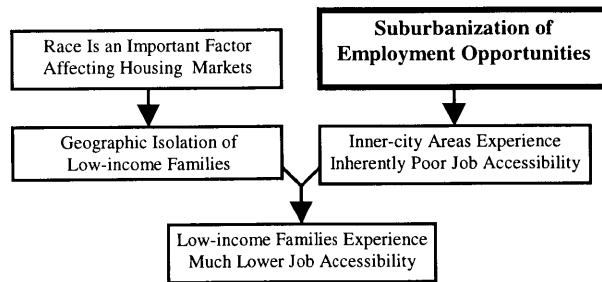
Note: Bold and enlarged component is the one examined in Section 4.3.

many working positions as Washington. Similar trends prevail elsewhere: Atlanta lost 40% of its regional employment share between 1980 and 1996; likewise, Ohio's suburbs have accounted for 90.5% of the state's total job growth since 1994. Population growth in central cities continues invariably to lag behind suburban neighbors. Are similar trends occurring in San Juan or Boston, and if so, to what extent? Might trends in one city highlight lessons for the other, and how do the phenomena in each region support or refute elements of the spatial mismatch hypothesis?

Using County Business Pattern data from 1990 to 1996, the section compares Boston and San Juan, highlighting important aspects of the labor markets in each city and providing a basis for later conclusions about the regions' transportation needs. To evaluate trends specific to low-income families, the section examines separately those industries most likely to have entry-level jobs. These industries are defined as: agriculture, manufacturing, retail, wholesale trade, and services – minus several large, key sub-sectors, such as chemical production, engineering services, management consulting, electrical repair and others. The reader may find in the appendix a full list of the industries defined in this category.

4.3.1. San Juan

San Juan's recent economy has been robust, to say the least. Between 1990 and 1996 the metro area's labor market grew by 39,900 jobs, or 13.3%, while the population grew only by about

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[11] This characterization may indeed be accurate in some respects, but not in terms of employment or population – two indicators of urban vitality.

6.3%.[12] Industries richest in entry-level jobs kept pace, growing by 13.8% over the six years. Economic expansion concentrated in the service industry, continuing trends of previous decades, while manufacturing employment grew least quickly.[13]

Growth was uneven geographically, however. Differences in trends among *municipos* were striking.[14] Figure 4.5, below, shows employment growth rates and job additions by municipality. Employment in San Juan's suburbs grew extraordinarily fast, while the central city's regional share of jobs decreased substantially. In these six years, Guaynabo more than doubled its employment, accounting for 36.5% of the entire region's job growth. Much of this growth may

Figure 4.5. Employment Growth in Metro San Juan, 1990 to 1996
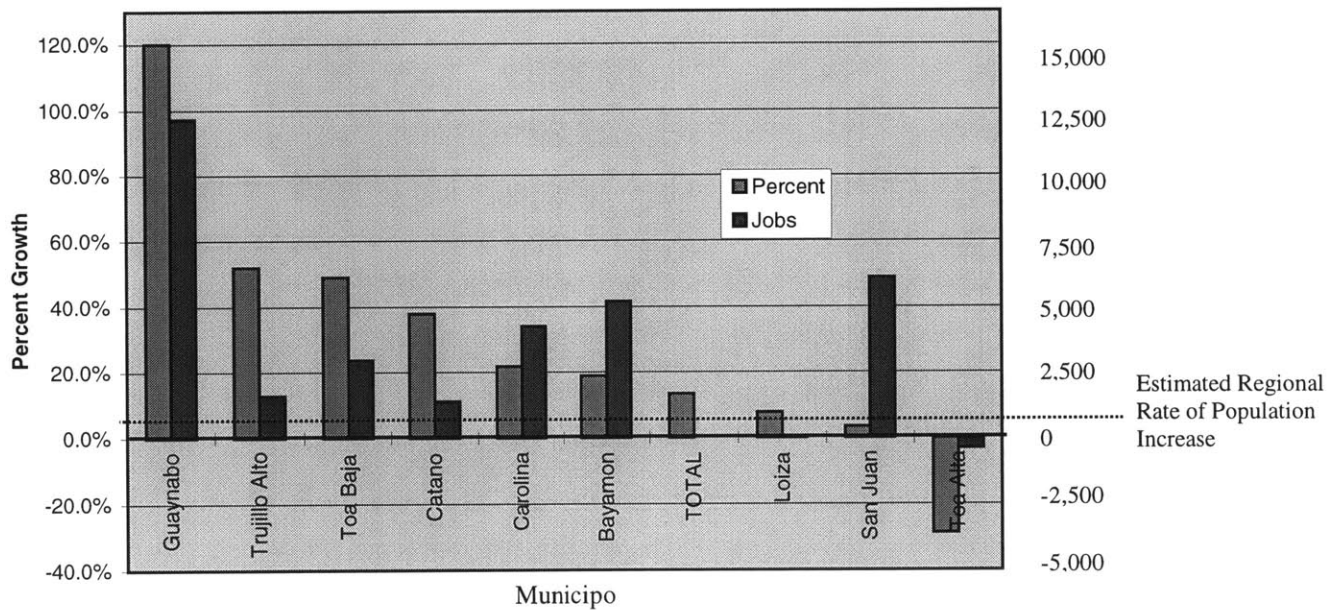
have been related directly to *Tren Urbano*: construction jobs increased by 535.3%, accounting for about one-third of the municipality's net employment gain. Nevertheless, Guaynabo posted the most significant job growth, even without the construction increase, and across the board the largest suburban municipalities all experienced very strong and rapid expansion. In fact, in all

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[12] This estimate of population change is based on an extrapolation of regional growth trends earlier in the decade.

[13] Statistically, some of this "growth" is attributable to the U.S. Census's reassignment of some jobs from the "unclassified" category to other economic sectors. Nearly 12% of the region's jobs were reclassified in this manner, giving some artificial boost to the services sector, as well as to others. The distribution of this boost among industries is unclear. However, it is very clear that services expanded most quickly between 1990 and 1996, while manufacturing lulled.

[14] In Puerto Rico, municipalities and counties are equivalent and called "municipos".

but one municipality, job growth far exceeded both the pace of regional population gain and the rate of employment growth in municipal San Juan. During this six-year period, San Juan's portion of total metropolitan employment diminished by 7.2 percentage points (from 71.2% to 64.0%), while its share of jobs in entry-level-rich industries shrank even more quickly, by 7.9 points (from 62.8% to 54.9%). As suburban municipalities gain a stronger hold on the region's employment, they will deplete job growth from the central city even more aggressively.

Table 4.8, below, shows how the San Juan municipality also fared differently by industry as compared to the rest of the region. In every economic sector except Finance/Insurance/Real Estate, the region's eight suburban municipalities far exceeded the growth rate in municipal San Juan. In some cases – namely construction, manufacturing and wholesale trade – employment in central San Juan shrank while expanding at an extraordinary pace in the suburbs. These shifts represent clear cases in which employment is relocating systematically from the central city to the surrounding counties. Entry-level-rich industries followed suit, growing by nearly 20,500 jobs in suburban municipalities while shrinking by 419 in municipal San Juan.

Table 4.8. San Juan Intra-Regional Employment Change (percent): 1990 to 1996[a]

	San Juan	All Other Municipos
Construction	-7.7%	181.1%
Manufacturing	-28.3	28.3
Transp./Pub.Utilities	22.5	116.7
Wholesale Trade	-15.5	77.4
Retail Trade	10.1	23.4
FIRE[b]	11.3	3.6
Services	43.4	89.9
Unclassified[c]	-93.3	-90.1
"Entry-level" Industries[b]	**-0.5**	**37.9**
All Industries	**3.4**	**37.9**

a – Mining and agriculture were not included in this table because together they employ only 788 workers regionally; thus, very small shifts in these industries could yield growth figures that would be misleading.
b – "FIRE" indicates Fire, Insurance and Real Estate; "Entry-level" Industries indicate those sectors particular *rich* in entry-level jobs.
c – The similar, unbiased change throughout the region in "Unclassified" establishments shows that the striking figures of this table are not simply a product of the Census Bureau's classification of some employers.

Not only is the proportion of jobs in entry-level-rich industries dispersing rapidly; the central city economy also is becoming increasingly focused on jobs suitable for white-collar professionals. In municipal San Juan during the six-year period, accounting and bookkeeping increased by

61.2%; medical doctors by 39.1%; home health care services by 44.7%; business services by 49.2%; computer and data processing services by 172.2%; and real estate brokers by 262.7%. These gains occurred while employment across all industries in the *municipo* expanded by only 3.4% during the same period. These results are important to keep in mind in the context of the areas that *Tren Urbano* will serve – mainly those along the region's central spine, precisely where employment is shifting most rapidly from entry-level to white-collar positions.

Clearly, metropolitan San Juan today presents the prototypical model of rapid, post-war suburbanization. Entry-level jobs are leaving the city while in the suburbs they increase at an extraordinary rate. Meanwhile, the central city's employment is shifting rapidly toward white-collar positions. If demographic patterns in San Juan reflect those of most American cities, then low-skilled workers living in the central core are facing increasingly long commutes that transit likely does not serve well. The role of affordable transportation is becoming increasingly vital in insuring low-income families' access to jobs.

4.3.2. Boston

In contrast to San Juan's steady economic expansion, Boston's economy this decade has experienced several fluctuations. After peaking in 1988, it bottomed out in 1992. From 1992 to 1994 it then recovered gradually. Since that time it has been expanding very rapidly. Because of such fluctuation, and the economic instability that accompanies it, results from examination of Boston would differ depending on the pair of years chosen to study. Thus, this section examines the Boston regional economy across the decade, in two-year intervals beginning before 1990, and pays special attention to the period after 1994, when the region's growth rate most closely resembles that of metro San Juan.

As the economy dipped and returned between 1988 and 1996, the region netted very little change in total jobs. However, shifts between industries were enormous. Construction and manufacturing employment declined by 30.8% and 24.6%, losing 27,300 and 92,900 jobs respectively. Meanwhile, the leading service sector expanded by 24.3%, adding 168,000 positions; no other sector added more than just 10,300 jobs (see Table 4.9, below). Because of

the decline in goods production, manufacturing for the first time fell to the third ranking employment sector. These shifts reflect long-term, nation-wide trends that have had momentum since de-industrialization began mid-century.

Table 4.9. Boston Regional Employment by Industry: 1988 to 1996 (thousands of jobs)

	1988	1990	1992	1994	1996	% Change: 1988 to 1996
TOTAL	**1,950.6**	**1,935.8**	**1,806.5**	**1,865.2**	**1,959.3**	**0.4%**
Agriculture	6.4	6.4	6.6	6.2	7.1	10.9
Mining	1.4	1.1	0.75	0.84	0.93	-47.0
Construction	88.5	70.3	50.4	52.7	61.2	-30.8
Manufacturing	378.2	331.7	296.5	280.4	285.3	-24.6
Transp/Pub.Util.	97.4	96.0	87.1	89.8	99.7	2.4
Wholesale Trade	129.8	131.0	117.1	121.6	120.6	-6.7
Retail Trade	373.6	350.7	325.5	329.5	341.4	-8.6
FIRE[a]	170.7	186.1	167.9	170.8	181.0	6.0
Services	693.1	757.8	754.1	812.5	861.6	24.3
Unclassified	11.5	4.6	0.6	0.8	0.4	-96.5

a – "FIRE" indicates Fire, Insurance and Real Estate; "Entry-level" Industries indicate those sectors particular *rich* in entry-level jobs.

Most significant about the Boston economy has been its geographic focus. Unlike in San Juan, employment has not been fleeing the central city. In fact, even with enormous sub-regional and inter-industry employment shifts, all five counties in the Boston region uncannily have maintained nearly the same proportions of regional jobs throughout the entire study period. Total employment in all counties correlated highly with region-wide trends, as gains in one industry made up for losses in others. Suffolk County actually experienced a slight increase in its share of regional jobs, winning some of the largest gains in total employment (see Table 4.10, below). Suffolk also lost a smaller proportion of jobs in entry-level rich industries than other counties (2.6% versus 4.1% losses). These trends differ substantially from those in most U.S. cities this century and this decade (Kain, 1999).

Table 4.10. Metro Boston Employment by County: 1988 to 1996 (thousands of jobs)

Employment	1988	1990	1992	1994	1996	Change: 1988 to 1996	8-Year Growth Rate
Essex	266.4	256	238.8	240.3	254.9	-7.5	-4.3%
Middlesex	762.6	741.7	695.4	708.3	746	-16.7	-2.2%
Norfolk	288.4	296.6	273.8	285.7	303.1	14.7	+5.1%
Plymouth	134.1	131.5	123	128.5	135.9	1.8	+1.3%
Suffolk	499	510.1	475.5	502.4	519.3	20.3	+4.1%
TOTAL JOBS	1950.6	1935.8	1806.5	1865.2	1959.3	8.7	+0.4%

Looking at long-term data, one hardly could characterize the geographic patterns of Boston's changing economy as anything similar to the consistent, rapid decentralization occurring in San Juan. Suffolk County seems to be holding its own and even growing faster than its neighbors. Still, the fact remains that Suffolk has only 26.5% of the metropolitan area's jobs and 20.6% of the region's employment in entry-level-rich industries. These figures of central-city employment are very low in comparison to San Juan, where the respective figures are 64.0% and 54.9%.

An important question is whether Boston's relative "stability" reflects (1) the region truly having reached an economic equilibrium after decades of suburbanization, or (2) the economic turbulence earlier this decade simply having temporarily arrested decentralization. To answer this question, let us look at geographic employment trends during the region's period of very fast growth, from 1994 to 1996. Employment growth in metro Boston during this period most closely resembles that of San Juan's economy since 1990.

Comparison of employment levels by industry in 1994 and 1996 (see Table 4.11, next page) shows that Suffolk County trailed all the region's other four counties. In particular, Suffolk experienced the only significant loss in manufacturing jobs while in all other counties the sector grew steadily. Suffolk also fared particularly poorly in both Public Utilities and Wholesale Trade, again losing many jobs as the suburbs gained. Industries rich in entry-level jobs also declined slightly in Suffolk while they grew quickly in suburban counties. In only one case did Suffolk outpace the region: Finance, Insurance and Real Estate. During this time of economic expansion, the clear trend for central portions of the region was a shift from traditional blue-collar jobs toward greater specialization in white-collar employment.

The results show that, while employment decentralization paused during Boston's period of economic recession, recent, fast-growth years have witnessed a return to rapid suburbanization. As in San Juan, the employment outlooks for low-income families seem to hinge increasingly upon the availability of affordable transportation over longer distances. Both San Juan and Boston display strong signs of employment decentralization, San Juan to a much greater extent. The trends in both cities, though particularly in San Juan, are clearly reminiscent of post-war cities that suburbanized quickly and thereby incurred much of their modern-day fiscal, economic

Table 4.11. Metro Boston's Intra-Regional Employment Change (percent): 1994 to 1996[a]

	Suffolk County	Other Counties
Agriculture	3.3%	15.6%
Construction	12.1	16.8
Manufacturing	-6.4	3.0
Transp/Public Utilities	-3.2	21.2
Wholesale Trade	-7.6	0.2
Retail Trade	1.2	4.2
FIRE[a]	9.6	2.3
Services	4.5	6.7
"Entry-Level" Industries[b]	-0.2	5.2
All Industries	3.4	5.7

a – Mining was not included in this table because the industry employs only 930 workers regionally; thus, very small shifts in this sector could yield growth figures that would be misleading.
b – "FIRE" indicates Fire, Insurance and Real Estate; "Entry-level" Industries indicate those sectors particular *rich* in entry-level jobs.

and social crises. The existing potential for negative effects from such decentralization remains much greater in metro San Juan, where given present geographic trends and concentrations of jobs, the largest movements of employment seem yet to occur.

4.4. Accessibility Analysis

To this point, the chapter has shown that race is a key factor in creating Boston's much more vast and spatially isolated areas of concentrated poverty. In addition, it has shown that in metro Boston, jobs concentrate relatively less toward the central city. Thus, if the modern interpretation of the spatial mismatch hypothesis is true, one should expect metro Boston to display greater symptoms of low job accessibility among low-income workers. Also, results have shown cogently that both cities are experiencing rapid employment decentralization, though the phenomenon is particularly prevalent when the economies are expanding, as San Juan's has been doing more steadily. It is possible that San Juan's geography of employment may be developing toward the likeness of Boston. This section builds upon the previous two by directly relating poverty concentration and employment decentralization to one another via a systematic analysis of job accessibility in each region.

Two spatial aspects of employment accessibility are examined in this section (see Figure 4.6, below). The first deals with the accessibility of locations to entry-level jobs, applying a Hanson-type gravity model (physical job accessibility). The second captures additionally the competition among workers for those jobs, applying a supply-demand accessibility model (competitive job accessibility). In context of the spatial mismatch hypothesis, these measures bridge the framework's two halves, directly addressing issues of transportation and poverty concentration that result from the spatial distribution of jobs and low-income residences.[15]

Figure 4.6. Accessibility Components of the Modern Spatial Mismatch Framework
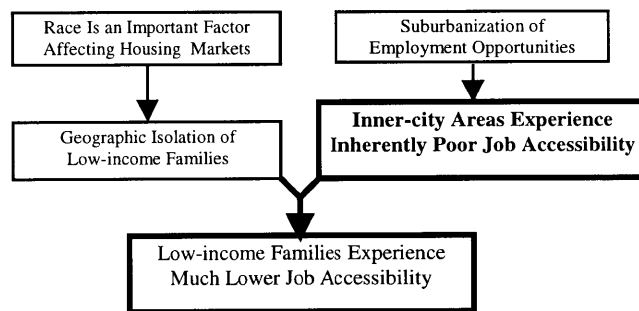
Note: Bold and enlarged components represent those examined in Section 4.4.

If the modified spatial mismatch hypothesis is accurate, one expects that accessibility should be systematically poorer in the inner city, where (1) there purportedly exists a dearth of entry-level jobs, and (2) transit does not adequately serve trips to and from the job-rich suburbs. In addition, one should expect that low-income families live in the metropolitan center, and as a result experience inherently poorer job accessibility. The following sections address for each city those aspects of job accessibility most relevant to the spatial mismatch hypothesis. Chapter 5 then further illustrates with a particular focus on San Juan the practical transportation and land use solutions for improving welfare recipients' accessibility.

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[15] For best understanding of the results presented herein, it is essential to keep in mind the meanings of the applied accessibility measures. The reader may wish to review Section 3.5.1, "Accessibility Indicators."

4.4.1. Boston Region: Accessibility

Metropolitan Boston is focused very strongly upon the regional center. MBTA buses, commuter rail and rapid rail serve central portions of the region extensively – radially feeding the "Hub" as Boston historically has been called. Several cross-town bus routes also serve a large number of customers. Likewise, employment and residential density focus quite strongly upon the regional center. Typical of U.S. cities with such form, Boston also supports a large, distressed inner city. While Boston's inner city neighborhoods are full of vitality by most standards, they nonetheless experience the typical concentrated poverty that characterizes so many post-industrial cities. As expected, welfare recipients – the economically poorest of any group – tend overwhelmingly to reside in municipal Boston, as well as in nearby urban communities, such as Somerville, East Cambridge, Lynn and Revere. Some outlying towns, such as Lowell, Lawrence and Brockton also support concentrations of recipient populations, and many recipients are dispersed about the metro area. Figures 4.7 and 4.8, on the following pages, display the relative locations of "entry-level-rich" employers, welfare recipients, and the MBTA's rail services. Notably, welfare recipients are somewhat *less* spatially concentrated than the whole of households below the poverty level.

As one moves from the metropolitan center, jobs concentrate upon major roadways, especially radial ones. The patterns are so distinct and evident that one accurately could trace the major roadway network with knowledge only of employer locations. The observations highlight both the spatial separation of commercial and residential land uses, and the strong influence of roadway development upon the locations of businesses and employment. Note also that jobs concentrate along the western Route 9 and Massachusetts Turnpike corridors, through Newton, and past the route 128 Beltway. This pattern of job concentration proves later to be a significant factor in terms of its influence upon accessibility results.

The major questions, of course, remain how well welfare recipients can reach these jobs via transit and how the distribution of employment and low-income workers affects job accessibility.

Figure 4.7. Boston Metropolitan Area: Employers in "Entry-level Rich" Industries
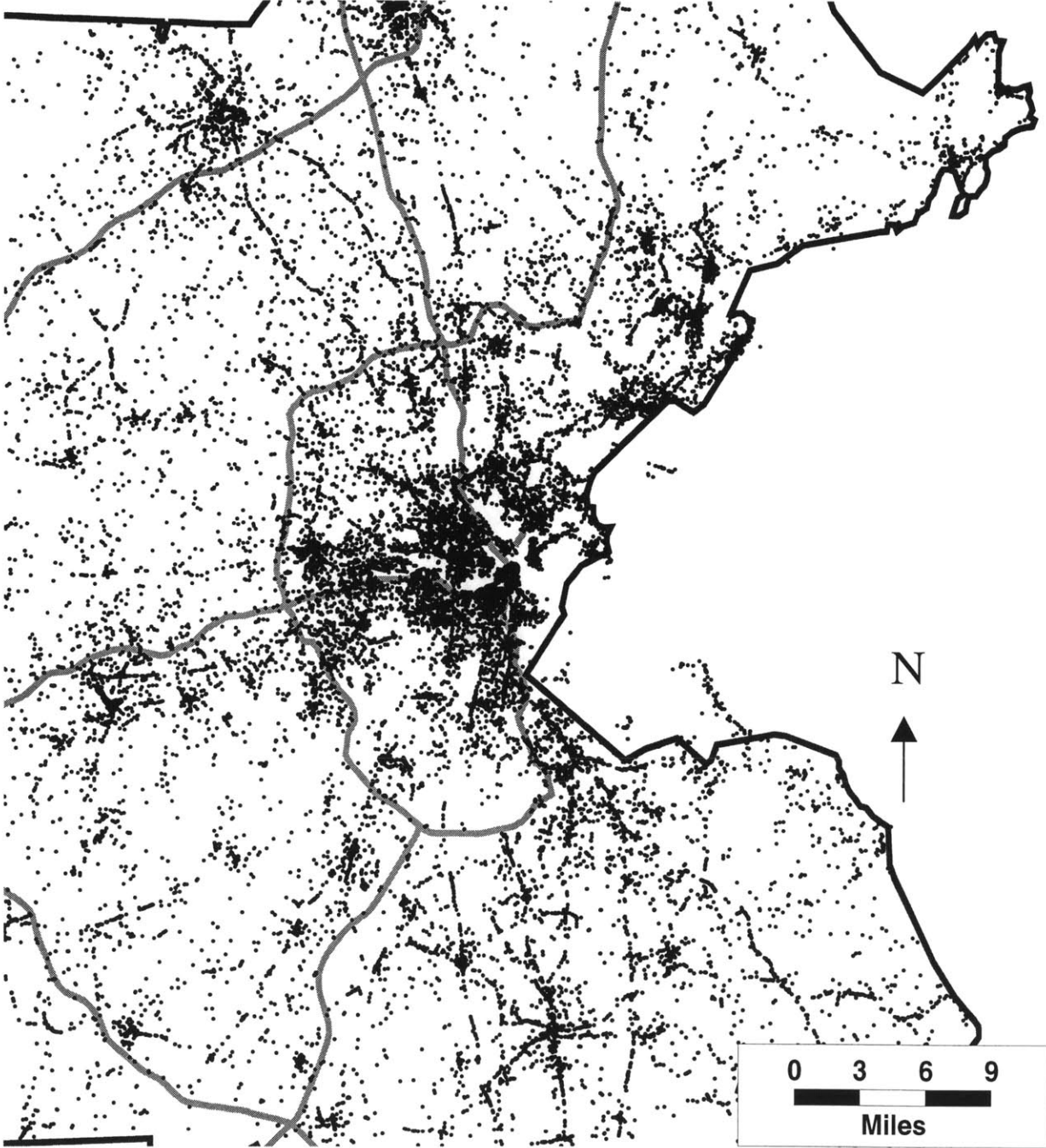
One dot equals a single employer.

Figure 4.8.   Boston Metropolitan Area: Welfare Recipients

Welfare Recipients

· = 1 estimated recipient

0   2   4   6

Miles

N
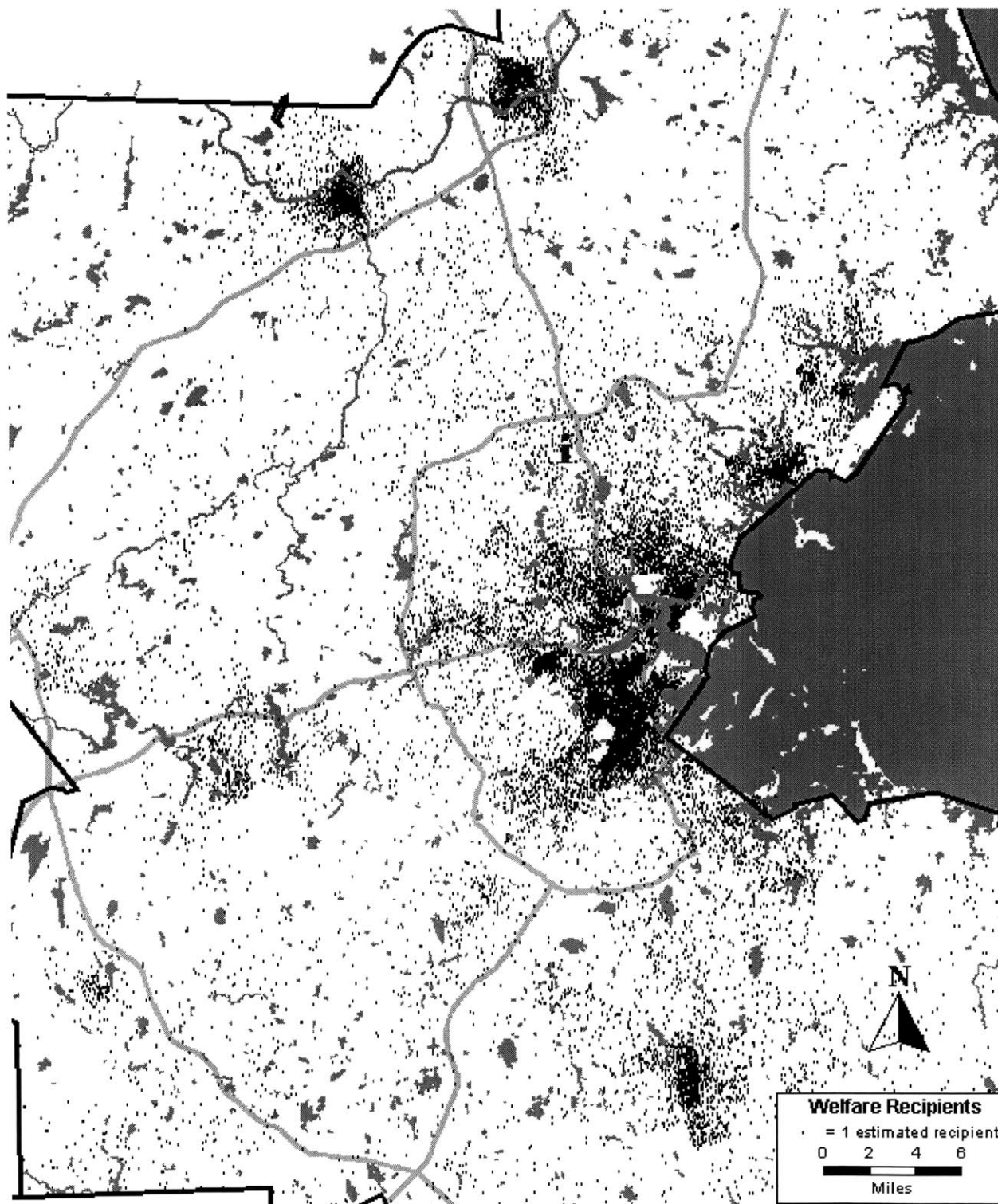
<u>Boston: Physical Accessibility (Gravity Model)</u>

Figure 4.9 (next page) maps job accessibility patterns in the Boston metropolitan area. These results come from the gravity model specified in Chapter 3 and represent the accessibility richness of locations to entry-level jobs, without constraining for their limited supply. The zones' shadings are grouped by standard deviation, to afford greatest statistical meaningfulness. The map shows unmistakably that land nearest the regional center is "accessibility richest" and also that physical job accessibility decreases rapidly and in relatively smooth contours with increasing distance from central Boston.

As compared to the larger set of low-income workers, welfare recipients experience relatively poorer job accessibility. This result arises from the fact that recipients reside less spatially concentrated in accessibility-rich central Boston than do the larger set of low-income workers. Recipients on average scored 2.71 standard deviations *lower* than the set of all low-income workers. This result seems particularly disheartening for those recipients living outside central Boston, where affordable transportation generally is not available and the concentration of opportunities is much lower.

Perhaps most significantly, these results plainly refute what one would expect to be true from a modern interpretation of the spatial mismatch hypothesis, which states that central city areas experience inherently poorer accessibility to entry-level jobs, because of industrial restructuring that has moved entry-level jobs to distant suburbs. Clearly, the evidence shows that it is actually inaccurate to state that inner-city areas experience inherently poorer physical accessibility. By contrast, they experience *superior* physical accessibility as a direct result of (1) the very high concentration of nearby jobs and (2) the relatively ubiquitous availability of affordable public transportation services. While the hypothesis' purported phenomena still may be true generally, they clearly cannot accurately describe the full set of circumstances affecting job accessibility in Boston nor likely those of other post-industrial cities. Clearly, if academics and policy-makers are to accurately characterize the true nature of job accessibility among low-income families, a new framework is needed.

Figure 4.9. Physical Job Accessibility in the Boston Metropolitan Area

Map Layers
☐ Boston TAZs
━ Interstate Highway

Physical Accessibility
Very Low
Low
Average
High
Very High
⊠ Other

N

0 2 4 6
Miles
by Std. Dev.
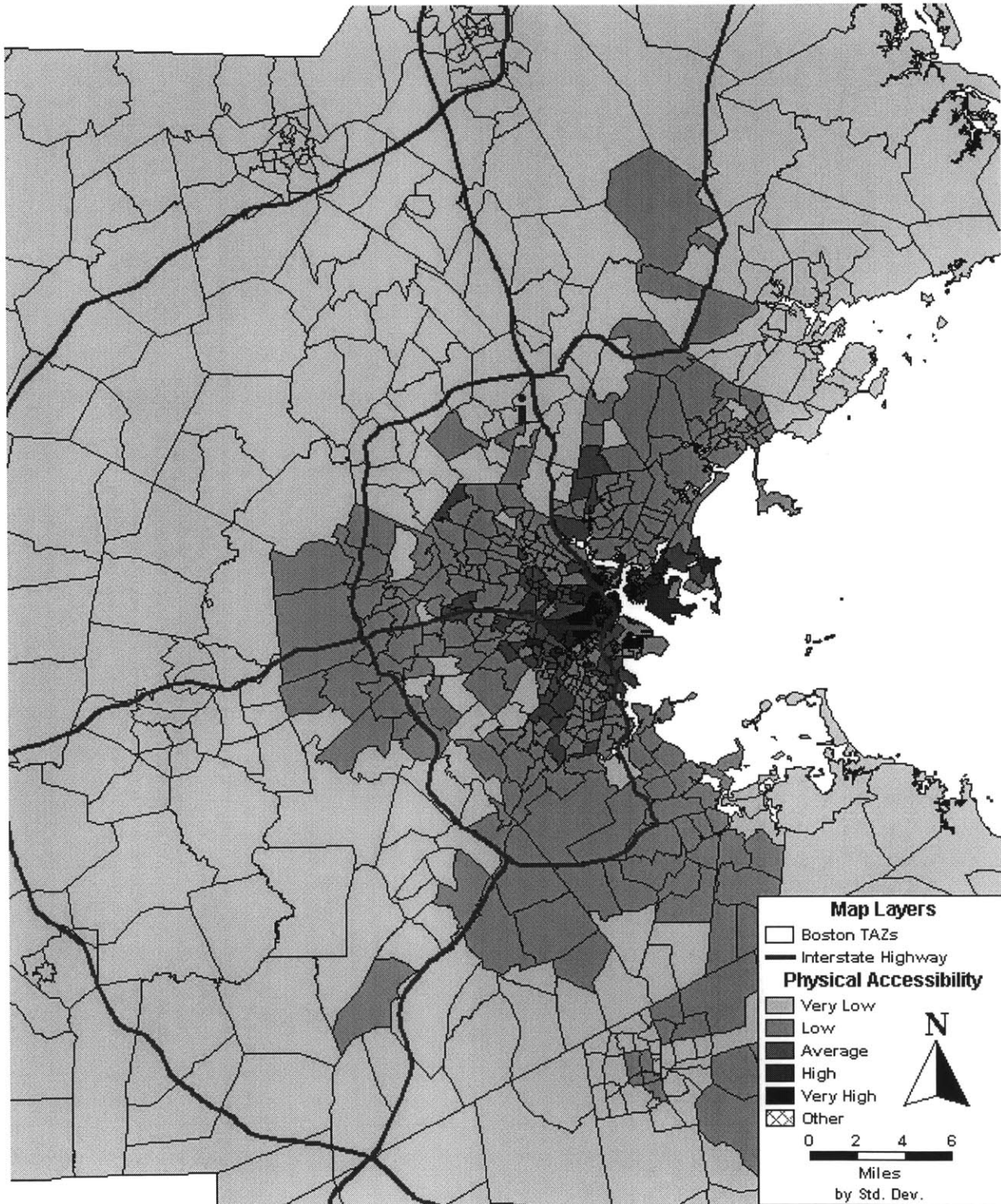
The results seem to highlight important principles regarding economies of density as well. Undoubtedly, low-income, transit-dependent families in central Boston experience better physical accessibility not only to jobs, but also to daily activities, shopping options, educational opportunities, and other important social, economic and recreational experiences. In this sense, density plays a very strong role in physically bringing together many valued opportunities of all sorts and thereby shortening travel. As Figure 4.9 illustrates, the ability of workers to switch jobs also is higher in central portions of the metro area since physical accessibility to jobs is much higher. Density also makes possible the provision of affordable transportation services that facilitate longer trips over the relatively opportunity-rich landscape. It is plausible, even, that the high concentration of transit-dependent workers makes feasible the provision of higher quality transit services from which all within the inner-city may benefit. The urban environment clearly is more accommodating to the accessibility needs of spatially constrained low-income households.

This concept of density economy also is consistent with the "bid-rent" literature, which posits that the value of land should increase the closer that a given location is to the central "market", as a result of the lower transportation costs associated with physically accessing valuable opportunities (Galster, 1974; Wheaton, 1974; Putzel, 1975). Evidence confirms that land values and rents per square foot are higher in central portions of the region, and also that low-income households residing there spend a greater portion of their incomes on rents (see Galster, 1974). To compensate, low-income households buy "less housing", sacrificing living space in the name of affordability, while gaining the benefits of affordable physical accessibility (Shen, 1998c).[16]

Finally, one should desire to know to what extent the scores reported by the model used here reflect real travel phenomena or perceived job accessibility. In this regard, maps in Figures 4.10 and 4.11 (next page), demonstrate that workers' job commutes by light and rapid rail are significantly higher in the zones that experience better job accessibility by transit. Visually, one easily may delineate the alignments across the urban landscape, as they ride ridges of good job

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[16] The text here again is mute on the issue of low-income families' relative preference to live in inner-city areas. Much evidence from the literature suggests that many barriers prevent low-income families or minorities from residing elsewhere, and that given the fair choice, a large portion would not live in the inner-city, even with their present incomes (see Massey and Denton, 1992).

Figure 4.10. Physical Job Accessibility in Central Portions of the Boston Metro Area
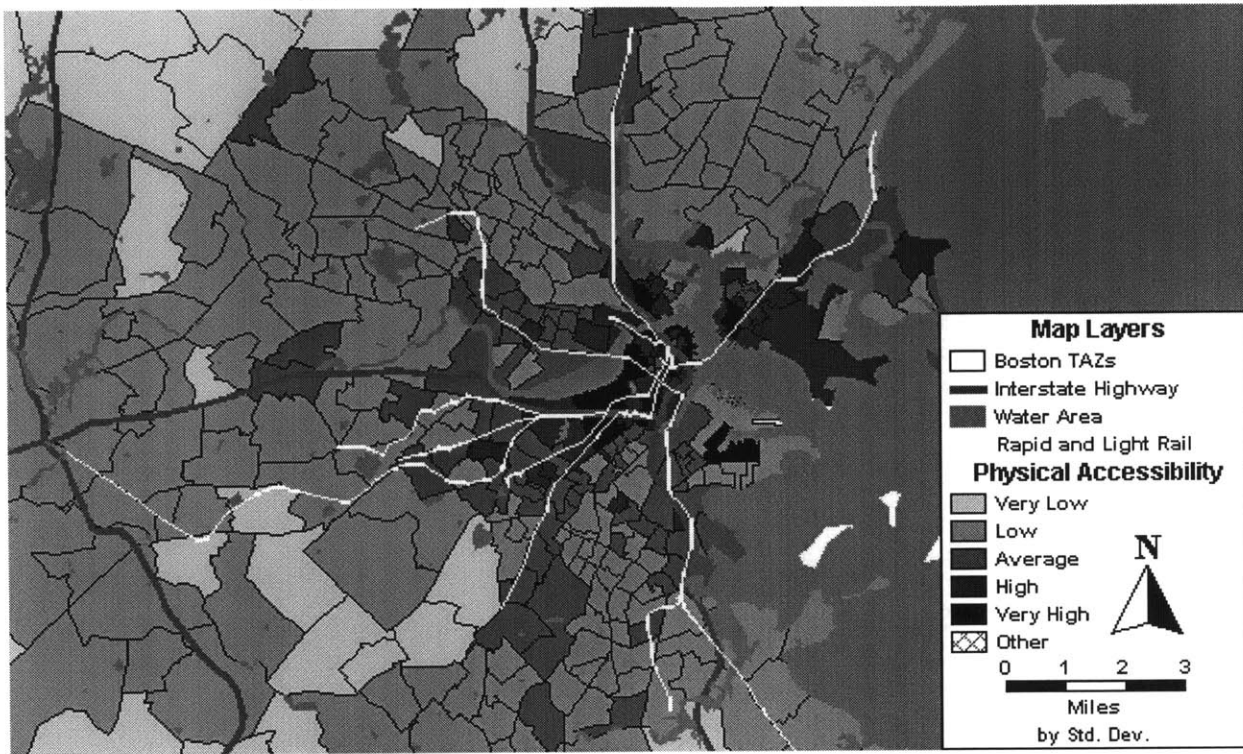
Figure 4.11. Proportion of Work Trips by Rail: Central Boston

accessibility. Clearly, a strong correlation exists between good job accessibility by transit and the geography of the MBTA's highest quality transit services, and evidence from workers' travel behavior reflects this fact. The transit data and housing literature both support the integrity of results presented here for job accessibility.

Boston: Competitive Accessibility (Supply-Demand Model)

Next the research applies the supply-demand model to examine competitive job accessibility in metropolitan Boston. The model measures each worker's job accessibility potential while also accounting for the accessibility-weighted labor market competition for the same set of limited opportunities. If results from this model reflect similar patterns as those found from applying the gravity model – with higher levels of job accessibility systematically concentrated toward the metropolitan center – then the prevailing interpretation of the spatial mismatch hypothesis, as delineated in Figure 3.5, must be rejected unequivocally. An entirely new model of urban economics, as it relates to transportation, would be needed. If, on the other hand, patterns are markedly distinct from those found with the gravity model, then circumstances of accessibility depend largely upon the particular differences discovered between the two sets of results.

Figure 4.12, on the following page, presents results from the supply-demand model. The picture presents a stark contrast to results found earlier, using the gravity model. Instead, low-income workers in the central city and inner suburbs systematically experience poorer competitive job accessibility than do their outer suburban cohorts. The region's highest levels of competitive job accessibility exist between the two beltways. Low-income families living in developing Framingham enjoy among the best entry-level employment potential in the region. Other ex-urban towns also post very high scores. By far the highest levels exist in the small North Shore antique and fishing towns of Gloucester and Rockport, a full 30.2 miles northeast of downtown Boston. Notable exceptions to the general trend include denser outlying towns, such as Brockton, Lowell and Lawrence, which even with their own transit systems experience relatively poor accessibility.

Figure 4.12. Competitive Job Accessibility in the Boston Metropolitan Area

Map Layers
☐ Boston TAZs
▬ Interstate Highway

Physical Accessibility
☐ Very Low
▨ Low
▨ Average
■ High
■ Very High
⊠ Other

N

0   2   4   6
Miles
by Equal Sized Intervals
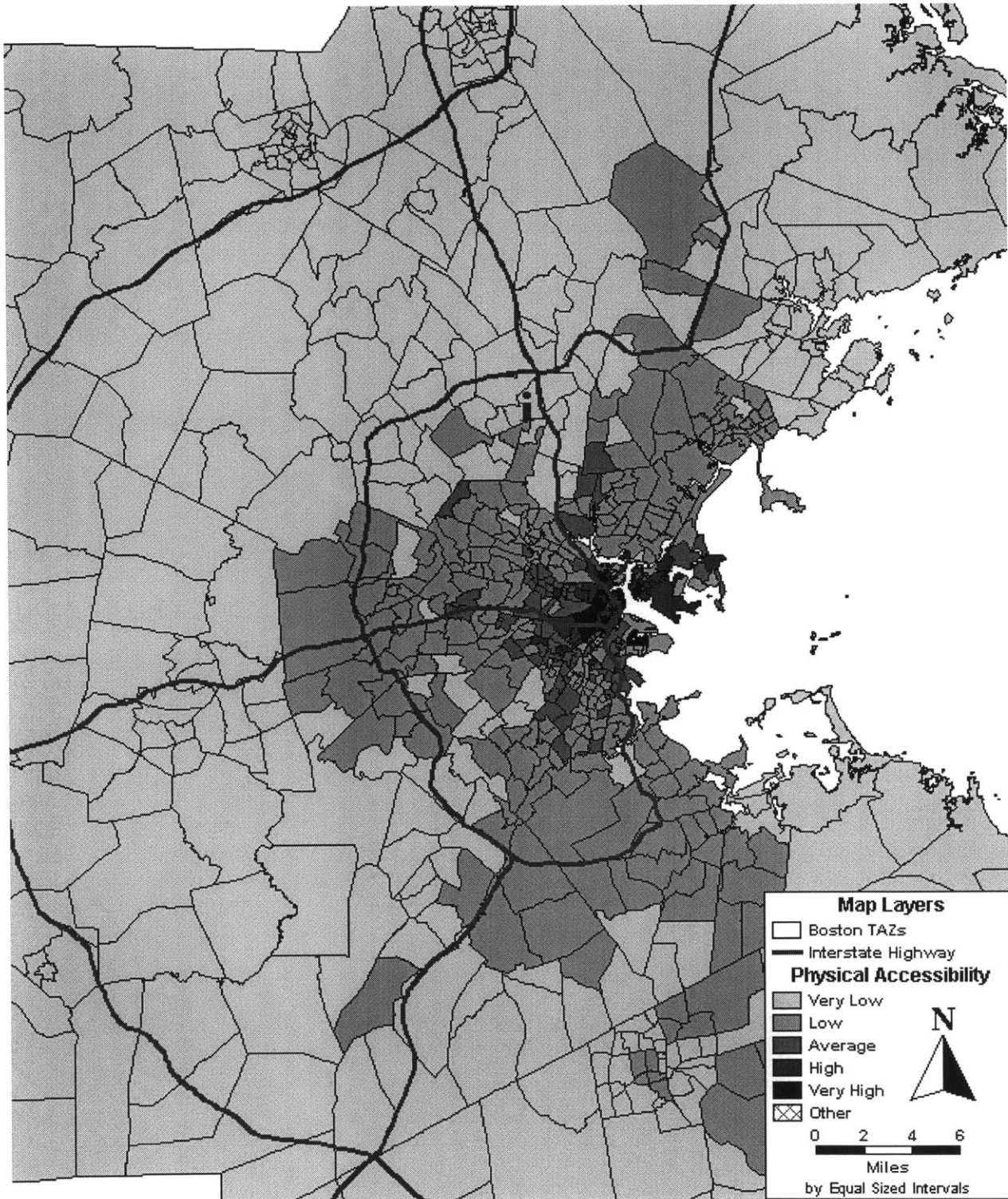
While this map, shaded by standard deviation, shows a homogeneously "accessibility poor" mega-region inside the Route 128 beltway, examination of the data reveals that, in fact, distinct levels of accessibility also thematically differentiate parts of the inner city and inner suburbs. Figure 4.13 (next page) demonstrates that inner-city and southern Boston fare uniformly more poorly than other areas inside the Route 128 beltway. Interestingly, of the few inner-city areas that do not experience such deficient accessibility, nearly all are adjacent to the Orange or Red Line subways. Sections of southern Brookline, Chelsea, Lynn and adjacent Nahant and Swampscott also fare particularly poorly. Together, these areas represent the set of low-income families who experience the lowest levels of employment potential in the entire metro region. In contrast, low-income families who live in the northwestern inner suburbs – Arlington, Belmont, Lexington, Winchester and Woburn – fare well by comparison. Two principal differences exist among these areas: in comparison to the inner city, northwest sections of the inner-suburbs support both (1) lower concentrations of low-income households and (2) a notably less dense network of MBTA bus services.

Before interpreting the results, it is important first to qualify them in terms of the model's specifications. First, the local peaks in these results seem to arise from the model's inclusion of walking times among neighboring zones. Since when commuting by foot was quicker than by transit the model used walking times as the zone-to-zone travel duration, some zones display sharp local peaks in accessibility. This result seems quite reasonable. Walking times are inherently large over small distances, such that travel by foot to or from the neighbor of a "hot spot" might require enough time so as to prevent workers from neighboring zones from enjoying similar levels of accessibility. Thus, some local "hot spots" arise. Including walking access surely favors ex-urban areas' scores to some extent, since those areas are more likely to endure relatively poor transit service, or in some cases no public transportation at all. However, the inclusion of walking times seems to improve the model's accuracy, since it accounts for the real ability of transit-dependent workers to commute by foot. The existence of some local peaks therefore seems quite reasonable.

Conversely, one weakness of this model is its exclusion of the auto mode. Some low-income workers and even some welfare recipients have access to an automobile and thereby may both

Figure 4.13. Competitive Job Accessibility Within the Route 128 Beltway

Map Layers
- Boston TAZs
- Interstate Highway
- Rapid Rail

Competitive Accesibilty
- Very Low
- Low
- Medium
- High
- Very High
- Other

N

0   .90   1.8   2.7
Miles
by Equal Sized Interval
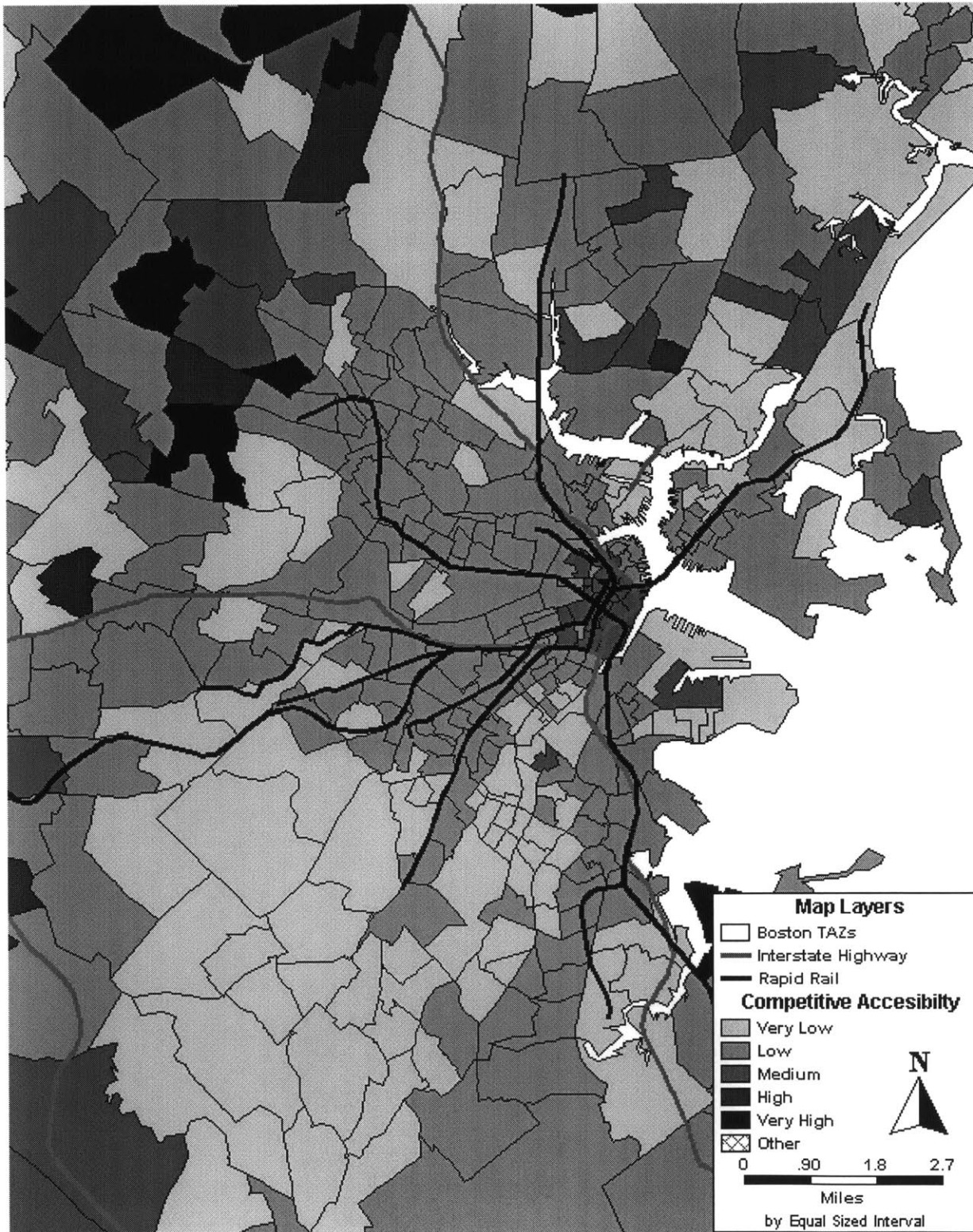
access distant locations and compete for employment more effectively. Therefore, results in this sense probably overestimate the importance of location by testing only the transit mode for low-income workers. Low-income workers who have a car surely experience better job accessibility than they are estimated to have here, since technologies that overcome space inherently reduce the significance of starting location (Shen, 1998a, 1998b). On the other hand, quite importantly, *transit-dependent* workers probably have *lower* job accessibility than estimated herein, specifically because in reality they must compete with some low-income workers who have access to an auto. Thus, if one views the results here as a characterization of transit-dependent workers' job accessibility, then the model very likely overestimates their true levels of accessibility. The geographic direction of this bias remains unclear since, although car ownership among low-income households is higher in the suburbs, physical accessibility by auto to the region is highest from the central city (Shen, 1998b). One may only conclude that the directional effect of auto is unclear, though its aggregate significance would be to reduce transit-dependent workers' accessibility. No matter the case, the results herein clearly speak only to the accessibility circumstances of transit-dependent workers.

It also is important to note that the supply-demand model is quite sensitive to its inputs for jobs, workers and travel times. In a comparable study of Boston, Shen (forthcoming) estimates a similar geographic distribution of entry-level jobs and travel times by transit, but a systematically different pattern of low-income workers.[17] In his model estimations, as compared to those in this research, job seekers are relatively less concentrated within the inner city and somewhat more prevalent in the suburbs. As a result, Shen finds that entry-level job seekers experience higher levels of competitive accessibility near the metropolitan center. It is apparent that differences in initial assumptions about input data may affect results strongly, though from comparative study of the data inputs it is unclear which estimate of workers is more accurate. The discussion and interpretation of results herein thus rest on the condition that Figure 4.12 presents a reliable estimate of competitive job accessibility in Boston.

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[17] The author (Lane) estimated "low-income workers" as being equal to the number of persons between 18 and 64 years of age who live below the poverty level, according to the 1990 U.S. Census. Shen (forthcoming), meanwhile, estimates "entry-level job seekers" as being equal to the proportion of employed persons in each zone currently

If so, the results demonstrate several important principles about the significance of poverty concentration and public transportation upon urban labor markets and the well being of low-income, transit-dependent households. Clearly, in poorer neighborhoods, poverty concentration significantly reduces workers' job accessibility by forcing them to compete more directly with one another for a limited supply of entry-level positions. In this context, the availability and breadth of affordable transportation becomes *critical* to low-income workers' economic well being. The results demonstrate that transit systems significantly reduce the negative effects of poverty concentration by allowing transit-dependent central city residents to compete for jobs outside their low-income enclaves. On the other hand, the geographic limitations of transit directly fuel the negative effects of poverty concentration by spatially constraining low-income workers to areas of relative job dearth. In this regard, evidence from Boston is convincing. As shown in Figure 4.12, because of transit, low-income, inner-city residents may compete with inner-suburb workers, who in turn may compete in the middle-suburb labor market, and so on. The major effect is a progressive redistribution of job accessibility – an "evening" of the economic playing field. As a result of public transportation, inner-city workers experience far better ability to compete for spatially distributed opportunities than they otherwise would. Conversely, similar inner-suburb workers experience a comparable *reduction* in their job accessibility because they experience greater competition from inner-city workers. The effect ripples outward from the dense inner city to just beyond the edges of the transit system's service area. It is for this reason, presumably, that one must reside well beyond Route 128 before experiencing any appreciable improvement in job accessibility.[18]

Beyond Route 128, the steep rise in competitive job accessibility closely reflects the geographic extent of MBTA bus services. Outer-suburb residents' superior competitive accessibility seems to originate more from the MBTA's geographic limitations than from any local system's provision of exurban service. The central city concentrations of transit-dependent, low-income workers simply cannot compete for jobs any farther out. Thus, local residents of these outlying towns experience somewhat better entry-level job accessibility by foot, commuter rail or what

working in an "entry-level occupation", multiplied by the total number of persons in the respective zone claiming to be unemployed. Shen's data for both components also were from the 1990 U.S. Census.

little local transit exists than do central city residents who enjoy dense bus service, a fairly extensive rail system, and the region's very highest concentrations of entry-level jobs. Their higher competitive job accessibility originates from a lack of competition for jobs. Conversely, inner-city and inner-suburb workers' lower accessibility results directly from their spatial inability to compete more effectively. If transit were more geographically extensive, the economic playing field would become more level.

Evidence from central portions of the region further support this pattern. In northwestern portions of the inner-suburbs, a less ubiquitous network of bus services prevents transit-dependent, inner-city workers from competing more effectively there for entry-level employment. As a result of the lack of transit, inner-city workers' competitive job accessibility is reduced, while low-income workers of the Northwest fare comparably better. The phenomenon again illustrates how the lack of affordable transportation options may reinforce inequity by intensifying the spatial effects of poverty concentration, while the availability of good public transit may help low-income workers expand their realm of job possibilities and thereby compete more effectively for employment.

Further Interpreting the Results

It is important to note that the effects of public transit upon *physical* accessibility remain inherently positive *for all parties*. As results of the gravity model showed, these consistently positive benefits are distributed most heavily upon workers in the central city – precisely those who are in greatest need. It is for this reason that the competitive model shows an expanded area over which they may compete effectively for employment.

The reader should note, however, that these results do *not* say that low-income workers will experience greater job employment potential by *traveling* to accessibility "hot spots". Rather, the results demonstrate that low-income families presently living in these areas perceive very good job accessibility from *their* starting locations. An important question, then is, "Just where

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[18] The alternative explanation, that inner-city workers themselves are competing effectively for jobs on the beltway, is untenable; travel time from Roxbury to the Route 128 beltway requires between two hours and three-and-a-half hours, one way.

are the jobs?" Would relocating low-income workers afford greater accessibility benefits? Alternatively, which transit services most effectively would improve job accessibility for those most in need? Which strategy would be more effective in Boston: improving transit or residential relocation?

4.4.2. Boston Region: Transit and Residential Relocation Alternatives

These questions are answered in part by Figure 4.14 (next page), which displays the local job surplus or deficit in each zone, measured as the numerical difference between jobs and low-income workers, divided by land area to control for variability in tract size. The resulting numerical values represent the relative *intensity* of job surplus or deficit in each zone. Negative scores therefore represent a greater number of low-income workers than entry-level jobs – the case of a deficit. Results are classified by 0.5 standard deviation. This map answers the question, "Just where are the jobs?" The jobs are in Waltham, Watertown and west Cambridge, as well as in Woburn Square and Winchester Center. Notably, these areas all are to the north of the Charles River. Jobs also concentrate consistently along Route 9, extending westward toward Framingham. Also, "hot spots" appear at regional shopping centers: the Assembly Square Mall, South Shore Plaza, Mystic Mall and Chestnut Hill Plaza, in particular. All of these centers show as significant job surpluses.

The map further supports what the models of job accessibility have shown. A deep dearth of jobs exists within inner city Boston, particularly around Dudley Square, in areas north and east of Franklin Park, and in areas to the north and west of Mattapan. These neighborhoods are precisely those that have gained notoriety as being Boston's most distressed. Deep job deficits are also evident in Brighton (except Brighton Center), particularly along the "B" route of the Green Line, which spans dense residential areas.

Notably, the map shows that outlying areas that scored well in terms of competitive job accessibility (see Figure 4.12) have little or no capacity to support additional low-income workers. Though in such areas the ratio of jobs to workers may be high, the numerical difference remains quite small, such that given only a few additional low-income workers, these

Figure 4.14. Intensity of Job Surpluses and Deficits Within Rte. 128

Map Layers
Census Tract
━━ Interstate Highway
▢ Municipalities
▨ Water Area
Rapid and Light Rail

Job Surplus / Sq. Mi.
-2100 or lower
-2100 to 59
59 to 2200
2200 to 4300
4300 or higher

0   .90   1.8   2.7
Miles
by 0.5 Std. Dev.

N
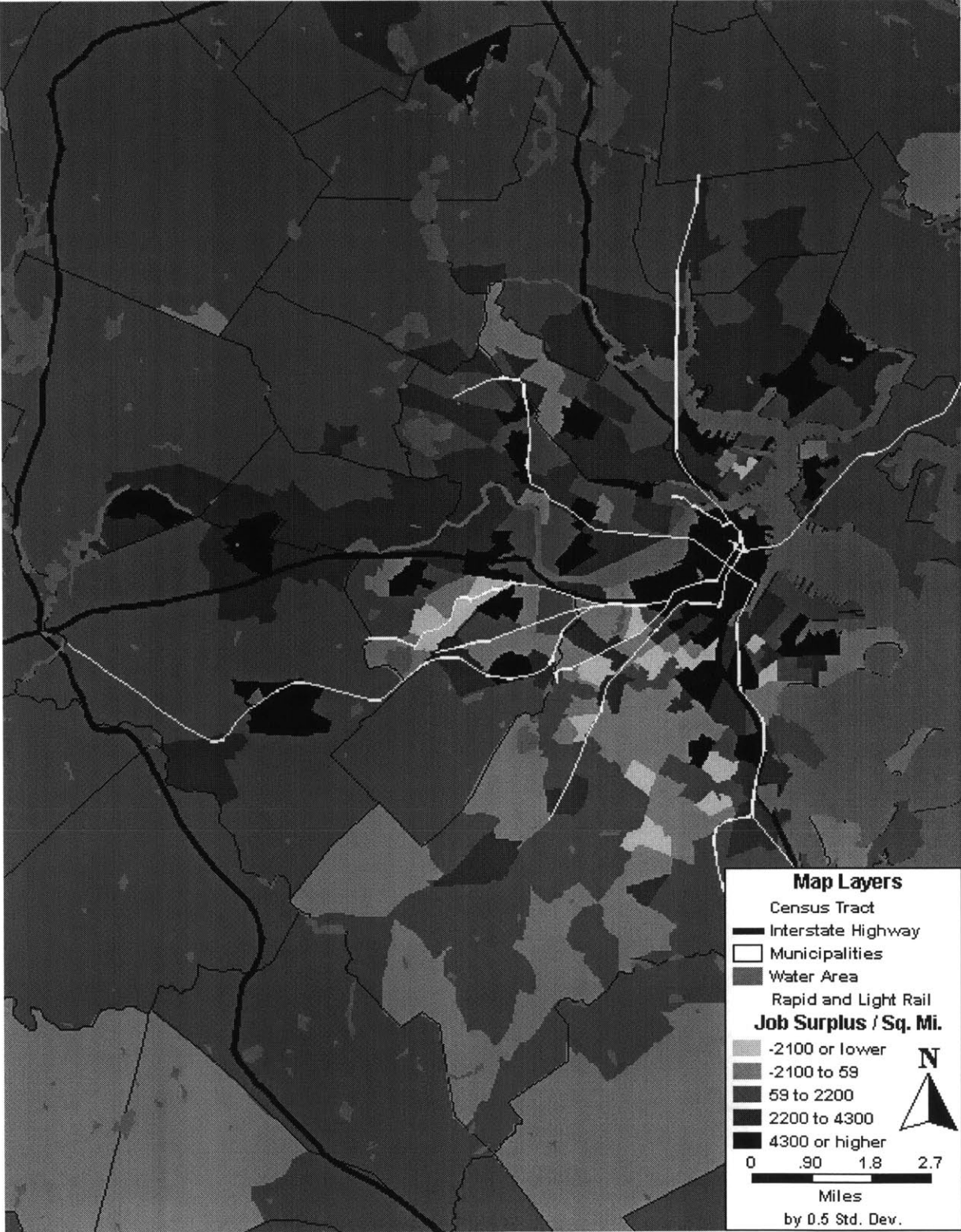
areas quickly would become "accessibility poor". This result emphasizes strongly that a city-to-suburb residential relocation program of any significant size would be ineffective at improving low-income workers' job accessibility in Boston and might even reduce their quality of life by separating them from the social networks, services, densities of opportunity and transportation options available to them within the central city. If public agencies were to pursue any residential relocation program, it seems that relocations *within* central portions of the region would have greatest potential for success. Alternatively, improving transportation services seems to have a much greater potential for success, particularly in terms of its effect upon a larger number of welfare recipients and low-income families.

Figure 4.14 also shows that notable surpluses exist in some areas of municipal Boston where transit presently serves trips from inner-city areas relatively well. The job centers include: (1) Back Bay/downtown Boston, (2) the South Boston industrial park, and (3) a north-south corridor in Dorchester along I-93, particularly near the South Bay Center and University of Massachusetts. However, one may assume that these employers, with a large pool of low-income residents so close by and good access to public transit (as evidenced by the area's very good physical accessibility), have found workers to fill most of their entry-level positions. These areas do not seem ripe for many job openings. Rather, large job surpluses in relatively inaccessible locations seem more likely have openings available. Evidence shows that one need not look far to find large job centers that transit serves quite poorly from the starting locations of the low-income population.[19]

To characterize the quality of transit service from areas of Boston's inner city to those of inaccessible job surpluses, the research examines the case of a tract on the border of the roxbudy and Dorchester neighborhoods, just north and east of Franklin Park. Only 0.15 square miles large, the tract has 48 welfare recipients, 377 low-income workers and an entry-level job deficit of 1,299 jobs per square mile (195 entry-level jobs would have to move into the small area for the index to become zero). Surrounding tracts for some distance share the same qualities. Figure

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[19] By better serving trips from (1) areas of job deficit and low *competitive* accessibility for workers to (2) areas of job surplus and low *physical* accessibility for employers (that is, employers' ability to be accessed by workers is low), one may plan transit services that will have greatest positive effect upon low-income workers' ability to gain employment.

4.15 (next page) displays the shortest door-to-door real travel times by transit or by foot from this neighborhood to the rest of the metro area.

As the map illustrates, travel times to job centers in all directions seem quite large. A one-way trip to just the edge of municipal Boston generally requires between 60 and 90 minutes. A trip just five miles northwest to Newton corner takes about 125 minutes. Travel to relatively close Medford Square takes over two-and-a-half hours – *one way*. Likewise, a trip to very job-rich Woburn Center takes three hours and five minutes, one-way. The true nature of spatial isolation becomes grimly evident in these figures. One gains a much fuller understanding of the tremendous spatial constraints that transit-dependent workers experience daily.

While the focus of this research is not to recommend services or policies for the MBTA, the evidence presented here compels at least some level of basic commentary. To improve low-income workers' job accessibility it seems imperative to pursue high quality services that bring job seekers to the north side of the Charles River, where many relatively inaccessible job surpluses exist. The MBTA should consider introducing high quality cross-town service between Roxbury and the job-rich corridor between Watertown and Waltham. Service in the proposed eight-mile corridor would connect to eight radial rail lines while on a one-seat ride supplying literally thousands of entry-level jobs to low-income workers. Also, the "T" seriously should consider offering deep discounts for travel on commuter rail lines. In numerous cases, commuter rail presently serves distant job-rich areas that buses could not reach effectively. The Worcester Line, for example, serves the very job-rich Route 9 corridor. Similarly, commuter rail directly serves Waltham and Winchester Center. A combination of additional bus service and deep commuter rail discounts might have bus service from Dudley Square to the intersection of Route 9 and the Worcester commuter rail line. Continuing service to Framingham all together would serve over 13,000 jobs in entry-level rich industries within ¼-mile of the bus line or rail stations. Finally, simply improving travel times on existing routes would help low-income workers reach nearby job locations much more easily. The MBTA has many opportunities to assist low-income families in reaching employment. A fuller study would reveal many viable options for delivering improved job accessibility.

Figure 4.15. Transit Travel Times from Boston's Inner City

Map Layers
- Boston TAZs
- Interstate Highway
- Water Area
- Rapid and Light Rail

Minutes
- 0 to 30
- 30 to 60
- 60 to 90
- 90 to 120
- 120 to 150
- 150 and higher
- Other

N

0 1 2 3
Miles
by Equal Sized Interval

4.4.3. Summary for Boston

Results from Boston have commented strongly on the spatial mismatch hypothesis, prompting a significant refinement of the relationships that compose its purported phenomena. Labor market competition has been shown to interact very strongly with the geography of transit services – highlighting both the significance of concentrated poverty and the importance of affordable transportation services for reducing its pernicious effects. Concentrated poverty reduces low-income workers' job accessibility, and racial inequity exacerbates the problem. However, affordable transportation counters these harmful effects by allowing low-income workers to compete more effectively for spatially distributed opportunities.

How generalize-able are these results to metropolitan San Juan, and what lessons from Boston may be applied? What specific effects can we expect *Tren Urbano* to have? More generally, how does a major new rail line affect the regional distribution of entry-level employment potential? The following section addresses these questions via study of San Juan.

4.4.4. San Juan Region: Accessibility

San Juan has several distinct job centers and concentrations of welfare recipients. The reader may refer to Figure 4.16 on the following page to gain a good sense of how entry-level jobs and welfare recipients are distributed about the metro area. The most significant concentrations of entry-level jobs are in the Hato Rey area, near *Tren Urbano*'s Roosevelt Station, and extending south along the Avenida Muñoz Rivera corridor to Rio Piedras and the University of Puerto Rico. Other job centers exist in Bayamón Centro, at Plaza Las Americas,[20] in some dense pockets of Santurce, and of course in the tourist districts of Viejo San Juan and Condado. Welfare recipients meanwhile concentrate overwhelmingly along the western bank of Laguna San Juan, south from dense portions of eastern Santurce to the neighborhoods of Barrio Obrero and San Jose. Recipients also concentrate in small, densely populated areas of Rio Piedras and Cataño, as well as in areas adjacent to Plaza Las Americas and in Bayamón Centro.

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[20] The dot density map spreads the jobs at Plaza Las Americas over the entire block group; however, nearly all are within the mall itself.

Figure 4.16. San Juan: Welfare Recipients, and Employers in "Entry-level Rich" Industries

Recipients Per Sq. Mi.
- 0 to 100
- 100 to 600
- 600 to 1100
- 1100 to 1700
- 1700 to 20000
- Other

San Juan TAZs
· = 25 Entry_Jobs

0   .60   1.2   1.8
Miles

N

The following analysis examines accessibility in San Juan in terms comparable to those used for study of Boston. In addition, it examines the "build" and "no build" cases of *Tren Urbano*, and the accessibility differences between them.

San Juan: Physical Accessibility (Gravity Model)

Figures 4.17 and 4.18 (next page) show results from the gravity model's estimate of physical accessibility for both the "build" and "no build" cases. The locations of welfare recipients' residences are plotted on each map to highlight *Tren Urbano*'s context within the city's demographic fabric.

Presently, San Juan's central spine, from the tip of Viejo San Juan to Rio Piedras, experiences the region's highest physical accessibility to entry-level jobs. The focus upon this corridor is quite remarkable. Phase 1 of *Tren Urbano*, which traverses most of this it, plans to reinforce this pattern and extend it westward to Bayamón. The central spine's form arises from the region's historical development, beginning from the city's old fortified island and extending through Condado and Hato Rey, finally joining the old Rio Piedras neighborhood. These maps indicate that, as planners have speculated, much potential exists for the new line to elongate this historical urban form even further.

Results compare closely to those from Boston. San Juan's central spine enjoys both the highest job densities and the most frequent and fastest bus service on the island. The high levels of accessibility seem highly sensitive to the forms of transit services. One easily may delineate from the "no build" map the confluence of bus services through central San Juan. Presently, however, no transit service provides a one-seat ride between opposite sides of the spine; any such trip must transfer. Such a service pattern augments the central spine's accessibility dominance.

Figure 4.19 (two pages forward) shows the difference in results between the "build" and "no build" cases. All portions of the metropolitan area invariably experience a positive improvement in physical job accessibility, though the magnitude of benefits is non-uniform, of course. Those areas immediately adjacent to the *Tren Urbano* alignment, or along nearby feeder routes, stand to

Figure 4.17. San Juan: Physical Job Accessibility, "No Build"
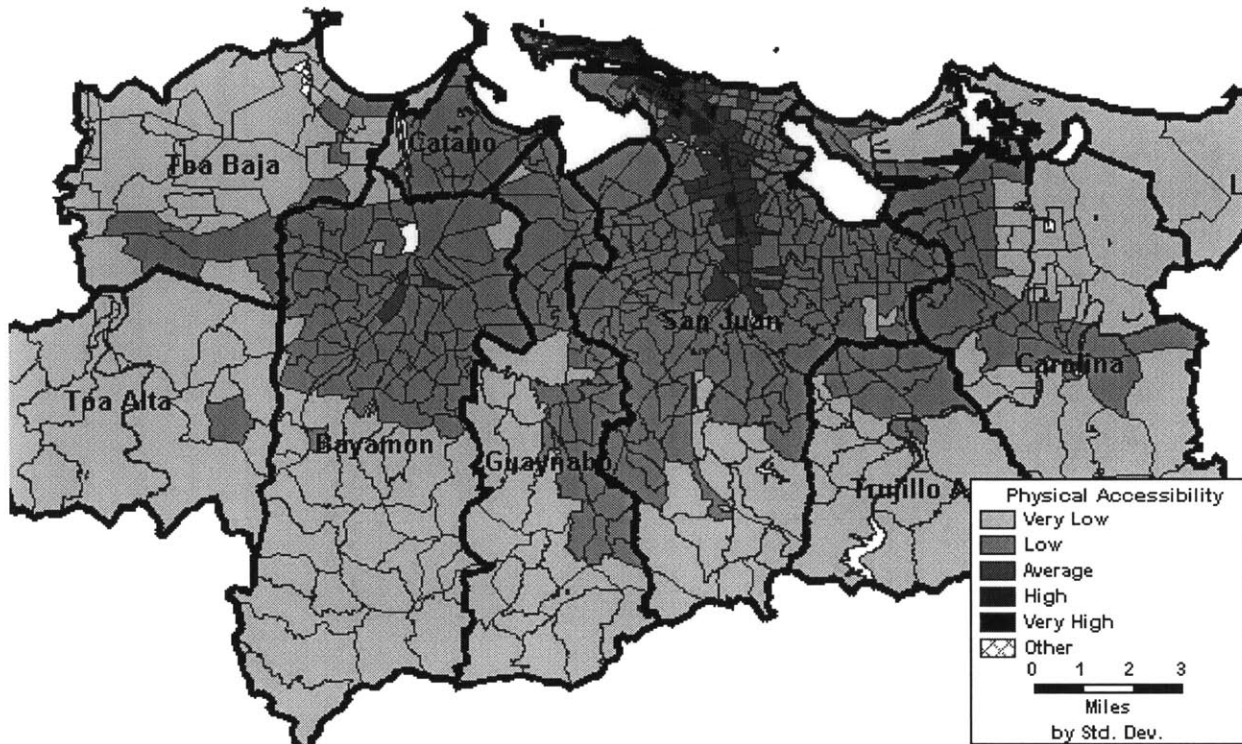
Figure 4.18. San Juan: Physical Job Accessibility, "Build"

Figure 4.19. San Juan: Change in Physical Accessibility as a Result of *Tren Urbano*

Chg. in Phys. Accessibility
- Very Low
- Low
- Average
- High
- Very High

by Std. Dev.
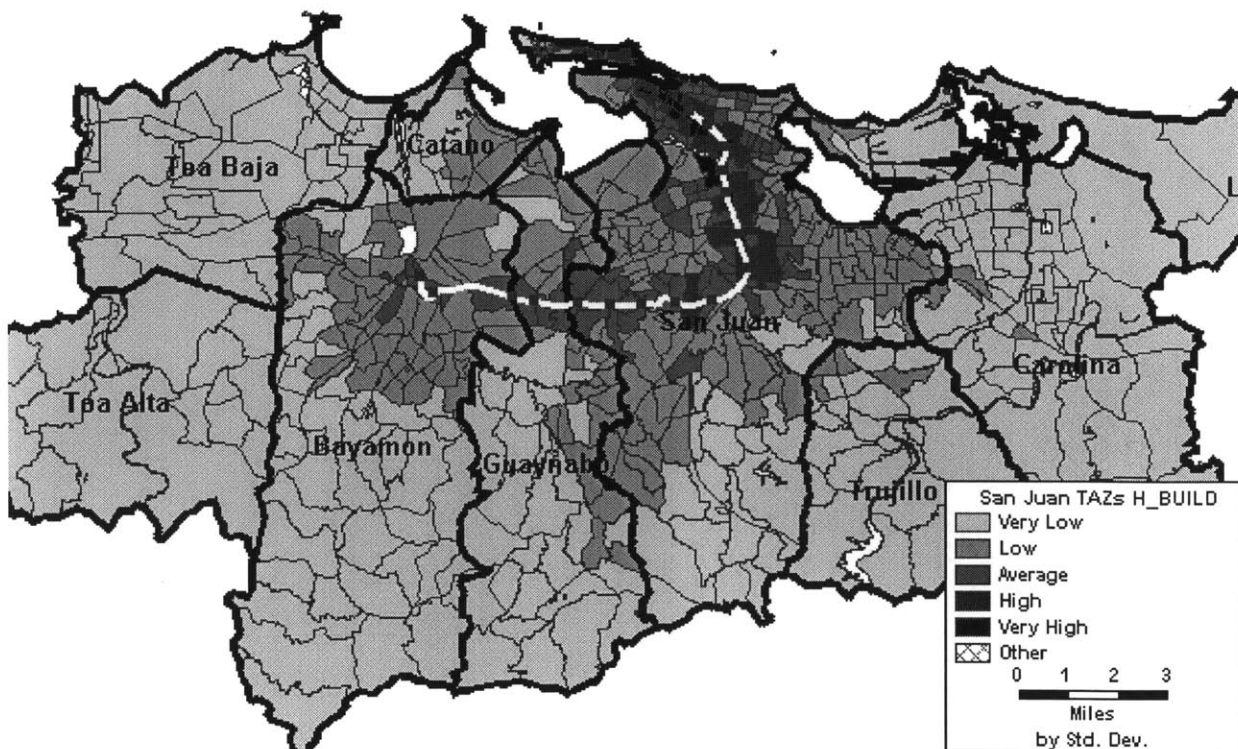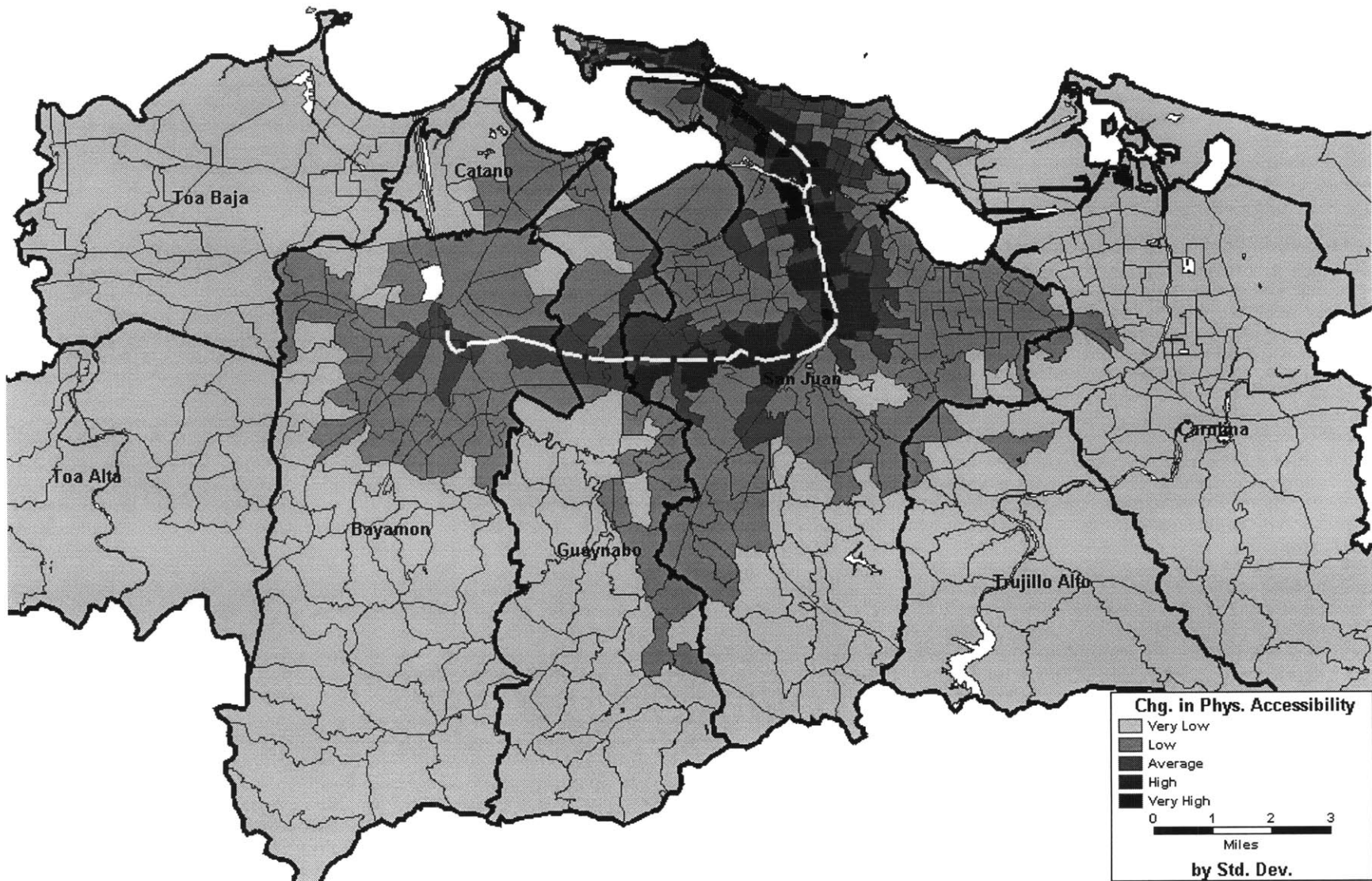
gain most. For example, one may delineate the Metrobus II corridor from Bayamón Centro to Hato Rey as a significant "gainer". Also, along the line's east-west portion, sections near the middle of the alignment seem to gain more than areas near *Tren Urbano*'s ends. This fact arises from the two-direction improvement in travel times that residents at the line's middle sections experience – a phenomenon that proves to be quite significant later in terms of the supply-demand model's results.

Some welfare recipients seem to gain much from the line's implementation, though many do not benefit much. Recipients living in the Rio Piedras neighborhood, in particular, seem to benefit greatly. Also, though few of the region's recipients reside proximate to the line's right-of-way, many in the San José neighborhoods live within a mile-and-a-half and thereby benefit moderately. On the other hand, a very significant portion of recipients stands to gain very little in the way of accessibility. Low-income residents of Cataño, for example, seem to remain quite isolated from *Tren Urbano*'s benefits. Also, a majority of recipients live relatively far from the alignment, dispersed about the metro area. The exact nature of job accessibility benefits to welfare recipients remains unclear at this point.

These results, as well as those from study of Boston, demonstrate that high quality public transit strongly affects physical job accessibility. *Tren Urbano*'s implementation will significantly and permanently change San Juan's urban form.

San Juan: Competitive Job Accessibility (Supply-Demand Model)

Thus far, results from the two cities have been quite consistent. Both reject the notion that central city locations experience inherently lower physical accessibility. Also, both demonstrate that high quality public transportation strongly shapes the form of accessibility for low-income workers. However, the most interesting questions still remain. Exactly what effects will *Tren Urbano* have upon low-income workers' employment potential in San Juan? When one accounts for competition among workers, how much do welfare recipients stand to gain or lose from the new line? Also, what are the general effects of a new rapid rail line upon employment potential in a region?

Figures 4.20 and 4.21, on the following page show some answers to these questions graphically. Notably, even when accounting for worker competition, accessibility in both the "build" and "no build" cases remains strongly focused on central portions of the metropolitan area. This result contrasts with those from Boston and solidly rejects the modern interpretation of the spatial mismatch hypothesis in terms of its applicability to San Juan. While a spatial mismatch between jobs and workers still may exist in San Juan, and may be developing as jobs continue to decentralize, it presently does not resemble at all the model presented in context of post-industrial U.S. cities. The difference seems to arise from the relative heterogeneity of San Juan's urban form and demographics.

Without *Tren Urbano*'s construction, two very significant "hot spots" of job accessibility exist: one in the central San Juan spine and another around Bayamón Centro, which supports a very large confluence of *público*s and an AMA terminal. With construction of the line, the shape of competitive job accessibility more closely reflects that of physical accessibility, extending generally along the *Tren Urbano* alignment with short "fingers" extending along bus and *público* routes. Notably, two small areas just outside of these "hot spots" remain "accessibility rich" in both cases. One is an area south of Bayamón Centro; another, significantly, is around Plaza Las Americas. Though a very large number of welfare recipients live in the affordable housing developments next to the mall, the shopping center supplies a far greater number of jobs.

By far the most striking aspect of *Tren Urbano*'s addition, however, is its enormous effect upon the geographic distribution of low-income families' employment potential. Figure 4.22, two pages forward, shows the percent change in competitive job accessibility among low-income workers in the metropolitan area. Note that the lightest two shadings represent losses, up to more than   -50%, while the three darker shadings represent competitive gains, up to more than 100% positive. Given the competitive model's mathematical structure and meaning in this context, gains literally represent cases in which *Tren Urbano* increases a zone's physical job accessibility more than it does competing workers'. Conversely, losses literally represent cases in which competing workers' ability to access jobs increases more than does the physical job accessibility of workers in the zone of interest. Remarkably, low-income families living in central Bayamón and central San Juan, along *Tren Urbano*'s alignment, stand to lose competitive job accessibility

Figure 4.20. San Juan: Competitive Job Accessibility, "No Build"

Figure 4.21. San Juan: Competitive Job Accessibility, "Build"

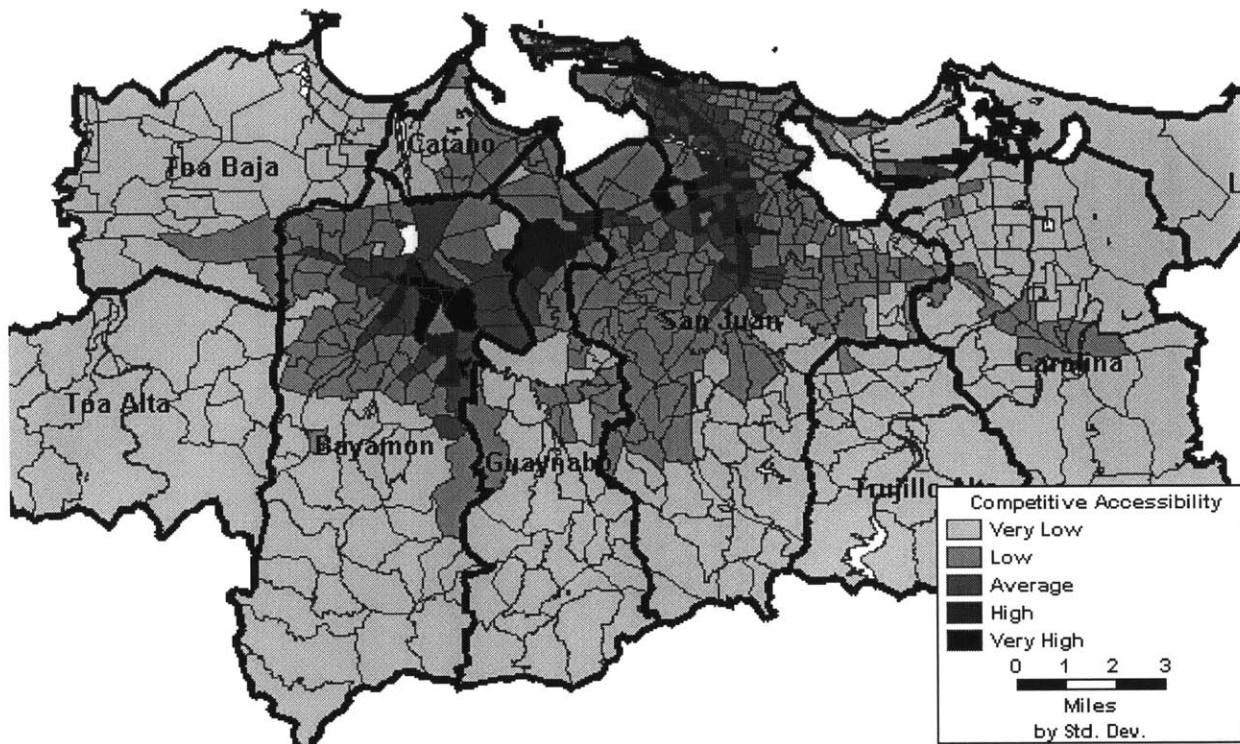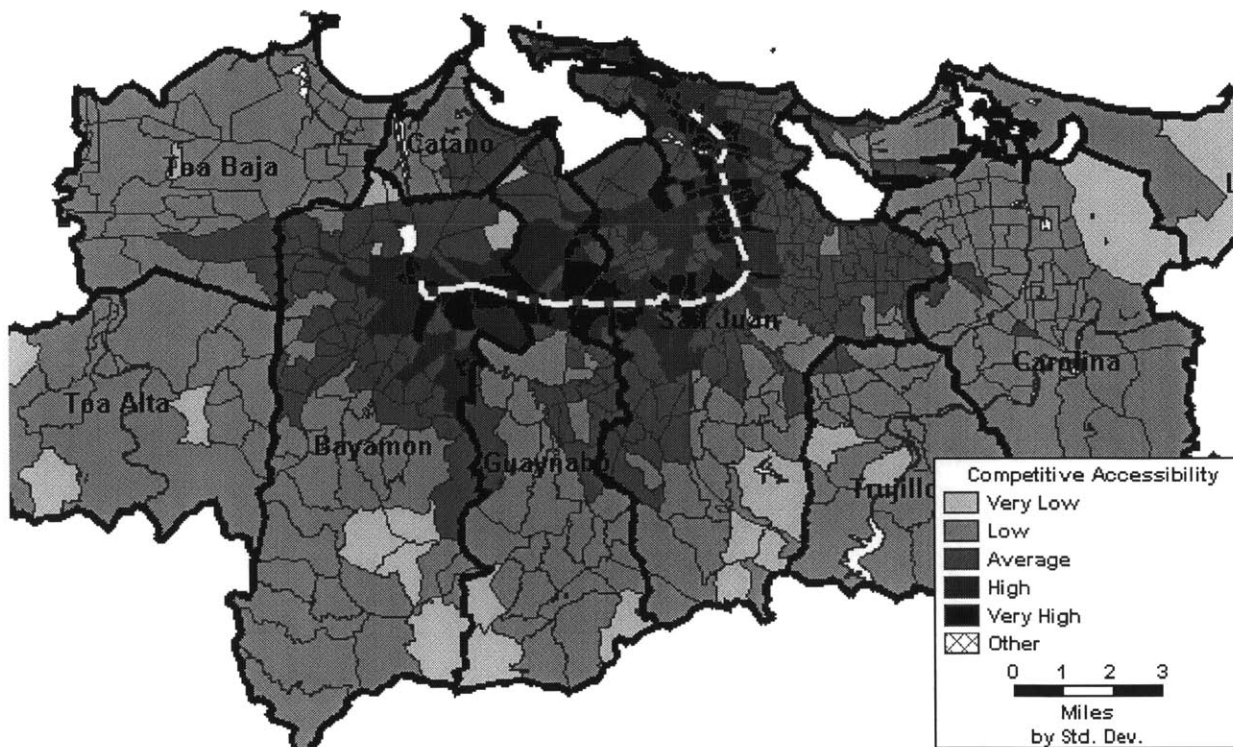**Figure 4.22. San Juan: Change in Competitive Accessibility as a Result of *Tren Urbano***
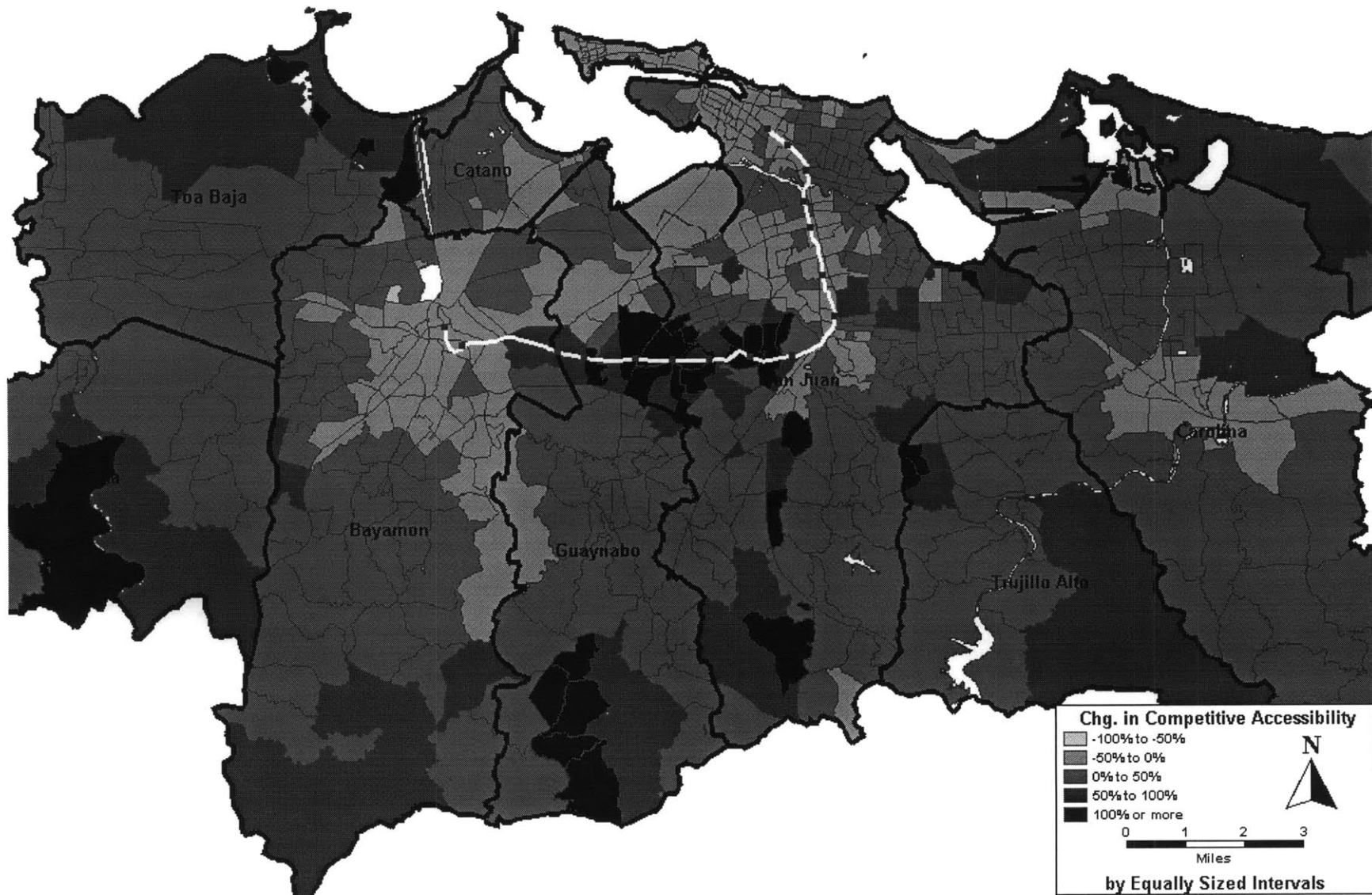
more than workers of any other area: by between 34% and 45% near Piñero Station (San Juan) and between 35% and 51% near the Deportivo Station (Bayamón). Meanwhile, low-income residents residing near the line's central portions, around Torrimar and Martinez Nadal stations, stand to gain by far the most – between 104% and 140%, effectively doubling their employment potential. Ironically, these areas also happen to be in San Juan's – and all of Puerto Rico's – wealthiest neighborhoods, where the potential for a low-income household to move in is relatively low. Aside from this "middle" section near Torrimar, areas farther from the central city also experience competitive job accessibility improvements, though only slightly. The pattern highlights how *Tren Urbano* evens the regional accessibility "playing field", basically allowing residents farther away to commute more easily to jobs within the urbanized area.

The results arise from a complex but real set of economic circumstances regarding *Tren Urbano's* redistribution of competitive accessibility benefits. Because the middle portions of *Tren Urbano's* service area will experience the largest improvements in travel times by transit, workers living in those areas will be able to access the concentrated job centers in central San Juan, Bayamón and Santurce much more easily. Likewise, they will gain better access to the intermodal centers served by *Tren Urbano* – in particular, Deportivo and Piñero, but also others along the alignment. As a result, low-income workers residing near either the central financial district or Bayamón Centro will experience smaller competitive advantages to accessing the nearby jobs or public transportation services that before were much less available to relatively distant, competing workers. Also, workers residing near the line's middle section present an additional, competitive "barrier" between the workers and opportunities at opposite ends of the line. The net result is that workers in central San Juan and Bayamón no longer will experience as much of the competitive advantages in the labor market as they once did, while workers living elsewhere will enjoy better ability to compete for employment in the central job markets.

To illustrate *Tren Urbano's* effects more generally, the author asks the reader to imagine a metro area in which all jobs concentrate at the region's very center. Meanwhile, imagine that some workers live near the central job market though a majority resides quite far. Furthermore, imagine that only very poor transportation services facilitate trips between the outlying workers' residences and the central job market. Obviously, the few centrally located workers would enjoy

far better physical and competitive job accessibility to the local, central job market, than would those workers who must commute very long times. Next, imagine that transportation services from and to the central job market were improved quite substantially, such that outlying workers now could both access and compete for employment in the central market much more effectively. In this case, the centrally located workers, being located only steps from all the region's jobs, of course would retain their dominance over competitive job accessibility; however, they also would experience greater competition for those jobs. In effect, their competitive job accessibility would decline somewhat, as a result of other workers' much better ability to access the nearby jobs from far away.

This case exactly describes the phenomenon occurring in San Juan, as a result of *Tren Urbano*'s implementation, and results of the physical and competitive job accessibility models demonstrate these circumstances quite well. In the case of San Juan, two regional job centers exist – one in central San Juan and the other in Bayamón – while some jobs also are located in San Patricio (north of the line in Guaynabo), Plaza Las Americas (just west of Hato Rey), central Carolina, dense Santurce and Old San Juan. It is no coincidence that workers in these areas – as well as workers in areas with fast transit connections to these job centers – also experience reductions in their competitive job accessibility. The region's greater mobility allows workers to compete more ubiquitously for jobs, thereby reducing somewhat the importance of location. Meanwhile, the single area of relatively few jobs that will have significantly better access to *both* major employment centers also displays by far the region's greatest increases in competitive job accessibility.

Similarly, if one considers employers' competition for low-income workers to fill their entry-level positions, businesses in the central San Juan area will have to compete much more with those located along the line's east-west portion, where transit services are being improved most and where few establishments presently exist. The reader may find on the following page Figure 4.23, which displays the change in employers' competitive accessibility to low-income workers. The map looks quite similar to the one calculated for low-income workers. In short, employers currently along the line's central portions will experience the largest gains in their competitive

Figure 4.23. San Juan: Change in Employers' Competitive Accessibility to Low-Income Workers

Legend:

San Juan TAZs EMP_CH:1
- -100% to -50%
- -50% to 0%
- 0% to 50%
- 50% to 100%
- 100% to 200%

Miles: 0 1 2 3

by Equally Sized Intervals

accessibility to low-income workers, though employers of central San Juan will maintain their dominance over labor market access.

Effects Upon Welfare Recipients

Importantly, the question remains as to how welfare recipients in particular will experience the job accessibility benefits of *Tren Urbano*. To answer this question the author examined welfare recipients' job accessibility scores with and without the line, as compared to the larger set of low-income workers in each case. Summary results are displayed below in Table 4.12.

Table 4.12. **Job Accessibility Change Among Welfare Recipients, as a Result of** *Tren Urbano***: Competitive Job Accessibility Scores**

	"Losers"	"Gainers"	TOTAL
Number of Recipients	4,429	15,868	20,297
Average Competitive Job Accessibility, "No Build"[a]	2.23	0.79	1.11
Average Competitive Job Accessibility, "Build"[a]	1.60	0.95	1.09
Amount Change	-0.627	0.153	-0.02
Percent Change	-28.1%	19%	-1.5%

a – The average for all low-income workers is 1.00.

Of the 20,297 welfare recipients, 15,868, or 78.2%, will experience a gain in their employment potential, while the remaining 21.8% will experience a reduction. The "gainers" on average begin with a job accessibility score of only 0.79 (1.00 is the mean) but finish at around 0.95 on average. Those workers whose scores decline, however, lose a more significant portion of their accessibility potential than the gainers win – about 28.1% on average, from about 2.23 to just 1.60. These results reflect recipients' residential locations. A large majority lives either dispersed about the metro area, or in the *barrios* near Laguna San Juan – areas that experienced small or sometimes moderate gains in competitive accessibility. Meanwhile, a significant minority resides within the zones near Bayamón Centro, Hato Rey and Plaza Las Americas, as well as in distressed Cataño – all locations where accessibility generally declined.

The weighted, net effect is a 1.5% decline in competitive job accessibility among all welfare recipients. Meanwhile, *other* low-income workers gain by a comparable amount. If one

considers the labor market of welfare recipients and other workers below the poverty level as a "closed system" – that is, these workers may compete only for a partitioned, entry-level section of the job supply – then one expects a 1.5% decline in welfare recipients' employment rate as a direct result of *Tren Urbano's* implementation. In short, it seems *Tren Urbano* will reduce recipients' employment potential slightly while improving other low-income workers' ability to gain work. The direction of these results compares well with recent research by Zhang (1998), in which he reports that *Tren Urbano* will improve wealthy commuters' job accessibility more than it will the accessibility of those who earn less. This fact arises from the line's span of relatively wealthy areas, particularly those along its east-west portion.

The reader should note that these observations do *not* say that *Tren Urbano's* benefits are inherently negative. To the contrary, somebody is receiving those job accessibility benefits that welfare recipients on average are losing – and those persons happen to be other low-income workers. The line will improve people's ability to travel and physically access a wide array quality-of-life opportunities. The provision of improved accessibility undoubtedly is an inherently good quality that literally enlarges the world of physically accessible jobs, services, educational activities and other quality-of-life opportunities. However, the results here show that while accessibility in San Juan invariably will improve, it will do so non-uniformly and to the slight detriment of some of San Juan's most needy population. Of *Tren Urbano's* various "redistributive" effects, about 22% of the poorest of workers will sustain a real reduction in their employment potential, as a result of the greater competition they will experience from other low-income workers for the limited supply of entry-level jobs. In short, though all welfare recipients will have an easier time getting to work, some will experience a harder time gaining employment.

4.5. Conclusions

The results highlight effects of public transportation that existing concepts of accessibility and urban rail transit do not formally take into account. Since resources such as jobs are limited and therefore economically scarce, and because the provision of transit services produces an

inherently uneven distribution of benefits, some persons undoubtedly experience negative effects as a result of a new service's implementation. In some cases, such as the one explored here, the negative effects may occur even in the same "units" as those the service purports to improve most. For example, *Tren Urbano* provides inherently better physical accessibility to jobs, though some experience poorer employment potential as a result, even along the line's trunk sections.

In addition, the results highlight empirically that the introduction of urban rail transit does not on its own ensure a re-concentration of population or employment toward the new service's alignment. While *Tren Urbano* greatly improves regional job accessibility for some portions of its service corridor, it more consistently effects a decrease in employment potential in existing job centers; meanwhile, it systematically improves employment potentials in suburban and ex-urban communities that will be able to compete much more effectively for central city jobs. The net effect is that, all other things remaining the same, living outside the central city will become somewhat easier. Employers of entry-level positions, also, will find it somewhat easier to locate outside the existing downtown and still find enough workers. In context of present trends of employment decentralization in San Juan, *Tren Urbano* seems to encourage more rapid exodus to the suburbs, given no other intervention. However, the tremendously large improvements the line affords in terms of physical accessibility concentrate overwhelmingly around its stations. In this respect, low-income workers who live near *Tren Urbano* stations will experience large increases in their abilities to access the multitude of destinations in San Juan that support their quality of life.

From Boston the research has observed how urban rail transit significantly improves the physical and competitive job accessibility of low-income workers and thereby counters the negative effects of poverty concentration by allowing them to compete for jobs outside local, low-income enclaves. From San Juan the research has observed that high quality transit significantly improves physical job accessibility for car-less workers but that, as a second-order effect, high quality transit may *spur* suburbanization. While *Tren Urbano* provides significant opportunity to positively affect land use patterns in the region, its net effect with no other interventions is allow more easily a further decentralization of the metropolis. Clearly, progressive public policies are needed to capitalize fully upon *Tren Urbano*'s physical accessibility benefits; else, they may not

be realized, and the pace of San Juan's suburbanization might only increase. The stakes are high; *Tren Urbano* is a pivotal turning point in San Juan's urban development.

The results indicate also that the existing, modern model of spatial mismatch is inadequate to explain the full scope of circumstances affecting the employment potentials of low-income families in urban areas. Existing literature generally overlooks the substantial interaction of transportation with these social and economic variables as they relate to urban labor markets.

Results confirm unequivocally that space is an important factor affecting job accessibility, and that furthermore, transportation plays a pivotal, indispensable role in this regard. While the existence of good, affordable transportation allows low-income families to compete more effectively for jobs outside their neighborhood enclaves, the lack of such service severely constrains their potential for employment and thereby contributes acutely to the economic dysfunction of inner-city areas. The unfortunate significance of race only augments the negative spatial effects of concentrated poverty by further increasing the size and intensity of isolated low-income enclaves. The job accessibility effects of worker competition and concentrated poverty are greatly underestimated in the literature, which furthermore overlooks the nature of these factors' relationships to affordable transportation.

In addition, the research shows cogently that racial segregation plays a powerful and pernicious role in reducing low-income families' job accessibility, specifically by concentrating many spatially constrained, entry-level workers into dense ghettos from which they must compete more intensely for a limited supply of accessible employment. Ellwood's 1987 epigrammatic conclusion, "The answer is race, not space," clearly oversimplifies the complex issues at hand. In fact, racial inequity greatly augments the significant barrier of spatial isolation.

In terms of specific policy alternatives for Boston, results indicate that the pursuing transportation options could be far more effective than implementing a residential relocation program. While poverty concentration does affect workers' job accessibility negatively, moving them to ex-urban areas would place upon them much greater burdens of spatial limitations. Furthermore, the capacity of outlying areas to support additional low-income workers remains

very small, despite their relatively high accessibility scores. If any residential relocation program were pursued, it should focus on making housing affordable *within* the central city area, particularly north of the Charles River. Overall, it seems clear that pursuing transportation options has much greater potential for success.

Finally, the results are revealing in terms of this methodology's usefulness in measuring the social and economic distribution of benefits, whether negative or positive, of urban transit investment. Accessibility is real and significant. Jobs, households and other quality-of-life opportunities choose their locations and define their levels of interaction based on basic principles of accessibility. A way to measure accessibility seems essential to the accurate assessment of transit investments' value. The methodology herein soundly accounts for this real benefit that traditionally has been too complex to examine and therefore overlooked. Importantly, the study delineates a practical process for measuring accessibility with existing GIS tools. Its application to the study of rail and bus transit investments could contribute greatly to planners' understanding of new services' effects upon the social and economic forces that affect urban living. Chapter 6 discusses further steps that will be important for integrating this methodology into a planning framework for standard practice.

From this point, the objective is to explore the specific transit services and land use policies that best would best help improve the physical job accessibility of those in San Juan whose employment potential is relatively low. The next chapter explores these issues in greater depth, building upon the observations presented thus far. ■

Chapter 5

Policy Analysis: San Juan

What makes *Tren Urbano* a success? The examination of benefits in this study has taken a perspective different from the traditional one. Instead of approaching the issue in terms of strictly improving ridership – that is, what San Juan can do for *Tren Urbano* – it has examined potential effects of the line directly upon the well-being of metro San Juan's residents. The previous chapter has shown that high quality rapid rail great improves low-income families' ability to access jobs and compete for employment. Furthermore, it has shown that *Tren Urbano* greatly will improve physical accessibility, such that workers around its stations will experience the region's very best ability to access and compete for employment. At the same time, *Tren Urbano*'s benefits will be distributed unevenly, such that welfare recipients will experience a slightly more difficult time competing with other low-income workers for employment. In light of this fact and the reality that *Tren Urbano* does not directly serve the entire metropolitan area, what complementary land use policies and transportation services would best help meet the accessibility needs of San Juan's population of greatest transportation need?

Measuring transit's success proves to be a difficult task, both because the definition of real achievement varies widely and because transit's benefits are so complex to quantify. Some potential benefits include encouraging economic development (Cervero, 1994; Zhang, 1998), bettering land-use patterns and urban design (Knight and Trygg, 1977; Rudy Bruner Foundation, 1992; Bernick and Cervero, 1994; Vuchic, 1996), improving the environment (EPA, 1990), reducing auto congestion (Johnson, 1993; GMAEC, 1997), promoting equity (Hoeveler, 1997; Zhang, 1998), and improving overall quality of life (Vuchic, 1996), among others. Of these, equity typically has been most sensitive to the level and quality of transit investment in the U.S. The few notorious cases in which rail investment has divided a region socially have been those in which low-income residents have perceived that the rail system has furthered inequity. If *Tren*

Urbano is to be a success, it must promote the social and economic prosperity of all of San Juan's residents.

5.1. Overview

This chapter identifies and prioritizes the strategies that would be most useful for helping San Juan's welfare-dependent workers reach employment. First, the most significant improvement in service to some transportation-disadvantaged households would be having access to any service at all. In this regard, the study identifies concentrations of recipients who are isolated from the system and who could be served effectively with simple extensions or additions to existing service.

Second, existing service could be improved for those who presently have access. Such improvements might include providing more direct service, providing new service, adjusting or increasing the frequency or reliability on particular routes. In this regard, the research maps entry-level job surpluses and deficits in the metro region – the latter representing relatively high concentrations of recipients where few jobs are located. Then it compares the geographic patterns of job "hot spots" and "cool spots" to competitive accessibility results from Chapter 4, and identifies a final set of origin and destination areas between which improved or additional service would be most exceptionally beneficial. From this examination the research both identifies those routes most important to low-income workers and suggests new services that would help low-income workers reach job centers more effectively. A policy of particular interest in this context is that of insuring afternoon *público* services. Many recipient households reside in sparsely populated areas that only *públicos* could or do serve viably. Currently, afternoon service remains far less reliable or frequent than in the morning, since operators often retire early for the day, having earned enough from the fare box for. This section therefore estimates the possible accessibility benefits of improving *público* service.

Third, the analysis examines the potential benefits of promoting specific transit policies or *Tren Urbano* extensions. *Tren Urbano* could be extended to Carolina, to the Airport or to Viejo San

Juan. The research evaluates the relative effectiveness of each proposed extension and prioritizes them in terms of their ability to provide direct access to additional entry-level jobs or recipient households not already served by the system.[1]

Finally, the analysis reviews particular land use policies that might have great potential for improving recipients' physical and competitive job accessibility. Specifically, such policies would include changing the locations of recipients by various means.

5.2. Strategy: Provide Access to the Transit System

For nearly all recipients, the issue of gaining employment first involves catching a bus or *público*. For some, however, public transportation never traverses their neighborhood. The major transportation issue for these households entails simply gaining access to the system. This section examines the coverage of existing transit services, identifies concentrations of recipients who currently have no access and proposes service adjustments based on their ability to provide access to these isolated households.

5.2.1. System's Existing Provision of Access

AMA, *públicos* and *Tren Urbano* together serve a great majority of the metro area's population. Using ¼-mile bands as a measurement tool, one finds that *públicos* cover 120.7 square miles of the region's 254.3, while the AMA system, which operates more line haul and trunk service, covers about 52.1 square miles. Phase 1 of *Tren Urbano* provides the most focused coverage – just 3.0 square miles assuming ¼-mile radii from stations, or 8.9 square miles using ½-mile bands. Notably, the smaller, more agile *públicos* more extensively serve sparsely populated areas, particularly in the region's mountainous areas to the south, but also in the east and west. The higher capacity, less agile AMA buses, on the other hand, focus service principally in

[1] Certainly there exists a large host of factors affecting whether any particular extension would be viable. The analysis here attempts to isolate the variable of recipients' access to the system and the entry-level jobs that may be accessible from *Tren Urbano*. The results easily could be used in a more thorough planning analysis.

densely traveled, urbanized corridors. Patronage reflects the respective service strategies – with a far greater share of journey-to-work trips in central San Juan going by AMA but a much larger proportion in rural areas traveling by *público*. Figures 5.1 and 5.2 on the following page demonstrate this phenomenon clearly.[2] Together, the two systems' technologies and service patterns complement one another very well.

Analysis shows that the AMA and *público* systems together provide excellent access to entry-level jobs though only moderate access to welfare recipients, who more often reside in rural areas of little or no service. More than 80 percent of entry-level jobs in the region are located within ¼-mile of an AMA or *público* stop, and *nearly all* fall within a ½-mile (see Table 5.1, below). Stations of Phase 1 of *Tren Urbano* serve within ½-mile of nearly 30% of entry-level jobs in the region – a very high portion given the line's limited extent. Excellent access to entry-level jobs reflects both the systems' nearly ubiquitous coverage of the metro area and the jobs' overwhelming propensity to locate centrally in San Juan. On the other hand, recipients experience much lower levels of access to the systems. Only one in ten recipients resides within ½-mile of a *Tren Urbano* station (and one in 27 within ¼-mile). Clearly, both *Tren Urbano* and the bus systems serve job centers more effectively than they do recipient households. At full build-out, however, *Tren Urbano* stations would serve within a ½-mile of a very substantial portion of both recipients and jobs – 28.8% and 79.9% respectively.[3] Still, the relative service to job centers would be much greater. Providing access to recipients therefore should be a priority of AMA and *público* services.

Table 5.1. Metro San Juan: Transit Access among Welfare Recipients and Entry-level Jobs, by Mode (percent)

	Welfare Recipients		Entry-level Jobs	
SYSTEM	1/4 mile	1/2 mile	1/4 mile	1/2 mile
Tren Urbano Phase 1 (rapid rail)	3.7%	10.0%	11.0%	28.6%
AMA (bus)	53.1	66.2	77.5	89.5
Públicos (jitney)	70.2	86.7	82.5	96.6

Note: these counts cover all of metro San Juan, a 254.3 sq.-mi. area. Counts for *Tren Urbano* are for Phase 1 only.

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[2] The two maps use exactly the same scales also; thus they are highly comparable displays. Interestingly very few trips transfer between the two modes – only about 6% in 1993 (Barton-Aschman, 1993).

[3] Later discussion addresses the marginal benefit of each extension in this regard.

Figure 5.1/5.2. Work Trips by AMA or Publico in Metro San Juan

Ratio of Publico to AMA Work Trips

Much More AMA
Somewhat More AMA
About the Same
More Publico
Other

0   1   2   3
Miles
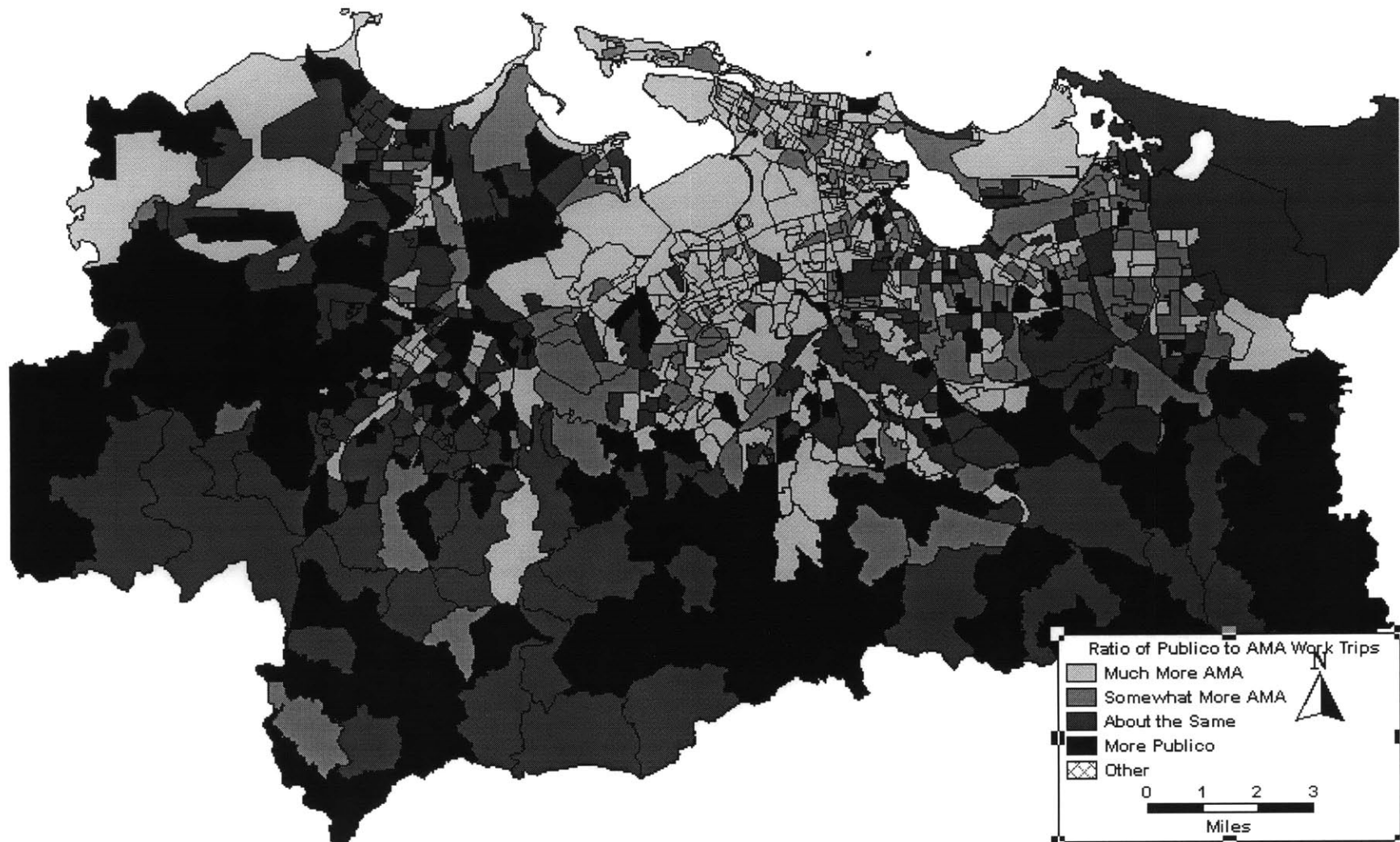
Comparison to Boston

One gains a better understanding of the relative quality of these figures by comparing them with the same counts from Boston (see Table 5.2, below). The most comparable area from Boston is that within the Route 128 beltway. In comparison with *Tren Urbano*'s Phase 1, Boston's rapid rail system proportionally reaches 3.4 times as many of its region's recipients and nearly twice the proportion of its entry-level jobs. Even compared to full build-out of *Tren Urbano*, the MBTA's rail lines still would serve a greater proportion of its region's recipients (32.7% versus only about 28% for *Tren Urbano*). However, at full build-out *Tren Urbano* would serve a *substantially larger* proportion of its region's entry-level jobs (about 69% compared to only 34.3% for the MBTA). It seems that although *Tren Urbano* serves a relatively small portion of the San Juan region's recipients, the rail system at full build-out has great potential to serve the job centers that low-income workers value most. Again, results confirm that providing good transit access to welfare recipients via AMA and *público* services should be a priority.

Table 5.2. Inner Suburbs and Central Boston: Transit Access among Welfare Recipients and Entry-level Jobs, by Mode (percent)

	Welfare Recipients		Entry-level Jobs	
SYSTEM	1/4 mile	1/2 mile	¼ mile	1/2 mile
Rapid Rail	12.6	32.7	21.3	34.3
MBTA Bus	84.3	95.2	74.8	90.6

Note: these counts cover portions of the Boston region within the Route 128 beltway, an area of 371.1 square miles.

Isolated Recipients

Even with *Tren Urbano*, however, a very large number of recipient households in San Juan will remain without any transit access at all – an incredible burden when one has no access to a car. It is important to realize that a seemingly good "86.7% coverage" rate means that a full 13% of recipients have absolutely no independent means of long-distance mobility.[4] These households cannot access *any* transit service within ½-mile of their residences. Just where are these isolated households located? Could additional transit service viably serve any possible concentrations of them? If not, what other means of providing mobility could be pursued?

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[4] The 86.7% rate is for ½-mile coverage of the existing *público* system. Approximately 6% of recipients nationwide do have auto access.

5.2.2. Strategy: Expand AMA or *Público* Coverage

Examination of the regional map of transit coverage reveals that the single greatest potential for serving the population of isolated recipient households exists in western portions of Loiza. In this sparsely populated, 6 square-mile area, there reside 836 welfare recipients – more than one-third of the entire region's isolated recipient population – and nearly no entry-level jobs. In terms of competitive job accessibility the zone scored 0.16, among the region's very lowest (regional weighted average was scaled to 1.00). Serving this area likely would be a financial challenge, since it supports a population density of only about 350 people per square mile. However, the potential to significantly improve the employment potential of so many recipients, even though dispersed, seems far too great to overlook.

It just happens that two "job rich" transit lines presently extend to the rocky, western tip of Loiza – serving its roadside shacks, outdoor fruit stands and shabby though charming beachside pubs. The two lines terminate currently in a large bed of dry dirt and gravel. One route is a *público* line that currently runs through Isla Verde into tourist areas of Condado. After serving hotel-lined Avenida Loiza in Santurce it finally terminates at Parada 18, a major transit center with connections to Old San Juan, Hato Rey and San Patricio. Second, AMA's Route B40 runs a scheduled 20-minute headway through the Isla Verde transit center and directly into the incredibly job-rich airport. The line continues south across the Theodore Moscoso Bridge, from where PRHTA plans to re-routes the line to the University of Puerto Rico's Río Piedras campus (*Tren Urbano* Feeder Bus Plan, 1999). The campus and surrounding, dense neighborhood not only offer a plethora of entry-level positions; they also support the Capetillo transit center and two *Tren Urbano* subway stations in the heart of San Juan. For low-income residents of Loiza, *the potential employment benefits of a simple extension of either line clearly are enormous.* While an extension may not gain much ridership, it would represent the lifeblood of economic activity for some of San Juan's poorest, most isolated households. For many of them, the world of available jobs, services and quality-of-life opportunities in central San Juan lie only as far as the availability of Route B40 or its parallel *público* service. Figure 5.3 on the following page shows these two existing routes in the context of Phase 1 of *Tren Urbano* and the region's transit centers. The opportunity for access seems tremendous.

This solution still would leave a significant number of recipient households isolated in sparsely populated portions of the region's southern and western fringes. Unfortunately, no particular concentration of recipients allows for any simple extension or re-routing of existing services to reach a significant portion of them. If AMA or the Puerto Rico Highway and Transportation Authority (PRHTA) do choose to provide special transportation services to these areas, for the purpose of connecting recipients to the opportunities presently unavailable to them, they should pursue the initiative on the basis of individual needs. In Boston, for example, the MBTA provides a van service called the RIDE for elderly and relatively immobilized persons, that brings otherwise isolated persons, along with their care-givers, to and from nearby transit stops or final destinations. The van service, though expensive, serves a great societal purpose, such that Massachusetts and the MBTA continue to fund and expand the service. Similarly, PRHTA could hire portions of the retiring *público* drivers and fleet who otherwise would leave operations permanently. Such a strategy would help maintain the *público* network, one of San Juan's transit system's greatest assets. Additionally, as an institutional mechanism, PRHTA should coordinate with the local transitional assistance agency to identify and serve those who would benefit most. A special service dedicated to addressing the mobility needs of these isolated households seems essential to both San Juan's and these households' well being. Other creative ideas surely exist, as do the tools for implementing such service; providers need only the means and will to identify and pursue solutions.

5.2.3. Strategy: Extend *Tren Urbano*

Alternatively, San Juan could choose to pursue the option of extending *Tren Urbano* to the airport, Old San Juan or Carolina. Would such extensions significantly improve recipients' access to *Tren Urbano* or job locations? In terms of job accessibility, which extension should receive highest priority?

As observed earlier, Phase 1 of *Tren Urbano*, provides access to employers far more effectively than it does to welfare recipients. Therefore, while extensions should be evaluated in terms of their abilities to improve access for both employers and recipients, improving recipients' access should receive greater weight. At least two rational measures support this view. First, the total

Figure 5.3. Routes That This Research Proposes to Extend into Loiza
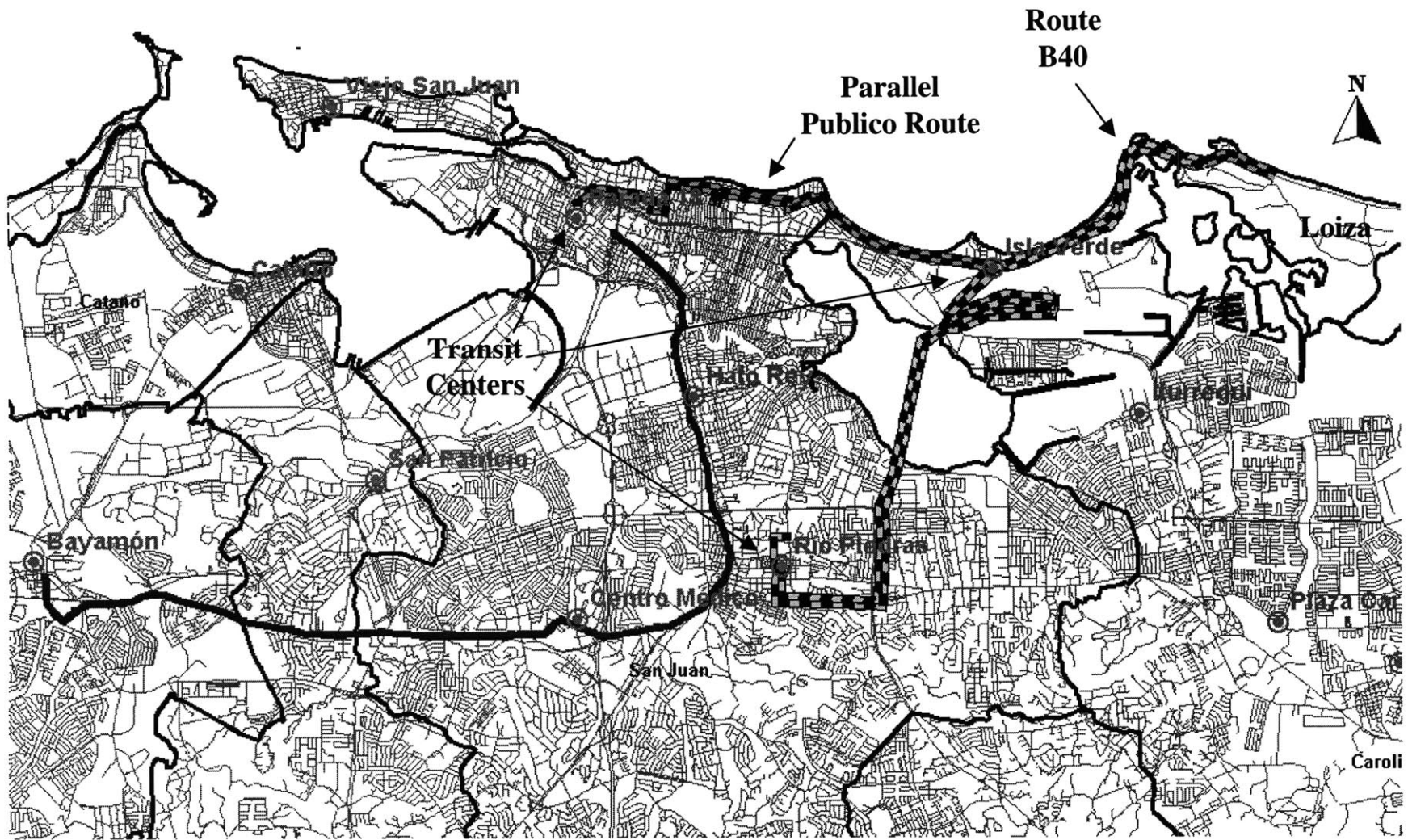
number of possible recipient-job connections is maximized both (1) when greater numbers of recipients and employers have access and (2) when an equal number of each have access. For example, if *Tren Urbano* provides access to eight recipients and two jobs (a total of ten locations), there are 16 possible pairs, though given five of each (still ten locations) there exist 25. Thus, if more employers currently have access, then the marginal benefit of providing access to additional recipients is greater. More importantly, however, providing access to recipients is simply more important. Since each recipient may take only one or two jobs, as long as more jobs have access than recipients, providing access to recipients remains inherently more beneficial to their employment accessibility. Furthermore, job accessibility comprises only one aspect of households' mobility-related needs. Quality of life depends also on physical access to cultural, social and educational opportunities and services. Thus, the evaluation of *Tren Urbano* extensions weights providing access to recipients more heavily than providing access to employers.

Table 5.3, below, shows the relative portions of the region's welfare recipients and entry-level jobs that would have direct access to *Tren Urbano*, given each one of its possible extensions. The reader should note that the "TOTAL" row equals the addition of the other four – a slight overestimate of the true proportions, since the extensions' service areas overlap with Phase 1 near intersecting stations. However, the numbers provide a good idea of the potential impact of a full build-out of *Tren Urbano*. In addition, it is important to note that the Airport extension's results do not include the vast majority of jobs at the airport itself, since they are located in the terminal, which remains more than ½-mile away. With quick shuttle services from the Airport Line into the terminal, one may view the actual number of jobs accessible from this extension as being higher than shown here.

Table 5.3. Recipients and Entry-level Jobs Within ½-mile of *Tren Urbano* Segments

	Welfare recipients	Entry-level Jobs
Phase 1	10.0%	28.6%
Old San Juan	2.6%	18.6%
Airport	8.4%	12.8%
Carolina	7.7%	9.6%
TOTAL	28.8%	69.7%

According to the results, Phase 1 clearly provides the greatest level of direct access to both welfare recipients and entry-level jobs. All extensions and Phase 1 itself invariably provide better access to job sites than to recipients. Comparing the three extensions, one immediately may eliminate the Carolina Line from the list of best candidates, since the Airport Line provides better access in both respects. Accounting for the underestimate of entry-level employment served by the airport extension, this line becomes even more attractive. Finally, the relatively short but expensive Old San Juan extension provides the highest reported access to entry-level jobs but would improve recipients' access very little and therefore is relatively less desirable. Thus, the Airport Line seems to have the greatest potential for improving recipients' direct access to employment via transit. In addition, the costs of constructing a line to the airport are lowest of the three extensions. Thus, in simple terms of capital cost effectiveness, an airport extension clearly would be the most beneficial investment for improving direct access to *Tren Urbano* for welfare-dependent households.

5.2.4. Summary

Of the service alternatives that would improve access to the transit system, the one of very highest priority seems to be extending AMA Route B40 and the parallel *público* line further into western portions of Loiza. To serve the remainder of recipients by transit, a set of special services, similar to Boston's RIDE, seems to constitute the most effective transportation solution for providing access. Section 5.6 later evaluates the effectiveness of relocating recipients as an alternative strategy. Finally, of *Tren Urbano*'s possible extensions, the Airport Line has potential to improve the largest number of recipients' access to the system.

5.3. Policy: Adjust, Preserve or Improve Existing Services

Some services' improvements could greatly improve recipients' ability to access employment. This section identifies the existing AMA routes most important to welfare recipients' job accessibility and explores additional, practical services that would have very good ability to improve their employment potential, in context of San Juan's larger system of transit services.

Since the institutional arrangements of San Juan's transit systems afford much greater ability for this research to influence *specific* improvements for AMA services than for *públicos*, this section's examination of key routes and new services focuses upon the former. In all cases, the analysis meanwhile takes into account the travel needs currently served by the *públicos*.

5.3.1. Job Surpluses and Deficits

To accomplish this objective, the research calculates the job surplus or deficit in each zone, measured as the numerical difference between jobs and low-income workers, divided by land area to control for variability in tract size. The resulting numerical values represent the relative *intensity* of job surpluses or deficits. Negative scores therefore represent a greater number of low-income workers than entry-level jobs – the case of a deficit. Figure 5.4 on the next page displays the result in a theme map classified by 0.5 standard deviation intervals. The map's view is zoomed to urban portions of the region, since outlying areas all exhibit relative balances between jobs and recipients, likely because of the lower intensity of land use there. The map shows clearly that by far the most vast areas of deficit exist in large, contiguous blocks of eastern Santurce and along the western banks of Laguna San Juan. Small pockets of significant deficit also exist in Cataño and in the eastern portion of Old San Juan, while less intense deficit "pepper" the landscape. Conversely, the area of most intense job surplus exists at Plaza Las Americas. The mall and surrounding businesses support about 12,000 jobs in entry-level-rich industries within a relatively small area that constitutes a major center of employment for persons of recipients' typical skill levels. Other significant surpluses also exist at or around:

- Hatro Rey Centro,
- western portions of Santurce (near Condado),
- Old San Juan, at Plaza Carolina,
- central Río Piedras,
- the San Patricio transit center, and
- Bayamón Centro.

Notably, though several pockets of surpluses and deficits exist, most of the region displays fairly balanced levels of jobs and recipients.

Figure 5.4. San Juan: Job Surpluses and Deficits

Catano

Carolina

San Juan

Bayamon

Guaynabo

Job Surplus
per sq. mi.

- ☐ -100000 or less
- ▨ -9600 to -6000
- ▨ -6000 to -1700
- ▨ -1700 to 2300
- ▨ 2300 to 6000
- ▨ 6000 to 10100
- ■ 10100 or more
- ▨ Other

0   .50   1   1.5

Miles

by 0.5 Std. Dev.

5.3.2. Strategy: Preserve Key Existing Routes

Multisystems' "*Tren Urbano* Feeder Bus Plan" (1999) adds 57 buses to the existing AMA network (an increase of 30%) and significantly improves service by the year 2001, reducing headways on most lines and implementing a service policy of new 20-minute maximum scheduled headways. Presently, maximum scheduled headways are 30 minutes, and actual average headways reach as high as 51 minutes on some routes because of many missed trips.[5] The Feeder Bus Plan also eliminates two express commuter services and adds five new routes, all of which feed *Tren Urbano* stations. In addition, the Plan shortens or modifies several routes, though the sum of its recommended changes seem minimal in light of a major new rail line's addition to the transit system.

From examining both the map of job surpluses and deficits and the system of existing services, the study identifies six key AMA bus routes that pair significant concentrations of jobs and recipients. The services that are provided by these key routes should be given the highest priority of being preserved or improved, either through a continuation of existing operations or by comparable replacement service. Table 5.4, on the following page, shows these routes, including the major job and recipient concentrations they serve. The table also provides information about the relative level of existing and planned services, according to Multisystems' "*Tren Urbano* Feeder Bus Plan" (1999), and most importantly, lists key recommendations in regard to the 2001 plans for each line. These recommendations take into account the particular benefit that each route provides to welfare recipients and the larger low-income population and should be considered in light of AMA's larger service goals. They reflect a greater emphasis being placed upon the well being of San Juan's most transportation-disadvantaged households.

Figure 5.5, two pages forward, highlights geographically these key routes in context of the region's job surpluses and deficits. The most important key service is identified as being Route A3, which provides a direct link between relatively isolated, "job accessibility poor" Cataño and entry-level job centers at San Patricio, Plaza Las Americas and Hato Rey. Multisystems'

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[5] This figure comes from Multisystems' bus monitoring report from October of 1998.

Table 5.4. Priority AMA Routes, and Recommended Adjustments to Them

	Rte.	Significant Destinations	Weekday Psgrs. (Rank)	Daily Boaridngs/ Rev-Mi. (Rank)	Headway 1998	Multisystems T.U. Feeder Bus Plan		Recommendation
						Headway 2001	Planned 2001 Routing	
1	A3	Catano (recipients) to San Patricio (jobs) to Plaza Las Americas (recipients & jobs) to Hato Rey (jobs) to Rio Piedras (recipients & jobs)	7,080 (4)	6.2 (2)	15	10	**No Change** in route	Keep as planned
2	A9	Rio Piedras (recipients & jobs) through San Jose (jobs & recipients), through eastern Santurce (recipients) to Parada 18 (jobs), to Old San Juan (jobs & recipients)	12,455 (1)	8.8 (1)	10	8	**Shorten** route to operate between Rio Piedras and Isla Grande (convention center)	**Restore route to Old San Juan; bypass Isla Grande**
3	C11	Eastern Santurce (workers) to Hato Rey (jobs, transit)	1,144 (18)	3.7 (9)	30	20	**No Change** in route	**Extend to Plaza Las Americas**
4	B15	Rio Piedras (workers, jobs) through San Jose (workers), to Hato Rey (jobs)	1,462 (15)	2.9 (15)	20	15	**Re-route** via Pinero Expressway to UPR Station	**Straighten the route through Hato Rey and extend it to Plaza Las Americas**
5	A5	Old San Juan (jobs, recipients) to Parada 18 (jobs, workers), along Avenida Loiza (recipients) to Isla Verde (jobs), near airport (jobs) and to Iturregui	9,691 (2)	4.6 (4)	8	7	**No Change** in route	Keep as planned
6	A6	Carolina (recipients) to Plaza Carolina (jobs), through Avenida 65 de Infanteria corridor (recipients) to Rio Piedras (recipients, jobs)	6,882 (5)	5.5 (3)	12	5	**Re-route** to Iturregui Ave. and operate express to Centro Judicial Station via PR8 and Pinero Expressway. **Replace** with new Route 7 (Central Judicial to Carolina via PR3) and new Route 46 (Centro Judicial to Iturregui via PR3)	Re-route and replace as planned

Note: Routes are listed in order of priority, from 1 (highest) to 6.

Figure 5.5. Key AMA Routes
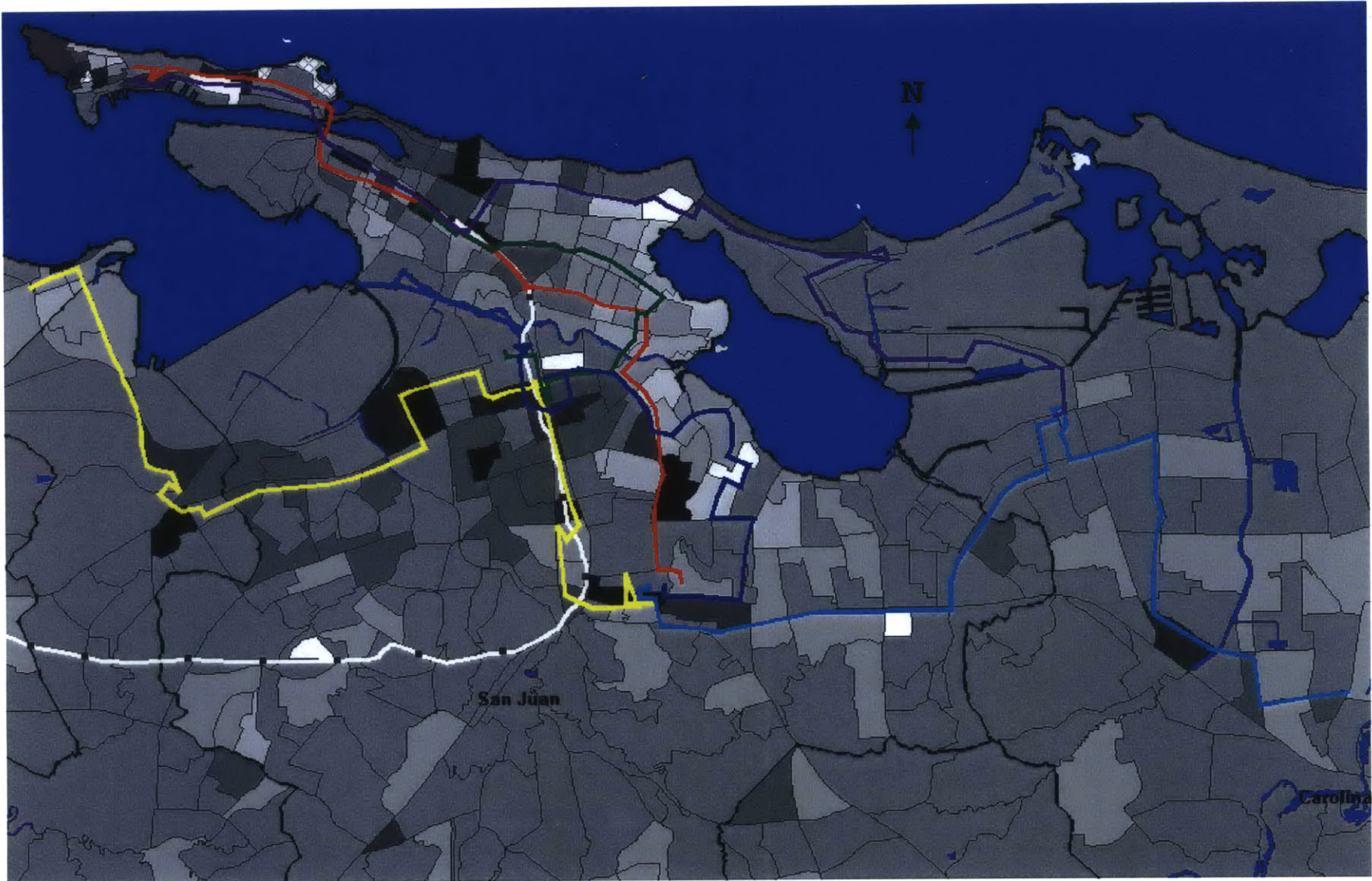
recommendation to add buses to this key service and shorten its scheduled headways from 15 to 10 minutes seems very encouraging.

A second service of primary importance is Route A9, which travels parallel to the north-south section of Phase 1, from Rio Piedras though dense, low-income neighborhoods of San José and Barrio Obrero, into the job-rich Ponce de Leon "central spine" and finally to job-rich Old San Juan. The A9 in 1998 boasted by far the highest ridership and the greatest density of boardings of any service other than Metrobus I. Furthermore, it is the *only service* that directly connects these low-income areas to job centers in either western Santurce or Old San Juan. While adding no buses to the route, Multisystems plans to shorten the route and thereby reduce its headways from ten to eight minutes. In the Plan, the route no longer travels to Old San Juan and instead loops at the future site of the convention center. Presently the service allows low-income workers in San José to reach entry-level jobs in Old San Juan within 50 minute's travel. Without the direct service, travel times between these concentrations of recipients and jobs might become too high for reasonable commutes between them. The current plan represents a certain reduction of the job accessibility of some of San Juan's most concentrated low-income households. As a result, this study recommends very strongly that AMA preserve A9's existing service to Old San Juan and simultaneously devotes some of the system's extra buses to this route to relieve overcrowding and reduce headways. It seems quite justified that the entire system's busiest route, through the region's poorest areas, serving as the only direct link to two major entry-level jobs centers, should receive some portion of the additional bus fleet. Extending and improving A9 therefore is this study's strongest recommendation for improving service on existing key routes.

The research identifies Routes C11 and B15 as the key services of next highest priority. Route C11, with fairly light ridership, connects San Juan's areas of greatest job deficit, in eastern Santurce, to jobs and transit services in Hato Rey. Meanwhile, Route B15 connects the low-income San José neighborhoods to Rio Piedras at one end and to Hato Rey at the other. While both routes presently serve key functions, they each miss a great opportunity to connect these low-income areas along Laguna San Juan to the tremendously job-rich Plaza Las Americas. The mall is just beyond Hato Rey, where these routes terminate, through well out of walking distance

from the bus lines. A simple, 1-mile extension of either would bring its service to the extremely entry-level job-rich shopping center. This research therefore recommends either a simple extension of both lines or the realignment of services such that workers in these low-income areas may receive a one-seat ride between their neighborhoods and Plaza Las Americas. These simple improvements undoubtedly would improve low-income families' physical job accessibility tremendously.

The route of next highest priority is A5, which provides direct service along the proposed *Tren Urbano* Old San Juan and Airport alignments. Examination of the map shows clearly that this route serves a large number of job centers and worker concentrations. Appropriately, the line enjoys AMA's second highest ridership levels. The route seems indispensable in its present form, not only to connect low-income workers to jobs, but also to establish the ridership patterns that would support implementation of the two *Tren Urbano* phases that would greatly increase low-income workers' job accessibility.

Finally, Route A6 provides a key link between Carolina and Rio Piedras. The route serves many low-income workers in Carolina locally as well as the job-rich Plaza Carolina mall, and no other service connects Carolina to central San Juan so effectively. Multisystems plans to replace this route with two high frequency services that would run along PR 3 – one to Iturregui and the other to central Carolina. This study confirms that the replacement services represent real improvements over the existing A6 route. Therefore, the study supports the re-routing and replacement as planned.

Overall, the improved services of Multisystems' Feeder Bus Plan look encouraging for all transit users in San Juan. However, the Plan cuts some low-income workers' key service to jobs in Santurce and Old San Juan, and like previous plans declines to capitalize upon the great opportunity to provide cross-town service between San José or eastern Santurce and the job-rich Plaza Las Americas mall. Preservation of the key AMA routes A3, A9, C11, B15, A5 and A6 is of highest importance to low-income workers in San Juan. Moreover, the simple adjustments recommended herein would greatly improve their ability to access employment.

5.3.3. Strategy: Improve or Create New AMA Services

Notably, not a single AMA route and only one *público* route crosses Muñoz Rivera Avenue. San Juan's central spine is such a strong destination that in terms of transit mobility it separates the two sides of the city. AMA and *público* routes use nodes along the spine as small hubs for service on either side. Such separation surely reinforces this corridor as the region's major destination center but likewise reduces travelers' ability to travel cross-town easily. *Tren Urbano* will strengthen this pattern even further. Thus, particular travel patterns that would need cross-town service are less accommodated by the existing and planned systems of transit services.

Low-income households in particular would benefit from such cross-town services. As Figure 5.4 shows, with minor exception Phase 1 of *Tren Urbano* does not provide direct travel between areas of entry-level job surpluses and deficits. Rather, job deficits tend to exist on one side of the line, while surpluses remain in many cases on the other and often along the *Tren Urbano* alignment. As a result, the most important travel patterns for low-income and welfare-dependent workers are perpendicular to the Phase 1 alignment, and they seldom originate near a *Tren Urbano* station. These trips are often either "cross-town", to jobs at Plaza Las Americas and San Patricio, or "radial", to areas along the *Tren Urbano* alignment itself. In the latter sense, the rail line may provide secondary service to many jobs. In both cases, however, perpendicular services are key. A very large portion of the region's entry-level jobs exist to the north and west of the Phase 1 alignment, particularly at and around Plaza Las Americas. For trips to these concentrations of entry-level jobs, the region's discrete, bilateral distribution of transit service increases the complexity, travel time and out-of-pocket costs of trips for these low-income, transit-dependent families.

These observations, coupled with supplemental examinations of existing *público* services and planned AMA services, the research identifies key connections in need of improvements. These links, which are served neither by *públicos* nor AMA,[6] directly connect the largest areas of very

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[6] *Públicos* or AMA already serve some important connections. These cases include areas within Bayamón (*públicos*), within Carolina (AMA) and within portions of western Santurce and Old San Juan (*públicos* and AMA).

high job deficits and surpluses. Figure 5.6, below, shows diagrammatically the links of proposed service improvements, specifically in the form of direct services between concentrations of recipient households and entry-level jobs. In most cases, these key links could be accommodated via simple extension of existing routes; however, the exact nature of service adjustments is left to the provider's service planners.

Figure 5.6. Connections of Proposed Service Improvements
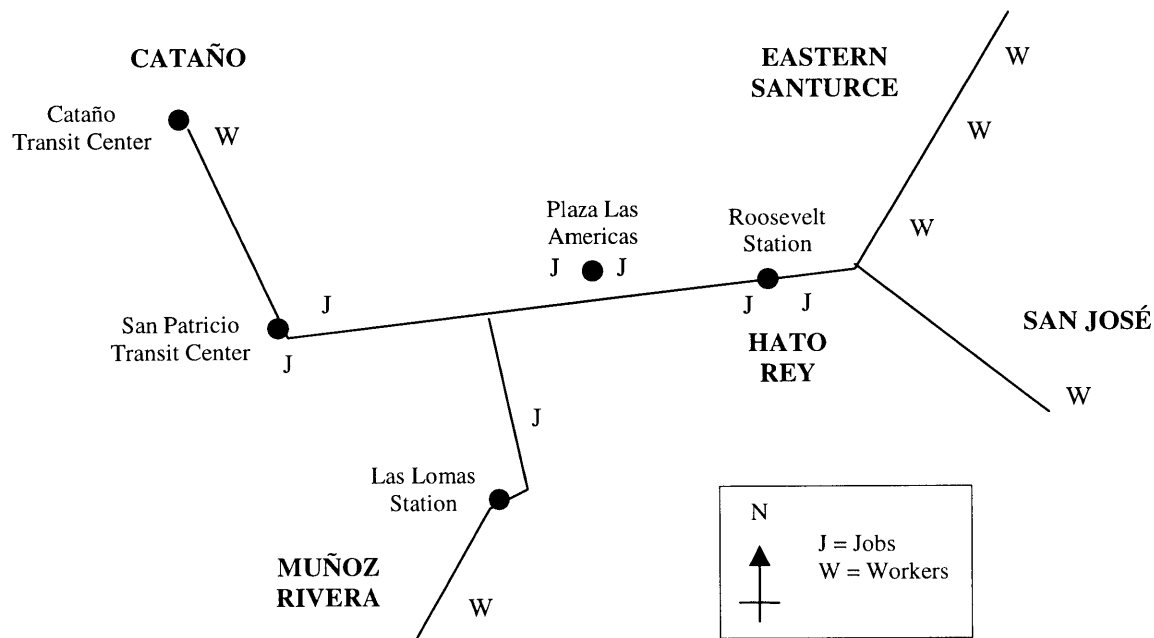
As an example of one solution to providing service over the corridors shown above, Figure 5.7 on the next page maps a system of three routes serving all portions of the links of the diagram above. Notice from the map how these three proposed routes provide service perpendicular t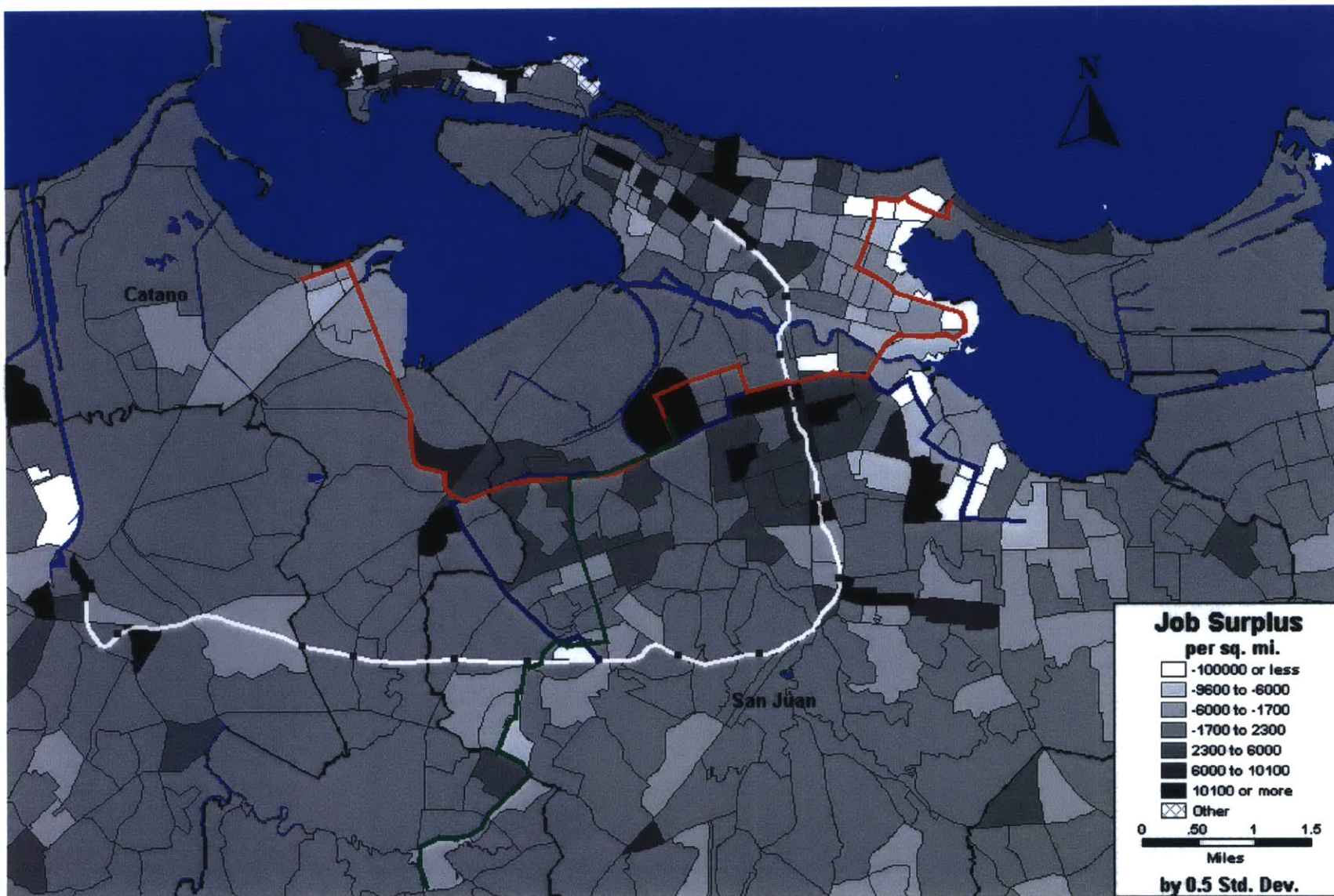o the *Tren Urbano* alignment – again, primarily accommodating cross-town trip patterns while feeding *Tren Urbano* service. The hypothetical Route 1 directly serves Cataño, San Patricio, Plaza Las Americas and Roosevelt Station before continuing on to eastern Santurce. The route follows portions of the existing routes A3 (a "key" service) and B16, terminating at Punta Las Marías. Meanwhile, Route 2 connects the majority of low-income, job-scarce areas south of *Tren Urbano* to Plaza Las Americas. This route serves areas that presently have no direct transit service. Presently, commuters in these neighborhoods may access parallel services to the east or west. This route could extend to Hato Rey in accordance with the Transit Center Plan. Different

Figure 5.7. Proposed AMA Routes

Job Surplus
per sq. mi.
- -100000 or less
- -9600 to -6000
- -6000 to -1700
- -1700 to 2300
- 2300 to 6000
- 6000 to 10100
- 10100 or more
- Other

0   .50   1   1.5
Miles
by 0.5 Std. Dev.

from the other two, this route traverses a unique alignment, duplicating no existing or planned services. In this sense, it serves areas presently not served by transit. Finally, Route 3 begins in San José and follows much of the B15 route (a "key" service), *through* Hato Rey, to Plaza Las Americas. Again, in accordance with the Transit Center Plan this route could traverse all of B15's alignment and terminate at Capetillo, such that Route 3 would be a simple extension of the existing B15.

For low-income workers, these corridors have the greatest need for improved transit services.

5.3.4. Strategy: Ensure Afternoon *Público* Services

In reality, *públicos* run much less frequently or reliably during the afternoon, since many drivers simply do return to their scheduled routes after collecting enough fares for the day. As a result, waiting times for *públicos* increase and travel slows from crowding. The increased travel times effectively place jobs and services farther away, thereby affecting accessibility. Since the accessibility models of Chapter 4 used "scheduled" travel times, they overlooked this important factor. In reality, keeping *público* services active during the afternoon might contribute to improving job accessibility even more than implementing Phase 1 of *Tren Urbano*. The issue is particularly relevant in terms of welfare recipients' job accessibility since, as shown earlier in Figures 5.1 and 5.2, *públicos* carry the lion's share of journey-to-work transit patronage in rural and ex-urban communities – precisely those areas where many recipients reside in dispersed patterns.

The comparative benefit of improved *público* service versus other options remains unclear, since it is uncertain to what extent service on each route suffers during PM hours or how the resulting matrix of origin-destination travel times changes as a result.[7] However, it is clear from the travel time data that when all *público* trips are made, average waiting times are significantly longer in outer, less densely populated and less well-served areas. Thus, the absence of a single *público* trip has greater effect on the travel times of those persons living in these ex-urban areas of lower per capita income and greater welfare dependency. Improving *público* services therefore might

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[7] Such a matrix adjusted travel times is unavailable and too difficult to estimate accurately with the available data.

have a large positive effect upon recipients' job accessibility, depending on the relative levels of improved waiting times. Measuring the exact size of such benefits deserves further study. Pursuing improved afternoon *público* services certainly would help the job accessibility of recipients, many of whom reside in relatively sparsely populated areas that only *públicos* do or can serve.

5.4. Policy: Change the Locations of Recipients

As shown, some of the problem of providing recipients access to employment opportunities in San Juan arises from a mismatch between their residential locations and the locations of entry-level jobs, that is augmented by concentrated poverty and the relative unavailability of affordable, ubiquitous transportation. In San Juan, a major obstacle for many recipients is simply gaining access to transit. A large minority of mostly transit-dependent recipients in metro San Juan has absolutely no access to transit at all. One not-yet-explored remedy to this problem entails, instead of merely providing the transportation connections, changing the locations of recipients. While in Boston this solution might not prove prudent, in San Juan even small shifts in recipients' locations could afford sizeable gains for their job accessibility. As maps in Chapter 4 demonstrate, low-income workers' distribution of physical and competitive job accessibility concentrate quite predominantly around the *Tren Urbano* alignment. Thus, policies that would relocate the lowest income households to areas nearest *Tren Urbano* have great potential to improve recipients' employment potential. For example, recipients relocating from rural areas of Toa Baja to within ½-mile of Martinez Nadal station would experience a full 706% increase in their physical job accessibility level and a 664% increase in their competitive job accessibility. Maps of job surpluses confirm that the economic capacity of centrally located areas to absorb jobless, low-income workers appears quite robust. A household locating along the *Tren Urbano* alignment would become immediately able to access a full 29% of entry-level jobs directly through the stations of Phase 1. *Público* and AMA connections certainly would increase this level much more. Clearly, the potential benefits of moving car-less, welfare dependent families from isolated regions of no transit access to neighborhoods adjacent to *Tren Urbano* would have a profound effect upon their physical ability to gain employment. In this sense, recipients also

could capitalize upon the economies of urban density found in this study's examination of Boston. Perhaps most profoundly, though, relocation strategies effectively address the problem of car-less, spatially isolated, welfare-dependent households.

Any policy-maker should take note that such top-down approaches require conscientious consideration of individuals' various needs, such that programs of voluntary participation tend both to be ethically better and to have greater potential for success. Also, one should be discerning about the "voluntary" nature of some policies. For example, making public assistance contingent upon residential relocation is one subtle example of a quasi *non*-voluntary policy. Also, one should not expect relocation to solve all problems. Relocation involves forming new social networks and adjusting to what sometimes amounts to a very different living environment. Furthermore, simple relocation to areas of better job accessibility does not insure employment; however it better *supports* finding and holding a job. Nevertheless, a wide range of creative and reasonable policies could be implemented as part of an effective relocation strategy.

Affordable and subsidized housing initiatives, for example, should focus their efforts geographically toward land with direct access to *Tren Urbano* – thereby simply encouraging low-income families to locate their households in job accessibility-rich locations that would better support their needs. Additionally, the local and island governments could implement regulations designed to encourage the most effective use of land near *Tren Urbano* stations – including mixed uses, affordable residences and transit-supportive designs. The government of Puerto Rico also could encourage low-income families to relocate to accessibility-rich locations by appropriately developing the lands it owns adjacent to *Tren Urbano* stations. Finally, location efficient mortgages (LEM) seem to have great potential for success in the *Tren Urbano* corridor. Given (1) the very high level of accessibility that those living near the rail line will experience, (2) an abundance of developable land within station areas, and (3) the need for affordable housing in accessibility-rich locations; LEM could be the second step after affordable rental housing for those coming off the welfare rolls. Having developed a habit of transit use, former recipients may "move up" socially and economically into location efficient mortgages, rather than into auto dependency. The prospect of helping San Juan's lowest income households while simultaneously encouraging long-term transit use and creating compact settlement patterns

seems irresistible for planners and policy-makers to pursue. Certainly, the policy of relocating recipients has great potential to improve their physical and competitive job accessibility levels, particularly for those recipients currently isolated from transit. The research therefore strongly recommends that local agencies pursue a concerted policy of relocation.

5.5 Policy: Integrate Child Care, Shopping, Job Training and Transportation Services

Finally, the research has touched only lightly upon the complex trip-chaining needs of recipient families. Since adult recipients generally travel not simply between work and home but rather also between job training services, shopping, and child care, transportation constraints become even more of a hindrance to obtaining employment. If, however, multiple destinations were located together, the transportation obstacle to finding and maintaining a job would become much smaller. *Tren Urbano* presents a great opportunity for co-locating destinations and services that are important to recipients and many other transit-dependent households. The government should encourage development around stations that makes child care, job training services and shopping options available – either via direct or market intervention. Doing so both would make a few additional jobs directly accessible from *Tren Urbano* and would make the services available in a manner of "one stop shopping." Literally, one stop would provide many of the services that recipients and others need for supporting a household while holding a job. The potential benefits to low-income, transit-dependent households are tremendous. Therefore, the research strongly recommends a policy of co-locating childcare, shopping, public transit and related support services.

5.6. Summary

As shown, several types of transportation and land use solutions could improve recipients' job accessibility significantly. These policies and strategies include:

- expanding service so as to serve those who currently have no access to transit at all;

- preserving existing bus routes whose services are of highest priority for maintaining recipients' job accessibility;

- adjusting services to more effectively meet the cross-town travel needs of low-income workers; improving afternoon *público* services;

- extending *Tren Urbano* to the airport;

- relocating recipient households to areas adjacent to *Tren Urbano* stations; and

- integrating child care and household-supporting services into development in *Tren Urbano* station areas.

Of the above, relocation has the largest effect on improving an individual recipient's job accessibility and also solves the problem of some recipients having no access to any transit services. The measure should be supported with complementary land use policies that reduce the need for complex trips that transit does not serve well. Of easily implemented solutions of larger scale, improving AMA bus services seems to have the greatest potential for improving recipients' job accessibility. Simply realigning some services or extending them into especially needy areas could help low-income households tremendously.

Six key AMA services that serve high concentrations of low-income households and entry-level jobs and should be preserved to ensure that good transportation links remain between these workers and employment centers. These routes are A3, A9, C11, B15, A5 and A6, in decreasing order of importance. Additionally, in regard to Multisystems' Feeder Bus Plan it is of high importance that Route A9 be restored to Old San Juan. Routes B15 and A5, also, should extend passed Hato Rey, to Plaza Las Americas, thereby directly connecting the region's largest concentrations of welfare recipients to its greatest concentration of entry-level jobs. Similarly, new or significantly adjusted service should provide direct cross-town services between recipients and areas of job surpluses, such as Plaza Las Americas and San Patricio. Cross-town travel patterns characterize a significant portion of low-income workers' journey-to-work travel needs yet no existing público or AMA routes serve them. Thus, the study proposes and delineates three cross-town bus routes that could be adjusted from existing route patterns or created additionally.

Together, transportation and land use policies could greatly improve welfare recipients' employment potential. The transportation solutions proposed herein generally complement *Tren Urbano*'s services by serving travel patterns and locations not accommodated by the rail line. Meanwhile, land use solutions capitalize very directly upon the very large job accessibility effects that *Tren Urbano* will have, by focusing on development that would use station-adjacent land very effectively. Policy-makers and planners should seize the great opportunity to implement these effective transportation and land use strategies. ∎

Chapter 6

Conclusions

The research has demonstrated some valuable conclusions about the interaction of race, poverty concentration and the spatial isolation of low-income families from entry-level jobs. Importantly it has made clear that public transportation plays a key role in this context, relieving some of the harmful effects of poverty concentration and evening the economic playing field for disadvantaged groups. In terms of its practical application to San Juan, the research has evaluated transportation and land use policies based on their effectiveness of connecting low-income families to both transit services and areas of entry-level job concentrations.

This chapter reviews the conclusions presented herein. Furthermore, it evaluates the usefulness of accessibility analysis for public transportation planning and identifies important steps that need to be taken to bridge the gap between theory (e.g., Chapter 4) and practice. Specifically, this chapter evaluates the readiness of GIS software, accessibility modeling and available data for meeting the needs of transportation planners and policy-makers who desire more quantifiable methods of measuring the benefits of major transit investments. It proposes a refined methodology for applying the techniques demonstrated herein and identifies the areas of research and institutional progress that should be pursued as a means of making accessibility analysis practical.

6.1. Results and Recommendations

The research's results addressed important aspects of race, poverty concentration and employment decentralization, as well as the roles of density and affordable transportation in facilitating greater job accessibility among low-income workers. In addition, the research

recommends specific transportation services and policies based on their effectiveness to improve access to jobs.

6.1.1. Theoretical Conclusions

Results showed cogently that in Boston some aspect of race plays a very strong role in affecting the residential locations of low-income workers, such that poverty concentration increases as a result. As compared to San Juan, low-income families in Boston experience much greater levels of spatial isolation from other income groups – as exhibited by the vastness and relative homogeneity of the region's poor areas. It is hypothesized that purported differences in the significance of skin color between Boston and San Juan explain some if not much of the differing levels of poverty concentration. The research does not comment, however, on to what extent reducing the effects of race in Boston might lessen the region's degree of concentrated poverty.[8] Nevertheless it is clear that as a result of some aspect of race, Boston's low-income families experience very high levels of geographic concentration.

Importantly, results from Boston leave to further research the exploration of auto's effect upon the competitive accessibility of low-income workers. For those who have access to a car, location surely would become less significant. Meanwhile those workers who really are transit-dependent would experience lower competitive accessibility. The research therefore comments most directly to the accessibility circumstances of those low-income workers who must rely on transit for mobility.

In this context, results from Boston show that concentrated poverty forces transit-dependent, low-income workers to compete more directly with one another for a limited supply of entry-level employment. As a result, transit-dependent low-income workers residing in the central city experience lower levels of competitive job accessibility, even though entry-level jobs continue to concentrate predominantly in the region's central portions. In addition, given no change in residential locations or transportation services, it seems low-income workers of Boston will

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[8] For example, given a reduction in the significance of race, there is no insurance that other factors might not serve then as effective substitutes.

experience a gradual decline in their ability to reach jobs so long as the economy remains robust. This effect results from the continuing decentralization of entry-level jobs from central Boston toward suburban areas.

In this regard results still show that contrary to some popular belief, entry-level jobs still concentrate predominantly in central city areas of Boston and San Juan in particular. In times of economic prosperity, however, both regions continue to exhibit strong symptoms of rapid decentralization, especially in terms of entry-level positions. In both regions' central cities, the only relative increases in employment, as compared to suburban areas, have occurred in skilled, white-collar, professional employment. San Juan's employment in particular has been decentralizing more consistently over time.

Perhaps this research's most notable conclusions relate to its observations about the role of public transit in context of the above phenomena. Public transportation helps to relieve some harmful symptoms of concentrated poverty by allowing low-income workers to compete more effectively for employment well outside their low-income enclaves. By providing better access to jobs around the region, good transportation reduces the significance of location and thereby evens the economic playing field for the most disadvantaged low-income workers.

The results also highlight effects of public transportation that existing concepts of urban rail transit do not formally take into account. Since resources such as jobs are limited and therefore economically scarce, and because the provision of transit services produces an inherently uneven distribution of benefits, some persons undoubtedly experience negative effects as a result of a new service's implementation. In the case of San Juan, for example, *Tren Urbano* will provide inherently better physical accessibility to jobs for all persons; however, the benefits will be distributed unevenly, both geographically and socially, such that some persons inherently will experience poorer *employment* potential as a result. The research has found that, as a result of *Tren Urbano*'s implementation, welfare recipients will experience a much easier time reaching jobs but a slightly harder time gaining employment. The effect results from a redistribution of job accessibility benefits toward other low-income workers. The direction of these results

compares well with recent research by Zhang (1998), in which he reports that *Tren Urbano* will improve wealthy commuters' job accessibility more than it will those who earn less.

In addition, implementation of *Tren Urbano,* given no other interventions, may spur suburbanization, since accessing opportunities from outside the city will become somewhat easier. Employers also will experience an easier time finding workers from outside the central city, such that Hato Rey's competitive advantage for entry-level workers will decrease slightly, though remain well above that of other areas.

In sum, the theoretical results indicate also that the existing, modern model of spatial mismatch as interpreted in this thesis is inadequate to explain the full scope of circumstances affecting the employment potentials of low-income families in urban areas. With some exceptions, contemporary urban economics literature generally overlooks the substantial interaction of transportation with important social variables in urban labor markets. The job accessibility effects of race, worker competition and concentrated poverty are greatly underestimated in most of the literature, which furthermore overlooks the nature of these factors' relationships to the availability of affordable transportation.

6.1.2. Practical Recommendations

For San Juan, the research studied in depth the land use and transportation solutions available for improving low-income workers' job accessibility and made appropriate recommendations based on the analysis. The research made similar recommendations for Boston, though more generally. Important answers that arise from the research's findings include to what degree a residential relocation program or specific transportation services might be an effective strategy for improving job accessibility.

For Boston, a city-to-suburb residential relocation program of any significant size would be ineffective at improving low-income workers' job accessibility in Boston and might even reduce their quality of life by separating them from the social networks, services, densities of opportunity and transportation options available to them within the central city. Rather,

improving transportation services seems to have a much greater potential for success, particularly in terms of its effect upon a larger number of welfare recipients and low-income families in the short-term. The research recommends particular transit services that would connect areas of low competitive job accessibility to areas of intense job surpluses that presently are relatively inaccessible to low-income workers. These recommendations include regular cross-town services from Roxbury to Watertown and Watham, as well as reverse-commute services along the job-rich Route 9 corridor. Results show that travel times by transit to relatively nearby areas of job surplus, such as these, can be *extraordinarily* high. There seems much potential to further assist low-income workers in reaching employment by improving public transportation. In addition, the research observes that many nodes of intense job surplus exist along commuter rail lines. Thus, the research strongly supports implementing a market-based, deep discount commuter rail program, coupled with strategic feeder bus services, so that low-income workers can better access entry-level jobs throughout the region.

For San Juan, the research first identified those recipients presently isolated from any transit service. It concluded that simple extensions of Route B40 and a parallel *público* line into western portions of Loiza would have potential to connect about one-third of all welfare recipients who currently have no transit access, to a plethora of entry-level positions in San Juan. Additionally, the research recommends prioritizing *Tren Urbano*'s airport extension as a means of improving recipients' and jobs' direct access to the system.

Second, the research identified several key existing bus routes and recommended appropriate adjustments to them where applicable. The most significant recommended adjustments include restoring the heavily ridden A9 route to Old San Juan, thereby maintaining the area's only direct connection from the low-income San José neighborhoods. The research also recommends devoting at least some of AMA's new buses to the line, to reduce crowding. In addition, the research proposes that services that traverse low-income neighborhoods extend one mile past Hato Rey, to the job-rich Plaza Las Americas mall.

Further examination of San Juan's geography of low-income households, entry-level jobs and transit services reveals that while workers' journey-to-work travel needs often are perpendicular

to *Tren Urbano*'s Phase 1 alignment, no existing or planned services cross the region's central spine, through which the new line spans. This bifurcation of the region further separates low-income workers from employment. In response, the research proposes specific, cross-town services between several concentrations of welfare recipients and entry-level job centers at Plaza Las Americas and San Patricio transit center. The research also found that insuring afternoon *público* services might greatly improve welfare recipients' job accessibility

Finally, results of the accessibility analysis showed that relocating recipients from outlying areas of no transit service to neighborhoods adjacent to *Tren Urbano* stations would have the greatest potential to improve individual households' physical and competitive job accessibility. Thus, the research strongly recommends making affordable housing available in *Tren Urbano* station areas and considering longer-term policies that would encourage or allow recipient households to relocate as a means of greatly improving their employment potentials. Location Efficient Mortgages seem to have much support from the findings herein and should be considered as a long-term strategy of both allowing low-income families to progressively improve their well being and developing transit patronage for the future. Complementary land use policies should encourage the co-location of essential quality-of-life destinations, such as childcare, shopping, job training services and the like.

The practical recommendations presented herein seem to have great potential to improve welfare recipients' employment potential.

6.2. Applicability of Accessibility Analysis to Transit Planning; Directions for Future Study

Accessibility analysis seems to be a powerful theoretical tool for measuring the benefits of transit investment. However, its direct applicability to practical planning purposes remains inhibited by some key factors – including issues of institutions, analysis techniques and an understanding of accessibility's influence upon other socio-economic variables. Implicitly, all transportation plans involve gauging the benefits of accessibility, but no dedicated framework exists for measuring it

or quantifying its value. If the appropriate means become available for easily applying the measurement of accessibility and extracting its meaning, planning for major transit investments could become a more clear and straightforward process.

Chapters 4 and 5 explore issues of accessibility in quite different means, mainly because the former involves theoretical analysis while the latter entails practical application. While the examination of alternative recommendations for San Juan applies concepts of physical accessibility, as explored earlier in Chapter 4, it declines to *quantify* in like terms the benefits of each proposed service or policy. Furthermore, it applies results from the competitive model mainly to land use and relocation alternatives while basing the evaluation of transit alternatives strictly on physical accessibility. Ideally, an integration of both models would supply the greatest level of understanding in regard to the real accessibility benefits of transportation alternatives. Such a method, the author envisions, would input a new matrix of travel times for each transportation alternative, then compute accessibility levels and finally evaluate the relative benefits of each considered option. Such analysis would incorporate both physical and competitive accessibility concepts. The examination herein of transportation solutions for Boston and San Juan relied instead on observations of job surpluses and deficits, in comparison to employers' accessibility to low-income workers. This method comprised an effective strategy for designing transportation alternatives; however, no analysis herein actually evaluated the effectiveness of such alternatives in explicit terms of the accessibility they proposed to improve.

The author originally had planned a methodology that entailed network simulation for completing the above analysis. In such case, simulation over the transit network would return a new matrix of travel times with which the accessibility functions would compute new distributions of job accessibility in the region. They, in turn, could be compared systematically to the "before" or "base" case, and a series of such alternatives could be compared to one another in the same regard.

Presently, TransCAD presents the most powerful GIS and network simulation tools that are applicable to such an analysis framework. However, several capacity or process-oriented limitations in the program prevent one from modeling an entire region's transit system or easily

simulating many alternatives. For example, to propose a new bus route on a path presently not served, the program would require (1) redefining the underlying transportation network, (2) rebuilding a transit network based on the underlying layer, and (3) remodeling the entire region's route systems upon the rebuilt transit network.[9] In short, one must start from scratch. The author found also, through laborious first-hand experience, that the program's many technical "bugs" make even some of its straightforward operations quite cumbersome. Ultimately, existing desktop GIS tools are not presently suitable for sensitivity analysis using network simulation.

Even without such simulation, however, the process of calculating and visualizing accessibility could become far easier and more manageable with automation through a GIS environment. Presently the operation of accessibility functions can take about five to ten hours for each run by performing a series of matrix manipulations in TransCAD (see appendix). Alternatively, a C program that would process such data instantly could require well over 100 hours to refine and de-bug. Ideally, such steps could be integrated into a seamless process in a GIS environment, thereby more easily allowing accessibility analysis to become integrated within a traditional transit planning framework.

Additionally, it is clear from the analysis herein that the quality of data and wise specification of model components are critical to obtaining accurate and meaningful results. Therefore, good data on employment, opportunity seekers and travel times are important to such analysis. Presently, while metropolitan planning organizations estimate and will provide travel time data, information about job seekers and employment opportunities remains difficult to find. First, definitions of each may vary; more importantly, sets of comprehensive, up-to-date data generally do not exist and must be estimated. If accessibility analysis is to become a part of standard practice, researchers first must gather a better understanding of the results' sensitivity to varying definitions of inputs.

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[9] This assumes that one previously had defined the underlying transportation network as a set of streets identical to those on which buses currently run. Such definition seems necessary when modeling the entire region, since if alternatively one were to define the underlying transportation network as the set of *all* streets, the program would grind to a virtual halt from the network's enormous size.

Finally, and perhaps most importantly, researchers must relate economic phenomena to scores for accessibility. If, for example, one could relate accessibility directly to employment levels, transportation costs, land values or other important economic variables, then its measurement would hold much greater meaning and potency. Zhang (1998) notes in this regard that for the Hanson-type accessibility model, "the calculated accessibility scores are unit free and have no intrinsic meaning;" thus, "it is important to incorporate [a] behavioral component into the measurement while maintaining its simplicity." Some research has pursued such an end, including O'Regan and Quigley's use of a simple travel time variable to predict youth employment (1996) or Sanchez's use of least squares regression to relate rough accessibility variables to labor participation (forthcoming). Joan Walker at MIT also is developing a more robust model of accessibility that would predict residential location. It seems that the efficacy of accessibility modeling could improve greatly with a refined understanding of the concept's relationship to important economic variables.

Overall, the research has contributed to the literature by applying its empirical tests both to theory and a practical case. The hope remains that the understandings developed herein ultimately may assist both low-income families in reaching employment and transit specialists in more effectively planning for persons living in urban areas. ■

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Appendix

- Industries Rich in Entry-Level Jobs
- Matrix Manipulation Steps for Accessibility Analysis in TransCAD

Industries Rich in Entry-Level Jobs

Standard Industry Classification (SIC) codes are codified by nine major industry groups and government. The first digit of each four-digit code generally corresponds to a major industry, while the second digit categorizes minor sectors within each group. Third and fourth digits classify businesses by very specific, minor groups. County Business Patterns, the published source from which employment figures were extracted for each county, only in a few cases delineate by 4-digit SIC. In most cases, to protect the privacy of individual businesses, County Business Patterns use only 2-digit SICs.

For purposes of this research, industry groups were categorized as being either likely or unlikely to support a large proportion of entry-level positions. Five major industries were included as being "entry-level rich", since nearly all of their sub-sectors were very likely to employ entry-level workers. In the cases where sub-sectors did not correspond to this general classification, they were included or excluded individually, as the case may be. All such cases are listed below, as are the major industry groups by their propensity to hire entry-level workers.

Major Industry Groups That Are *Included* in Set of "Entry-Level Rich" Industries:

> Agriculture
> Manufacturing
> Wholesale Trade
> Retail Trade
> Services

Major Industry Groups That Are *Excluded* From the Set of "Entry-Level-Rich" Industries:

> Mining
> Construction
> Transportation, Communication and Public Utilities
> Finance, Insurance and Real Estate

Of the major industries included, the following sub-sectors are excluded from the larger sets (SIC code is listed):

> Manufacturing:
> > 28 Chemicals and Allied Products
> > 29 Petroleum and Coal Products
> > 35 Industrial Machinery and Equipment

37 Transportation Equipment
38 Instruments and Other Products (includes medical apparatus, laboratory equipment, etc.)

Services:
73 Business Services
74 Automotive Repair, Services
75 Miscellaneous Repair Services
80 Health Services (Clinics of doctors)
81 Legal Services
86 Membership Organizations
87 Engineering and Management services

Of the major industries excluded, the following sub-sectors are included in the set of "entry-level rich" industries (SIC code is listed):

Transportation, Communication and Public Utilities
41 Local and Interurban Passenger Transit
42 Warehousing

Matrix Manipulation Steps for Accessibility Analysis in TransCAD

The procedures below delineate the accessibility modeling aspects of this research. Given the appropriate data, in a compatible form, and the computing resources to carry out this analysis, the computation of accessibility scores require between five and ten hours with this method, for the first-time user. The steps outlined in this section assume that the researcher has a database of analysis zones (called "Data.dbf" for purposes of these instructions), containing the following information for each:

- Zone IDs, numbered sequentially starting at 1 and corresponding to those IDs from a respective map, if applicable;
- land area of the corresponding territory (in square miles for the procedures below);
- number of jobs or job opportunities or employer locations;
- counts of the population of interest (e.g., welfare recipients); and
- counts of the persons with whom the population of interest would compete for jobs.

Also, the analysis assumes that one has a 3-column database containing perceived travel times by transit between all pairs of zones (called "Transit.dbf" for purposes of these instructions). Such information generally is available from a metropolitan planning organization or from a consultant who may have modeled regional travel demand. As a convention, the procedures below term the single matrix file that throughout contains the data of greatest interest the "primary matrix", and the important dataview as the "primary dataview." In addition, the following steps acknowledge and account for the bug in TransCAD that does not allow one to fill matrix cells horizontally with data from a dataview.

First, one wishes to account for transit-dependent persons' ability to walk to their destinations as an alternative to using transit, which in several cases may take longer than travel by foot. Since the models' outputs increase exponentially as travel time approaches zero, the models are inappropriate for application to very short travels in regional analysis. Thus, the procedure herein simply eliminates the walking mode for *intra*-zonal travel. Otherwise, the models would return scores for the entire region that reflect nearly identically the individual scores calculated for traveling only by foot within the same zone. This is one inaccuracy of the model; however, given several hundred other zones, the imprecision is relatively very small. Also, the analysis considers only nearby, neighboring zones as possible candidates for the walking mode. If, for example, one could walk one-way for a perceived two hours by foot or take transit for a perceived three hours, the model uses the transit travel time. Only in the case of a neighboring zone does the model sometimes use the walking travel time. Finally, for the gravity model the procedure controls for variable size of the zones by dividing job opportunities within each zone by its respective land area. The result is a measure of relative opportunity intensity in each zone and reflects the spatial concentration of employment. If this step were not taken, the model invariably would produce results biased toward larger zones, which even in rural areas generally have more jobs as a function of their vast coverage.

The first set of steps, below, calculates walking times between each zone and its respective neighboring zones.

- Use **Procedures-Statistics** to make active TransCAD's Statistics functions.

- While the map is open and the zones of analysis are in the active layer, use **Statistics-Adjacency Matrix** to create a matrix containing ones and zeros that represent whether zones share a common border. TransCAD creates three matrices in this process, the last two of which measure the length of borders and the "adjacency level". One may delete these latter two matrices.

- While the map is open and the zones of analysis are in the active layer, use **Tools-Distance** to create a matrix of straight-line distances between zone centroids.

- Use **File-New-Matrix File** to create an empty matrix based on the zones of analysis. Then use **Matrix-Combine** to put the distance and adjacency matrices into a single file.

- Use **Matrix-Contents-Add Matrix** to create an empty, third matrix in the file. Then, with the new matrix active, use **Matrix-Fill-Fill With Formula** to calculate walking times in minutes between each zone and its neighboring zone(s). (For this operation, I assumed a walking speed of 3.5 mph, a "circuity" factor of 1.2, and a relative value of time, as compared to in-vehicle travel time, of 1.96, as delineated by Barton-Aschman Associates in their San Juan Regional Transportation Plan travel model.)

The process above yields the estimates of perceived walking time between adjacent zones. Next, the following process converts the Transit.dbf database of perceived transit travel times into a matrix. Then it creates a final matrix of travel times among the zones that is based on the minimum times of transit and walking modes, using outputs from the first step.

- While dataview of analysis is the active window, use **Matrix-Import From Dataview** to create a matrix of travel times among the zones.

- Use **Matrix-Contents-Add Matrix** to create an empty, second matrix in the file. While the new, empty matrix is in the active window, use **Matrix-Fill-Fill With Formula** to fill it with values *identical* to those of the first matrix.

- While the second matrix is in the active window, use **Matrix-Merge** to merge into it values from the previously created "walking times" matrix. When doing this, make sure to choose the option that says, "Missing source values should be ignored," so that missing values in the "walking times" matrix do not overwrite. Also, choose, "Target range: all cells."

- Finally, use **Matrix-Contents-Add Matrix** to create an empty, third matrix in the file, called **Cij**. While this new, empty matrix is in the active window, use **Matrix-Fill-Fill With Formula** to fill the matrix with the *minimum* of either of the first two matrices.

The results are a matrix with travel times equal to the minimum of walking and transit modes between each pair of zones. The next set of steps uses these times to calculate accessibility scores for all the zones based on a Hanson-type model.

- In the dataview, use **Dataview-Formula Fields** to create a field named "Job Density," that divides jobs by area to calculate the job density in each zone.

- Use **File-New-Matrix File** to create a new file with an empty matrix. Then, while highlighting a vertical column of this empty matrix, use **Matrix-Import Rows or Columns** to fill *all its columns* with the job density estimates from **Data.dbf**.

- Use **Matrix-Transpose** to transpose this matrix, thereby creating a new file.

- In the primary matrix view, use **Matrix-Contents-Add Matrix** to create an empty matrix called **Oj**. Then, use **Matrix-Merge** to fill all cells of **Oj** with data from the transposed matrix file.

- While in the primary matrix view, use **Matrix-Contents-Add Matrix** to create a new, empty matrix called **f(Cij)**. Then use **Matrix-Fill-Fill With Formula** to calculate impedance factors, which are a function of **Cij**.

- Use **Matrix-Contents** to create a new, empty matrix called **Oj * f(Cij)** Then use **Matrix-Fill-Multiply/Divide Matrices (Cell by Cell)** to multiply these two matrices and obtain individual cell values for accessibility.

- Then open the **Matrix-Settings** dialogue box and choose "SUM" from the Marginals drop-down box. This step calculates final accessibility scores for each zone, which one may view in the new, right-most column. Use **Matrix-Export Rows or Columns** to create a new table from the *column marginals* (make sure to choose this option in the dialogue box).

- Next, with the primary dataview in the active window, use **Dataview-Join** to join the column of accessibility scores to the zonal data. This step relates the accessibility scores directly to a map.

Having completed calculations for the Hanson-type model, the researcher may build upon some of the previous steps for computation of the Supply-Demand type model, whose process is delineated below.

- Use **File-New-Matrix File** to create a new file with an empty matrix, called **Oj**. Then, with one column highlighted, use **Matrix-Import Rows or Columns** to fill *all cells* of this matrix with values of **Oj** from the Data.dbf dataview.

- Use **Matrix-Transpose** to transpose the matrix. This automatically will create a new file. Once the step is complete, with the original matrix of **Oj** in identical rows as the active window, use **Matrix-Merge** to fill all cells of the original file with data from the transposed file.

- Use **Matrix-Contents-Add Matrix** to create an empty, second matrix called **f(Cij)**. Then use **Matrix-Merge** to fill this new matrix with values of **f(Cij)** from the file in which we calculated the gravity-model accessibility scores.

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- Use **Matrix-Contents-Add Matrix** to create an empty, third matrix called **Ai (Oj)**. Then, with this new matrix in the active window, use **Matrix-Fill-Multiply/Divide Matrices (Cell by Cell)** to multiply the first two matrices.

- Use **Matrix-Contents-Add Matrix** to create an empty, fourth matrix called **Wk**. Then, with one column of this new matrix highlighted, use **Matrix-Import Rows or Columns** to fill *all cells* of this matrix with values of **Wk** from the Data.dbf dataview. To facilitate this step, make sure that in the "Data.dbf" dataview, **Wk** appears in the right-most column.

- Use **Matrix-Contents-Add Matrix** to create an empty, fifth matrix called **Dj Calculation**. Then, with this new matrix in the active window, use **Matrix-Fill-Multiply/Divide Matrices (Cell by Cell)** to multiply the **Wk** matrix by the **f(Cij)** matrix.

- With the **Dj Calculation** matrix still in the active window, use **Matrix-Settings** to choose "Sum" in the Marginals drop-down box. Doing this orders TransCAD to calculate the sum of each row or column in the matrix.

- With any one row of **Dj Calculation** highlighted, use **Matrix-Export Matrix Rows or Columns** to export the *Row* Marginals (make sure the appropriate box is checked off) to a new table, called "Dj.dbf". This step will open a new dataview with two columns – one with the zone IDs, the other with the values of Dj.

- With the new dataview in the active window, use **Dataview-Sort** to sort the values of Dj. Then, fill any values of zero with the smallest allowable number – for example, 0.01.

  (The reason that some Dj sum to zero is that the respective columns in the **f(Cij)** matrix (the impedance function) contained extremely small values. Even when multiplied by values of **Wk**, they remained small, rounding to zero in these cases. However, they should be a pinch greater than zero, both to reflect greatest accuracy and because these values serve as the denominators of the accessibility model. If the researcher finds that these cells in particular change the final results in an unpredictable and inaccurate manner, the author recommends that he or she eliminate the respective zones from the analysis, thereby preventing scores for these zones from affecting the Dj denominator at all. Elimination is nearly always, if not always, a plausible option, since the zones whose values of Dj are close to zero are also those zones whose Hanson-type accessibility to the rest of the metro area is very low. In most if not all cases, they are at the metropolitan fringe or on an isolated island.)

- Use **File-New-Matrix File** to create a new file of one, empty matrix. Then, with any one column of the new matrix highlighted, use **Matrix-Import Matrix Rows or Columns** to import the values of **Dj** into *all columns* (make sure the appropriate circle is darkened). Then, use **Matrix-Transpose** to transpose the new matrix. This command creates a new file.

- Then, with the *primary* matrix file in the active window, use **Matrix-Contents-Add Matrix** to create an empty, sixth matrix called **Dj (Wk)**. With the new **Dj (Wk)** matrix in the active window, use **Matrix-Merge** to import values from the transposed matrix into this one.

- Use **Matrix-Contents-Add Matrix** to create an empty, seventh matrix called **Ai (Oj) / Dj (Wk)**. Then, with the new matrix in the active window, use **Matrix-Fill-Multiply/Divide Matrices (Cell by Cell)** to divide **Ai (Oj)** by **Dj (Wk)**.

- With any one column of the **Ai (Oj) / Dj (Wk)** matrix highlighted, use **Matrix-Export Rows or Columns** to save the *column* marginals to a new table. (Make sure to "x" the appropriate box.) Once the table is created, use **Dataview-Modify Table** to change the column heading of the results to something more meaningful.

- Finally, with the primary dataview of the analysis zones in the active window, use **Dataview-Join** to it join together with the new table just created. This step relates the final results to the corresponding map.

Now theme map it!