

**The Intermodal Connection:  
Integrating New Rail Lines with Existing Transit Services**

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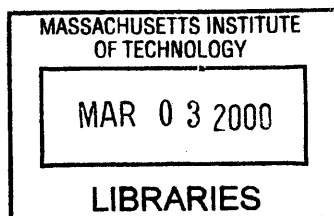
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**Abstract**

Many North American cities have recently opened or extended existing heavy and light rail systems to provide high-quality public transport alternatives. Due to the high capital and operating costs of rail transit, however, expanding the service coverage in a cost-effective manner requires more flexible and less capital-intensive supplementary modes such as buses. Integrating bus and rail services well can allow a transit system to serve a broad variety of travel needs. One recent example of a city pursuing rail transit is San Juan, Puerto Rico, where the 11-mile Tren Urbano heavy rail line is now under construction and expected to open in 2002. Tren Urbano will connect with existing bus and público (privately-operated jitney) systems. Over time, bus and público services have generally declined as the region has grown more automobile-dependent.

This thesis considers the broad question of how to integrate bus and rail services successfully, focusing on the transition from a bus-only system to an intermodal system. Specifically, this thesis first develops a framework for analyzing specific integration strategies and evaluates several potential approaches a transit agency can pursue. It then discusses various planning principles that can assist decision-makers with strategic and tactical integration issues. Some of these issues include operating arrangements, fare integration, network design, and schedule coordination. To support these principles and to provide insight for the San Juan case, this research evaluates the intermodal integration experiences of five cities in the United States (Los Angeles, Miami, San Francisco, Washington, and Portland). In some cases, transit became more effective in both traditional and non-traditional travel markets when buses were used to supplement rather than compete with rail. In other cases, inattention to buses and a general lack of schedule, fare, and route coordination resulted in less favorable outcomes.

Finally, this thesis applies the analytical framework, planning principles, and case study lessons to develop and evaluate strategies for integrating San Juan's existing transit network with Tren Urbano. For the buses, it focuses on evaluating service proposals for key corridors and finds that the current network structure is well-suited to feeding Tren Urbano and serving existing bus riders. For the públicos, it addresses more fundamental institutional issues. It explores the possibility of developing new contracted feeder small bus or van service to Tren Urbano, redirecting routes to avoid direct competition with públicos, and creating "Tren Urbano Plazas" to attract suburban motorists to transit.

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## Chapter 1: Introduction

In the past quarter century, many North American cities have built new heavy and light rail lines to provide people with high-quality alternatives to mounting traffic congestion in busy transportation corridors. While these systems by themselves have attracted new customers to transit, they are also components of much larger transit networks. Since new rail investments are large-scale, long-term and highly visible efforts, agencies must focus on the finance, design, and construction aspects of rail projects. It is easy to underestimate the importance of integrating the rail system with existing transit services.

Given the symbiotic relationship between rail and bus, these modes can and should complement each other in an integrated multimodal network. Transit's overall effectiveness and efficiency depends in large part upon designing a coordinated system that utilizes the strengths of each mode. Often the urban rail component forms a system's symbolic backbone because of its service quality and visual presence. Compared to buses, trains generally operate more frequently and rapidly, carry greater passenger volumes, emit no visible pollution, and often run with full grade separation. Stations provide better passenger facilities than roadside bus stops and have the potential to encourage transit-friendly development. However, the cost of building and operating rail transit severely constrains network extent and coverage. To expand its reach and broaden its customer base, a comprehensive transit system requires flexible, less expensive options such as bus to supplement rail service.

Opening or extending a rail line draws attention to transit. It presents an agency with a rare and vital opportunity to improve a system's overall level-of-service, to create excitement about transit, and to realize large long-term ridership gains. While the rail line may attract the most attention, an agency should take advantage of this moment to showcase the complete system by designing and demonstrating how an integrated network of buses and trains can meet a variety of travel needs. Nevertheless, achieving transportation and other goals with new rail investments is inherently a long-term effort. Systems may take decades to mature because individual travel behavior and land uses do not adapt to new transit systems overnight.



Clearly, a fundamental difference exists between long-term system design and short-term implementation issues. The transition to a new rail system can create uncertainty by disrupting established travel patterns and operating procedures. (The transition can be equally challenging when introducing Bus Rapid Transit or other forms of high-quality, high-capacity transit). The rail line may speed the commutes for some current transit customers, but changes in bus routes may introduce transfers for others. Transit employees may fear that the rail line will bring bus service cutbacks and jeopardize jobs. Meanwhile, a rail line adds substantial new capacity to the transit system that people are unlikely to fully utilize immediately. Some shifts from buses or automobiles to rail may initially occur, but it probably will take years for travel patterns to stabilize and even longer for land use and lifestyle changes to occur. Transit agencies and elected officials often face tremendous pressure to demonstrate immediate results of rail projects to the general public and to the media. Consequently, it is tempting to pursue short-term strategies to boost rail ridership, such as reconfiguring the bus system to serve only the rail feeder market. In the worst-case scenario, such strategies may result in ridership losses, political embarrassment, and other unfavorable results.

The challenge facing transit agencies is to manage the transition to new rail systems effectively, minimizing short-term impacts while making progress to achieve long-range objectives. Given this context, this research aims to develop a framework and analytical methods to assist transit planners with the process of integrating new rail lines with existing transit systems. It focuses exclusively on new or extended heavy rail and light rail lines and assumes that the decision to move forward with these projects has already been made.

## **1.1 Background**

Integrating pre-existing transit services with new rail lines is a complex task. Clearly, it involves many technical decisions ranging from fare integration to network design and schedule coordination. As importantly, these decisions also affect transit employees, politicians, construction workers, voters, riders, and other stakeholders in the transit system. An in-depth analysis of how intermodal integration impacts all these groups is not the focus of this research. Nevertheless, one should acknowledge that

integration policies that might make technical sense may be difficult to implement in a “real world” environment.

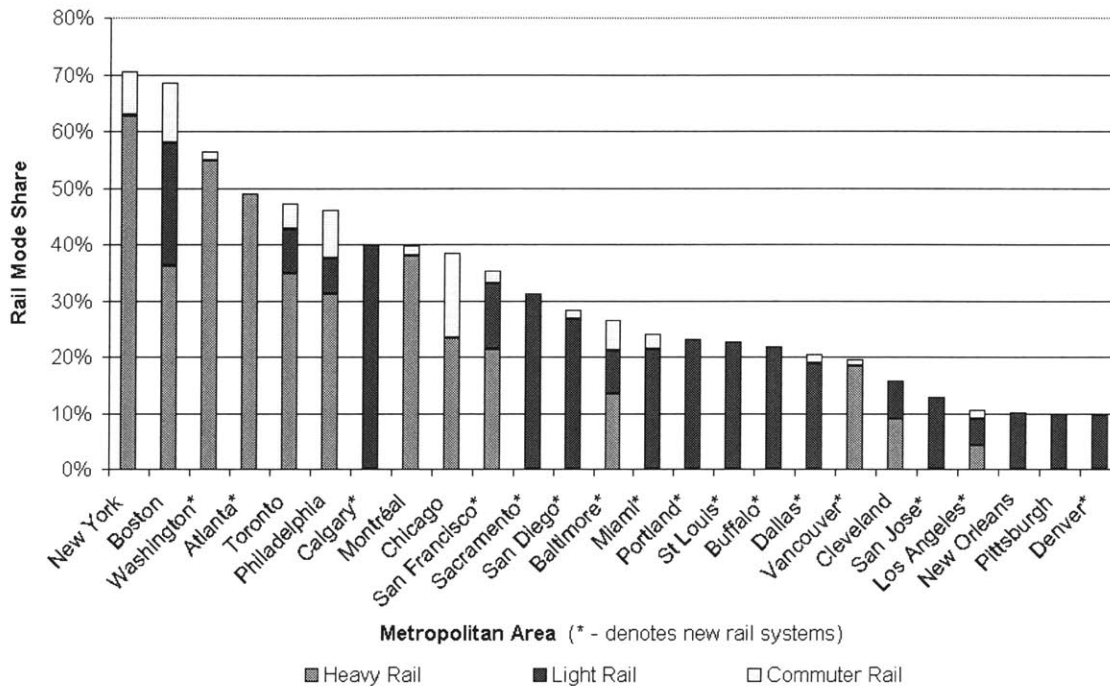
Transportation providers are important stakeholders. It is fairly clear that operating a successful intermodal system requires the cooperation and dedication of front-line employees. However, bus operators may feel threatened by a new rail line or other high-capacity transit improvements. Presumably the rail line will reduce demand for bus service along parallel corridors. Since trains can carry far more passengers per operator than buses, some drivers could potentially face unemployment if a transit agency decides to reduce bus service. Transit unions, which have historically resisted privatization efforts, might also oppose rail systems particularly if they contract out operations. At the same time, private carriers may also be hostile to rail investments, which they may view as high-quality, subsidized competition.

Bus riders form another important stakeholder group. Building a rail system is inevitably a high-profile and high-cost strategy compared with maintaining or expanding a bus system. If a rail line lags behind ridership expectations, experiences construction problems, or fails to capture a substantial portion of system ridership, bus riders may feel that the rail system is receiving undue resources and attention. Relative to buses, the high level-of-service on rail may also reinforce this perception: rail will usually offer a quicker ride and shorter headways than the average bus route, simply because it runs in heavily-travelled corridors along separate rights-of-way with a wide catchment zone. Sometimes, separate transit operators as well as a lack of intermodal fare coordination can further reinforce the perception that there are distinct and unequal bus and rail systems.

Launching a new rail line may also directly impact the commutes of current transit customers as bus routes are reconfigured to interface with rail. In many instances, express buses that operate in rail corridors are either eliminated or truncated at rail stations in order to avoid service duplication. Route restructuring often makes sense from both the operator’s and customer’s perspectives if it translates into greater bus service coverage, shorter headways, or expanded hours of operation. However, the introduction of a transfer can make transit less convenient for express riders. A significant challenge is to retain these customers by softening the impact of transfers with integrated fares and

schedules. An agency must weigh system efficiency and service improvements against political concerns, and then take steps to mitigate potential adverse impacts on bus customers.

Figure 1-1: Percentage of Unlinked Transit Trips Taken by Rail



Source: APTA, 1999.

While a new rail line may attract many riders, it is unlikely to be the largest component of a transit system until it becomes extensive enough to reach a wide population and employment base. Figure 1-1 compares the number of unlinked trips taken by bus and rail (heavy rail, light rail, and commuter rail) for North American metropolitan areas with multimodal systems. Since some riders use more than one vehicle to complete their trips and thus are “double counted”, this measure gives an imperfect but rough indication of the relative significance of bus and rail modes. In North America, the number of rail trips exceeds bus trips in only three cities: New York, Boston, and Washington. Each features an extensive set of rapid transit and commuter rail lines radiating from strong central business districts. Atlanta, Toronto and Philadelphia have rail mode shares ranging from 40 to 50 percent. Even in cities such as

Montréal and Chicago that have extensive rapid transit systems, most people depend either on both the bus and train, or exclusively on the bus. With the exception of Calgary, smaller scale rail systems with just one or two lines typically capture only 10 to 30% of the total unlinked trip mode share.

One could also employ other measures besides unlinked trips to compare bus and rail systems. Using passenger miles, for example, would show that rail lines often play a more significant role in the total system, even in cities with limited rail service. Rail usually captures a larger percentage of total travel relative to boardings since people typically travel longer distances on rail (particularly commuter rail) than on buses. However, using passenger miles instead of ridership may be difficult to justify politically, since it can raise the perception of “favoring” certain groups of transit riders over others.

Given these considerations, multimodal planning should acknowledge the significance of buses – as a means to access rail stations and as a network in its own right. This is particularly true in cities developing new rail systems, where the great majority of transit riders will still depend upon buses for at least a portion of their transit trips. Although the ridership density per route mile is likely to be higher for rail than for bus, buses will continue to cover a larger area. Developing a mature rail network over the long-term through incremental system expansion will require support not only from the general public and politicians, but also from transit providers and customers.

## **1.2 Motivation**

A rail investment or other major transit infrastructure project is a complex undertaking that typically takes many years or even decades to implement. Given this long time frame for rail projects, planners, engineers, and managers initially concentrate on financing, physical design, and construction itself. Decisions about fare and service integration with existing transit modes are often deferred until later and may not always receive adequate attention. Consequently, although integration efforts have led to large ridership gains on both trains and buses in some cities, others have produced less impressive results. This work has two primary motivations: to address intermodal integration issues generally with application to any North American metropolitan area

developing a rail system, and to make specific recommendations for San Juan, Puerto Rico, where the Tren Urbano heavy rail system is currently under construction.

The opening of many new rail systems throughout North America in the past quarter century has brought this issue to the forefront. Tables 1-1 and 1-2 list major North American cities that have opened heavy and light rail systems since the mid-1970s (they do not include commuter rail systems, another fast-growing rail mode). In addition, older rail systems in cities such as Boston, Chicago, and Toronto have also expanded.

Table 1-1: Heavy Rail Systems Built since the Mid-1970s

City	Opening Year	Length (Miles)	Rail Operator	Bus Operator(s)
Atlanta	1979	46	MARTA	Same
Baltimore	1984	15	Maryland MTA	Same
Los Angeles	1993	18	LA MTA	Same
Miami	1984	21	Metro-Dade Transit	Same
San Francisco	1974	95	BART	San Francisco MUNI, AC Transit, SamTrans, others
San Juan	2002	11	Tren Urbano (contracted service)	AMA, Metrobús, Públicos
Vancouver	1986	17	BC Transit	Same
Washington	1976	96	WMATA	Same; also Ride-On, Fairfax Connector

Source: 1997 National Transit Database (FTA, 1999), agency web sites

Table 1-2: Light Rail Systems Built since the Mid-1970s

City	Opening Year	Length (Miles)	Rail Operator	Bus Operator(s)
Baltimore	1992	22	Maryland MTA	Same
Buffalo	1985	6	NFTA	Same
Calgary	1981	18	Calgary Transit	Same
Edmonton	1978	9	Edmonton Transit	Same
Dallas	1996	20	DART	Same
Denver	1994	5	Denver RTD	Same
Jersey City	2000	21	New Jersey Transit	Same
Los Angeles	1990	41	LA MTA	Same
Portland	1986	33	Tri-Met	Same
Sacramento	1986	20	Regional Transit	Same
St. Louis	1993	17	Bi-State Transit	Same
Salt Lake City	1999	15	Utah Transit Auth.	Same
San Diego	1981	50	S.D. Trolley	San Diego Transit
San Jose	1987	28	SCVTA	Same

Source: 1997 National Transit Database (FTA, 1999), agency web sites

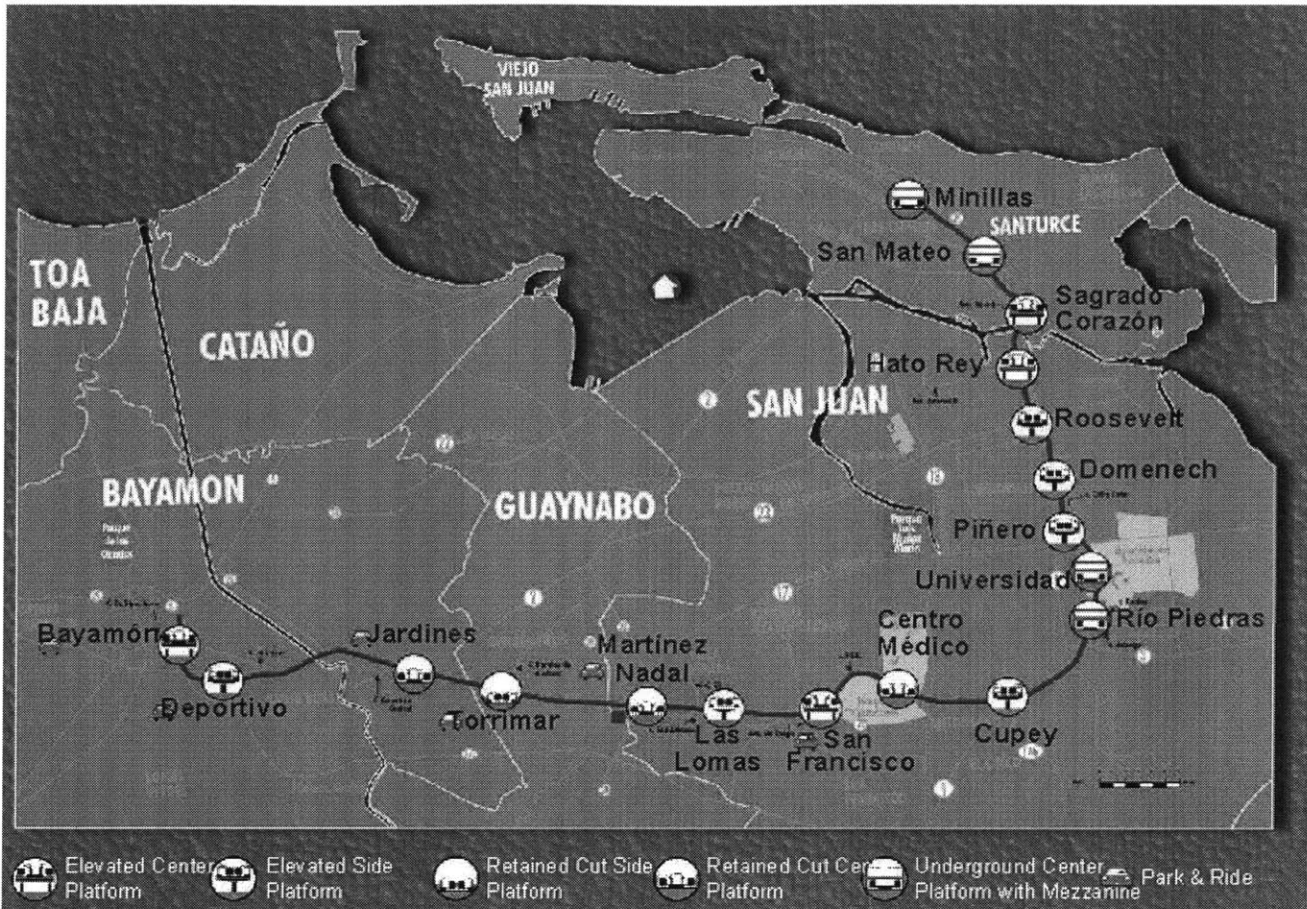
In most situations, transit agencies building new rail systems produce integration plans internally or with the help of consultants. Of course, their work is limited to the specific environment of interest. Most agencies do not have the financial resources to

analyze peer systems and learn from their experiences, or to develop an analytical process to weigh alternative strategies. This is sometimes complicated when different rail and bus agencies operate in the same metropolitan area. Research on this topic has tended to focus on specific aspects of multimodal systems such as transfers, fare policy, or network structure, but not how these various aspects relate to each other. In addition, few papers discuss the process of moving from a bus-only operation to an integrated bus and rail system or the political implications of such shifts. From this standpoint, this research aims to develop a comprehensive analytical approach to integration issues with a concentration on the transition phase to an intermodal system.

### **1.3 The San Juan Context**

A specific motivation for this work is the need to develop an integrated transit network strategy for San Juan, Puerto Rico. San Juan is the latest American city to make a major financial commitment to rail as a catalyst in transforming its existing surface transit system, consisting of buses and *públicos* (regulated jitneys), into a high-quality multimodal network. Phase I of Tren Urbano, Puerto Rico's first modern urban rail line, is set to link Sagrado Corazón at the southern edge of Santurce with the western suburb of Bayamón. The 17-kilometer, 16-station heavy rail alignment passes through major trip generators such as the Hato Rey business district, Universidad de Puerto Rico, Río Piedras, and Centro Médico (see Figure 1-4). Phase IA, currently in the advanced planning stage, will extend Tren Urbano from Sagrado Corazón to Minillas in the center of Santurce. Subsequent extensions to Viejo San Juan, Isla Verde, and Carolina may move forward depending upon the funding and "success" of the initial segment. Phase I Tren Urbano is now well into construction with initial revenue operations expected in 2002.

Figure 1-4: Map of San Juan's Tren Urbano System



Source: Tren Urbano web site

Meanwhile, San Juan's existing transit system has faced serious challenges for many years. Severe roadway congestion, automobile-oriented land uses, decades of deferred maintenance and declining ridership have taken their toll on both the bus and público systems. Overcrowding and a limited span of service can make the transit riding experience unpleasant and inconvenient. In the last few years, however, significant steps have been taken to address these long-standing issues. The Autoridad Metropolitana de Autobuses (AMA) or Metropolitan Bus Authority (MBA) bus system underwent major route restructuring at the beginning of 1998. The new system features a core network of high-frequency trunk lines supplemented by feeder routes running at least every half-hour on weekdays. Routes converge at a half-dozen transit centers located strategically throughout the metropolitan region, enabling most passengers to reach their destinations with a single transfer. While the previous system had more lines, most routes ran very infrequently, a problem compounded by a lack of reliability. The shift from a high

connectivity but low quality route structure to one based upon transit centers has helped to stimulate ridership growth. Annual boardings increased from 16.6 million to 24.3 million between 1996 and 1998 (APTA, 1999).

The two Metrobús services have also achieved some success. Metrobús I, operated by a private contractor, parallels the Tren Urbano alignment from Río Piedras to Sagrado Corazón and continues on to Viejo San Juan using exclusive bus lanes. Metrobús II, operated by AMA, runs from Bayamón to Santurce via Hato Rey, serving the endpoints of Tren Urbano but following a more direct route along Avenida Roosevelt. While Metrobús employs bus technology, it has managed to distinguish itself as a higher-quality service, offering better frequency and using a separate right-of-way in some areas. This service quality is used to justify a premium fare. Interestingly both Metrobús I and II have generated strongly positive rider responses but negative reaction from pre-existing bus and público services.

In contrast, the públicos have continued a long decline. A few North American cities such as New York and Miami also have unsubsidized jitneys (both legal and illegal) in addition to large-scale conventional transit networks. However, nowhere in the United States are jitneys such an integral component of the total transportation system as in San Juan and the rest of Puerto Rico. Except for routing and fare regulation, drivers essentially can run whenever they want with whatever vehicles they own. To stay afloat financially in a low-profit business, however, drivers must keep their costs low which generally results in poor service quality. Aged vehicles, lack of air conditioning, overcrowding, and infrequent off-peak service make públicos unattractive particularly relative to the automobile.

Any “paradigm shift” to improve público service quality in anticipation of Tren Urbano faces two major obstacles. First, the público drivers want to maintain their independence without government interference, using fare revenue as their income. Second, government officials are reluctant to intervene since the público drivers now provide an essential service without financial assistance. Without intervention, however, the públicos face an uncertain future at best in light of growing automobile use as well as improved bus and rail services.



Since both the buses and públicos already face difficult challenges of their own, transit planners must clearly pay extra attention to integrating these modes with Tren Urbano. With the introduction of Tren Urbano, the surface transit system must improve even more – an estimated 55% of the year 2010 projected 115,000 daily Tren Urbano customers are expected to access stations by bus or público (USDOT et al., 1995). Most of these are anticipated to be net new transit trips (in addition to current bus and público riders), approximately equal to half of all current AMA riders. The problem of developing an effective multimodal network is particularly difficult in San Juan. Separate transit providers with varying operating procedures and standards can complicate integration efforts. In addition, public perception towards transit is indifferent at best as the automobile’s popularity has soared over the past several decades. Finally, because of the significant cultural differences between San Juan and cities on the American mainland, effectively addressing transportation challenges requires blending successful strategies used elsewhere with unique approaches that are sensitive to the local environment.

#### **1.4 Thesis Objectives**

The primary purpose of this research is to develop and evaluate strategies for integrating existing transit services with new rail lines and to apply the findings to San Juan. The primary objectives are:

- (a) To formulate an analytic framework to develop and evaluate integration proposals
- (b) Evaluate various bus-rail integration practices from the perspective of the transit operator, customer, and other stakeholders
- (c) To understand the experiences of other North American cities that have developed new rail systems
- (d) To recommend specific integration strategies that adapt practices used successfully elsewhere to San Juan’s special transportation environment

## 1.5 Methodology

This thesis adopts a multiple-step research approach. First, it develops an analytical framework to address bus-rail integration planning issues. This framework emphasizes a planning process broken into a series of strategic (long-term), tactical (medium-term), and operational (short-term) decisions. It also defines evaluation criteria, general objectives for any intermodal system, and alternative approaches to meet these objectives. Using this framework, this thesis develops planning principles for bus-rail integration. The discussion primarily focuses on long-term strategic decisions since they require advance preparation and have significant impacts on service delivery and customer perceptions of transit.

To support the general planning principles in this thesis and to provide insight for the San Juan case, this thesis evaluates the intermodal integration experiences in five cities (Los Angeles, Miami, San Francisco, Washington, and Portland). Each of the selected case studies meets one or more of the following criteria: (a) major restructuring of the surrounding bus network took place in response to a new rail line, (b) a new rail line altered the social or political landscape with respect to transportation, (c) multiple regional transit operators complicate route and schedule coordination, or (d) demand responsive services meet some transportation needs. Admittedly, cultural differences might limit the applicability of some of the lessons learned in these cities to San Juan. However, automobile ownership levels, land uses, and travel patterns in San Juan are somewhat similar to the selected case study cities. In addition, Miami was specifically included in the case studies because its heavy Latin American influence and private jitney system resemble the San Juan environment. The case studies can be found in Appendix A, with references to them throughout the text.

With the developed planning principles and case study evidence, this thesis then analyzes the situation in San Juan and makes recommendations for system improvements. First, it identifies major integration issues in San Juan, including the strengths and weaknesses of existing transit services and potential political obstacles. Second, this thesis critically evaluates proposals for AMA and Metrobús route restructuring in conjunction with Tren Urbano. Appendix C contains a detailed technical analysis of

proposals for specific routes to support a set of recommendations. Finally, it identifies the viability of alternative approaches for integrating the públicos with Tren Urbano.

## **1.6 Thesis Organization**

**Chapter Two** develops an analytical framework and defines alternative approaches which planners and other stakeholders can use to evaluate various integration proposals. It also explains how this research builds upon previous work.

**Chapter Three** discusses planning principles for intermodal systems. It also emphasizes how external social and political factors can complicate seemingly simple planning decisions. Specifically, it addresses network theory and fare coordination and their influence on mode choice and route design, transfers, and automobile access to rail stations.

**Chapter Four** examines several strategies for integrating San Juan's existing transit system with Tren Urbano. The first section defines objectives and evaluates service modification strategies for the AMA and Metrobús systems. The second section addresses the privately-operated públicos, primarily identifying new operating paradigms that may best achieve desired service characteristics economically.

**Chapter Five** summarizes the major findings of this research and makes recommendations for follow-on research.

The **Appendices** contain material referenced throughout the text. Specifically, the appendices include the evaluation of specific bus route modification proposals, an analysis of the implications of the Americans with Disabilities Act (ADA) on vehicle procurement, and case studies from cities with mixed intermodal integration experiences.

## **Chapter 2: Analytical Framework**

This chapter develops a framework to analyze intermodal integration strategies. First, it reviews existing literature and explains how this thesis builds upon previous research. Highlighting critical technical and non-technical issues, it then develops a planning process to guide decision-makers preparing to open a new rail line. It also distinguishes between “feeder”, “minimalist”, and “integrated systems” approaches to bus-rail integration planning. Finally, it defines objectives and associated criteria to help formulate and evaluate service modification proposals.

### **2.1 Previous Research**

Intermodal integration involves many complex issues ranging from transfers, network design, and fare coordination, to the political implications of associated service changes. To date, extensive research has covered many of these topics individually, but often not in a multimodal context. In addition, relatively few papers address the transition from bus-only systems to integrated bus and rail systems. This section highlights some of the most relevant research covering one or more aspects of intermodal integration, but is by no means exhaustive.

One of the primary objectives of this paper is to identify ways to integrate Tren Urbano and regular buses in San Juan with the deteriorating público network. Several papers and studies discuss strategies to improve private jitneys like the público system. Takyi (1990) discusses the conditions under which jitneys can sustain economic viability, namely in cities with cheap labor, inadequate conventional transit services, and low expectations for service, comfort, and safety. His paper also identifies potential roles jitneys can fill in a larger transportation system (e.g. supplemental peak hour service, service on narrow streets). Takyi contends that buses and jitneys provide different types of services and therefore can and should complement rather than compete with each other. A primary limitation of his analysis, at least in terms of the case of San Juan, is that jitneys become less attractive as income and automobile ownership rise.

Lau (1997) builds upon previous research by identifying niche markets for jitneys as well as government intervention strategies to rescue failing jitney systems. Lau develops an analytical framework to evaluate potential intervention strategies. Applying

the framework to San Juan's públicos, Lau recommends a set of "experimental strategies" on poorly performing público routes, routes that could supplement Tren Urbano, and routes that would directly compete with rail. Possibilities include contracting service to established carriers in corridors with poor público service, government assistance with vehicle procurement, fare integration, and contracting operations on a short-run basis with público drivers on routes that compete with Tren Urbano.

Kaysi et al. (1999) investigate the role that the private sector (particularly jitneys) may play in the public transportation operations. Their paper identifies the challenges facing these services and develops potential external intervention strategies to assist the private sector. These include regulation, financial assistance with capital expenditures, and moving to other market arrangements such as contracted operations. The private sector can also supplement instead of compete with conventional transit modes (e.g. providing paratransit services or additional peak-hour runs on overcrowded routes). The paper also outlines specific strategies to improve the situation in San Juan. These include imposing new regulations that require público drivers to improve their vehicles and to provide scheduled service, encouraging operators to penetrate the new Tren Urbano feeder market, and developing new market arrangements such as contracting out services to private carriers.

Extensive research has also been conducted into other integration issues such as fare integration. Barr (1997) develops a methodology for evaluating intermodal fare coordination decisions. His research primarily focuses on fare technology (e.g. smart cards, magnetic stripe cards) and pricing policy. While improved technology can improve revenue collection and rider convenience, Barr argues that favorable pricing policies can produce clear benefits for users but may have positive or negative impacts on revenue. The purpose of Barr's work is to assess the impacts of fare integration through an analytical framework based on usage, financial, system, and external criteria. Another objective is to apply this framework to the specific case of Tren Urbano.

Hirsch et al. (2000) recount how New York City Transit's recent fare integration improvements have translated into double-digit ridership growth on both its subways and buses. The authority has implemented an Automatic Fare Collection (AFC) system

throughout the network featuring a stored value ticket called the *Metrocard*. Customers can either use the *Metrocard* as a debit card that allows free intermodal transfers or as an unlimited-ride ticket for a specified time period. Hirsch et al. analyze *Metrocard*'s impacts on various ridership markets and system utilization. Their study is referenced in Section 3.3.

Besides fare coordination, research efforts have also focused on developing theoretical approaches to optimize transit networks. Baba (1995) formulates a theoretical and computationally intensive model for a generic bus route network. To provide transit agencies with a framework for bus route restructuring, his work develops a methodology for solving the bus network design problem (BNDP): determining the best bus route configuration and frequencies given bus transit demand, the street network, available resources, and operational constraints. It adopts a heuristic approach, focusing on route generation and frequency determination/vehicle allocation, encompassed in a single automated design procedure. Baba's methodology improves upon previous BNDP heuristic approaches by (a) incorporating a fleet size constraint, (b) identifying major trip patterns and demand to guide route design, and (c) solving the BNDP using either a general or transit center network design. This work develops a detailed route generation and vehicle allocation procedure. The thesis then applies the proposed methodology and automated design procedure to San Juan, Puerto Rico.

Lee and Vuchic (2000) present an iterative approach to handle the Bus Network Design Problem, which they call more generally the Transit Network Design Problem (TRNP). Three general objectives for an optimized network include (1) user travel time minimization, (2) the transit agency's profit maximization (or net cost minimization), (3) social benefit maximization or social cost minimization. For simplicity, they focus on user travel time (including waiting, transfer, and in-vehicle travel times) minimization as the primary criterion for their analysis. The algorithm used to determine an optimal network consists of three major steps. First, an initial network is generated with a minimum number of routes using a shortest path algorithm. Second, travel flow is assigned to specific routes. Finally, the alignments of certain transit routes are modified to reduce passenger travel times. This iterative approach also addresses the dynamic characteristics between variable transit trip demand and optimal transit network design.

More specifically, the algorithm contains a feedback mechanism that recognizes the dependent relationship between transit demand, transit supply, automobile usage, and in-vehicle travel times.

Other work has analyzed multimodal transit systems, also from a theoretical perspective. Wirasinghe (1979) develops an analytical model to describe a generalized rail line and its feeder bus network. This model presents a nearly “optimal solution” to feeder bus route design and rail station placement. To keep the model tractable, however, Wirasinghe makes some key assumptions that limit its applicability; for example, the model assumes a regular grid street network as well as ignores travel time variability and schedule coordination needs. Nevertheless, it roughly approximates the relationships between transit demand volumes, waiting times, walking distances, and operating costs. Kuah and Perl (1988) build upon Wirasinghe’s work by presenting an analytical model for the design an optimal feeder bus network for a rail line. Unlike Wirasinghe’s work (and many other Bus Network Design Problem approaches), it includes bus stop spacing as a parameter, since stop spacing affects walking time and in-vehicle travel time. It also assumes that rail stations already exist, removing one decision variable from the analysis.

Chowdhury and Chien (2000) develop a method to optimize coordination in a general intermodal network featuring a rail (or major bus) trunk line supplemented by intersecting buses. The goal is to minimize an objective function – first among individual routes and then the entire network – that includes both supplier (the transit agency) and user (passenger) costs associated with transferring. Supplier costs are captured by the operating costs of the trunk and secondary routes; user costs are represented by wait, transfer, and in-vehicle travel times. The major decision variables include route headways and slack times, or the extra time built into the schedule to increase the probability of making a connection. With this objective function, Chowdhury and Chien propose a four-step procedure to develop coordinated schedules. Their model assumes that the rail line operates maintains a deterministic headway, which keeps the problem tractable but is not always realistic, while bus arrivals at transfer stations are stochastic with approximately a normal distribution. The model also assumes fixed demand, which could limit its applicability since service frequency and ridership are clearly interrelated.

By highlighting important issues such as travel time, transfers, route directness, and headways, these network models may prove useful to transit agencies planning new rail lines and supporting bus services. However, it is generally very difficult for a model to incorporate all the complexities of a large regional transit network. Furthermore, theoretical models may give the impression that planners can simply design transit services from scratch. In reality, transit operators and customers may be resistant to major changes.

As a prime component of transit networks in general and particularly intermodal systems, transfers have received considerable attention. Matoff (1994) and Hickey (1992) argue that providing everyone “one-seat”, transfer-free rides is logistically impossible given the spatial layout of most North American metropolitan areas. Schumann (1997) describes how a hierarchy of integrated transit services (e.g. regional rail, trunk bus routes, circulators and shuttles) can be effective in allowing transit to serve low-density areas and non-radial trips. They suggest that multimodal systems that feature network connectivity (i.e. many points where passengers can switch between intersecting routes) allow transit systems to become more responsive to multiple travel patterns. This thesis builds upon their work by providing case study evidence to support these concepts and developing incremental strategies for implementation.

Although it is beyond the scope of this thesis, the physical design of transfer facilities at rail stations is a key component of an intermodal system. The Transportation Research Board’s “Transit Capacity and Quality of Service Manual” (Kittleson & Associates, 1999) provides guidelines on bus waiting areas, park & ride and kiss & ride facilities, pedestrian flow within stations, ticket machines, and accessibility issues. Horowitz and Thompson (1995) define some generic objectives for evaluating the design of transfer facilities.

Other research has also investigated ways to mitigate the negative impacts of transferring in order to achieve the full benefits of network connectivity. Vuchic and Musso (1992) present a systematic classification and analysis of transfers based on the headways of a passenger’s initial and connecting routes. Part of their paper addresses station layout and scheduling between frequent, intersecting rail lines which exchange large volumes of passengers. At the other extreme, they also focus on developing a



“Timed Transfer System” (TTS) to improve transfer convenience between two or more long headway transit routes, a strategy commonly employed to increase customer convenience in systems covering dispersed activity centers with infrequent service. Becker and Spielberg (1998) elaborate on the timed-transfer issue. They describe the conditions under which it may be feasible to establish timed transfer centers in a network, and develop a procedure for system scheduling. They also found that in the case of Norfolk, Virginia, the introduction of a timed transfer network increased ridership slightly despite a cutback in service hours and improved customer perceptions of the system.

Hall (1999) investigates holding strategies to improve the probability of making a successful transfer when an initial vehicle is delayed. Of course, holding also lengthens waiting times for passengers on the connecting vehicle. The objective of the holding strategy Hall develops is to minimize total passenger delay. He models the waiting process in two steps, first optimizing holding times for known vehicle arrival times, and then expanding the analysis to stochastic arrival times. When the length of the initial vehicle’s delay is known, Hall demonstrates that the optimal strategy will be either to not hold the connecting vehicle or dispatch it at the initial vehicle’s arrival time. In the stochastic case, it is difficult to find the optimal dispatch time. Hall identifies a point at which it makes sense to dispatch a connecting vehicle based upon the distribution of arrival time(s) of the initial vehicle(s). The topic of real-time holding strategies is beyond the scope of this thesis; for further information, Hall’s paper provides references on this subject.

Clearly, transfers can impact travel time, customer perceptions, and ridership. A study by the Central Transportation Planning Staff (CTPS) (1997) in Boston attempts to quantify this so-called “transfer penalty.” Empirical data were collected and analyzed for metropolitan Boston, a region with an extensive multimodal network that relies heavily on transfers. The study concludes the “transfer penalty” is more onerous than initial waiting time and over twice as onerous as in-vehicle time. Liu et al. (1997, 1998) reach similar findings using a methodology that involves both stated preference data and simulation. They also find that the “penalty” is greater for intermodal transfers (e.g. between bus and rail) than for intramodal (e.g. bus-to-bus or rail-to-rail) ones. Section

3.5 discusses the results of this research in more detail. These studies are based on the premise that a transfer-free bus ride may be better than a trip that involves both bus and rail. This is an important consideration when deciding whether to discontinue express buses that parallel a new rail line.

Other research has also attempted to investigate the holistic effects of bus-rail integration on transit systems that have introduced new rail systems. However, most of the existing literature that examines intermodal systems questions the appropriateness of rail investments from a revisionist perspective, usually emphasizing economic factors over other criteria. In contrast, this thesis looks at ways to coordinate existing bus service with a new rail line at the time rail is being constructed.

Richmond (1998) attempts to explore this issue by comparing North American cities with new light rail systems with those that have pursued bus “solutions”. He concludes that in virtually all cases, new rail lines have disrupted existing bus systems by diverting financial resources from buses to rail construction and operations. He also accuses transit agencies of reconfiguring bus networks to force passengers (particularly from express buses) onto trains, resulting in additional transfers and artificially higher rail ridership. In contrast, Richmond contends that express bus systems in Ottawa, Pittsburgh, and Houston have been as or more successful than rail systems, but at much lower capital costs.

Higgins (1981) examines the experiences of the San Francisco Bay Area’s BART system about seven years after the system’s opening. Higgins’ paper focuses on two major points. First, he asserts that in retrospect an all-bus system would have been more cost-efficient for the Bay Area than a coordinated rail and bus feeder network. Secondly, he suggests that it might be better to maintain existing parallel bus services instead of rerouting buses to new rail lines. He posits that automobiles may be more attractive than a combination bus and rail trip. Citing that the operating and capital costs per passenger trip were higher on rail than on local buses, he concludes that express buses should operate on BART corridors instead of trains.

Denant-Boèmont and Mills (1999) also approach intermodal integration from an economic perspective. Citing systems in the United States, Canada, and Europe, they conjecture that many new rail lines do not produce enough benefits to outweigh financial

assistance. In the cases where rail systems do make economic sense, Denant-Boèmont and Mills argue that cities may want to pursue intermodal competition instead of coordination because coordinated multimodal operations “may well incur excessive costs.” Citing free-market economic principles, they posit that on-street competition between bus and rail might be beneficial to passengers, even though they acknowledge that the level-of-service on each mode may decline as a result of market saturation.

This thesis builds upon previous research by taking a comprehensive, analytical approach to intermodal integration. It differs from other work because it addresses critical issues that arise when transit agencies are preparing to transition from bus-only systems to intermodal systems. Rather than delving into individual aspects of intermodal integration, much of which current literature covers in great detail, this research explores how these aspects interrelate. Furthermore, it develops a framework that also emphasizes service, ridership, political and other evaluation criteria instead of just focusing exclusively on transfers or economic considerations.

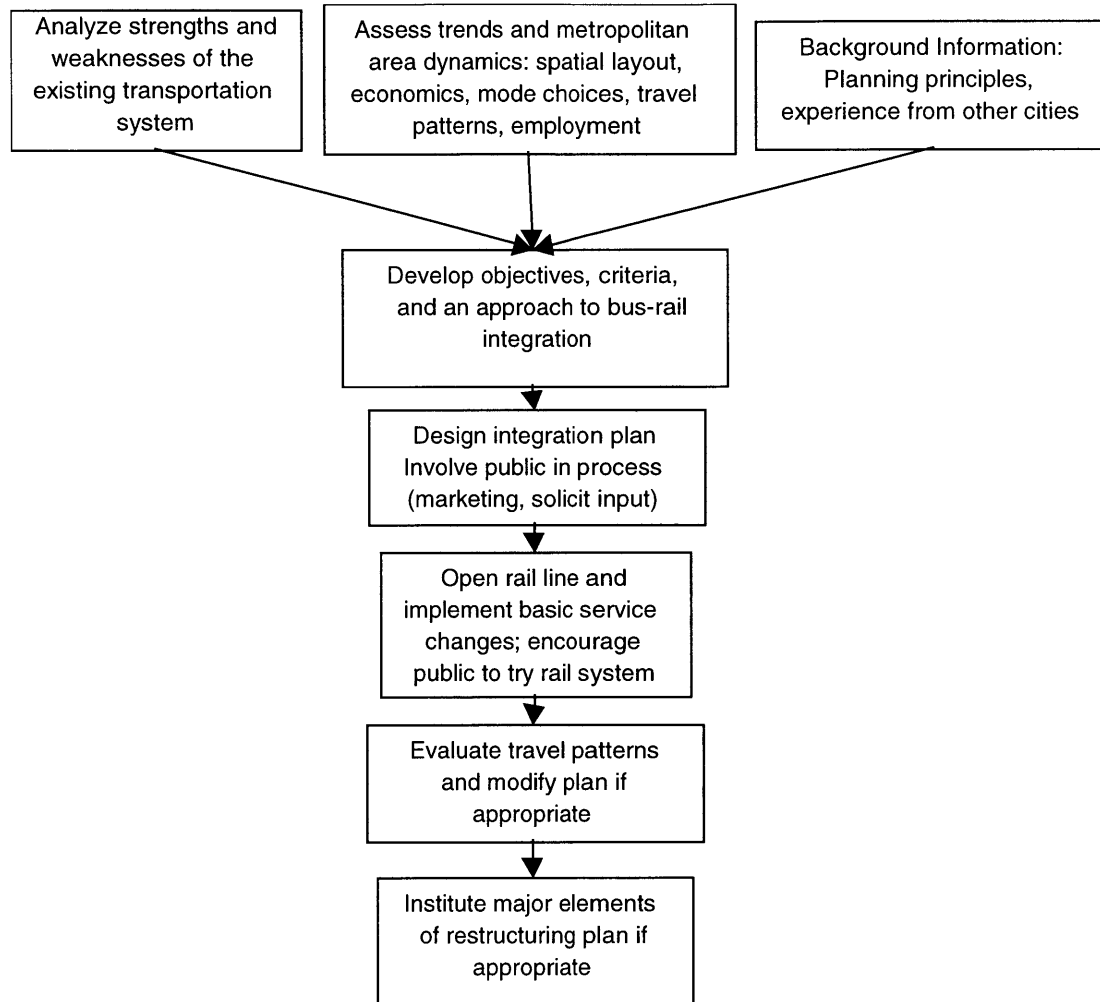
## **2.2 Planning Process**

Formulating and evaluating an integration plan can be a long and complex process. A major objective of this thesis is to develop a step-by-step analytical framework to assist decision-makers in evaluating various proposals. Figure 2-1 outlines this planning process.

At the start, transit planners must understand the financial, social and political constraints of their operating environment. Resource limitations are likely to preclude significant service expansion given the major investment in the rail line itself. Nevertheless, the ostensible purpose of the rail line is to attract new customers to transit, not merely to shift people from buses to trains. Accomplishing this basic objective almost always requires a net increase in service. Boosting system utilization and reallocating buses, particularly from lines that duplicate rail markets to ones that supplement the rail line, can limit the need to expand bus operations to some extent. However, a “zero-sum” approach whereby an agency redeploys all bus resources to serve the rail feeder market will shortchange current riders and may result in overall ridership

losses. Thus, an agency should be prepared to initiate some additional bus service to satisfy induced rail accessibility needs.

Figure 2-1: Outline of Planning Process



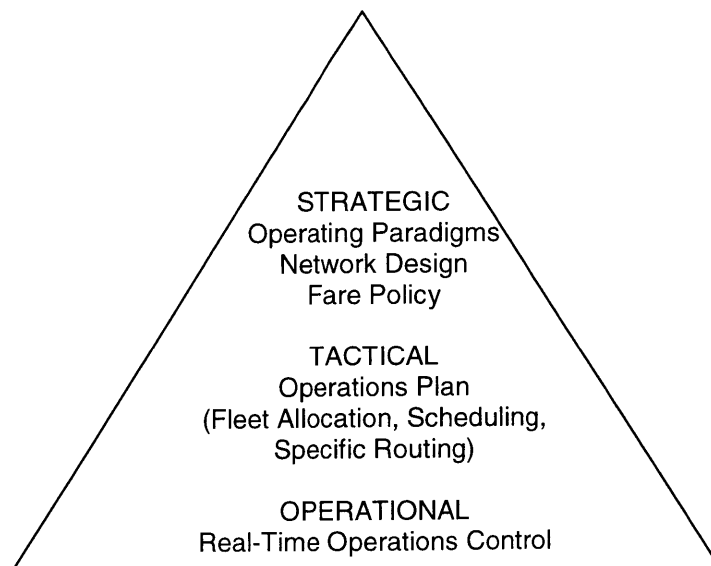
Other preliminary steps in the planning process include assessing the strengths and weaknesses of the existing system and determining major travel patterns and trends, in order to identify areas for improvement. Given these *a priori* considerations, planners should also define objectives and establish criteria to measure how they are meeting these objectives. An approach, or a general strategy, must then be developed to meet these objectives.

In the planning process, decision-makers should also understand the basic principles of intermodal integration. Important issues include fare coordination, network

theory, and transfers. Chapter 3 discusses these items individually as well as how they interact and influence each other. In addition to these generic principles, the experiences of North American cities with new rail systems offer further insight into the critical political and logistical challenges that can arise. The appendix includes case studies of Los Angeles, Miami, San Francisco, Washington, and Portland to support the ideas presented in Chapter 3. With a grasp of these main concepts and knowledge of the lessons learned from other cities, one can design and prepare an overall integration plan. Meanwhile, soliciting public input throughout the process may bring fresh perspectives to the discussion and familiarize customers with potential changes.

Formulating an integration plan requires a series of decisions that fall into three major categories: strategic, tactical and operational. The pyramid shown in Figure 2-2 illustrates the relationships between these categories. The *strategic* level includes long-term decisions such as the transit organization's network design and fare policy. Although there are relatively few specific decisions to be made at this level, they are very important because they require advance preparation and can significantly facilitate (or inhibit) intermodal integration. *Tactical* decisions must be made more frequently. A common tactical decision is the formulation or revision of the operations plan, which usually occurs in conjunction with changes in driver assignments. This allows agencies to respond to demand shifts by redeploying resources. *Operational* decisions are very short-term in nature, consisting of real-time responses to schedule delays, service disruptions, ridership surges during special events, etc.

Figure 2-2: Pyramid of Major Strategic, Tactical, and Operational Decisions



This research primarily focuses on strategic planning because this lays the foundation for subsequent tactical and operational decisions. (Some strategic engineering decisions, such as the physical layout of bus stops and rail platforms at stations, are beyond the scope of this research.) Although an agency can make strategic level decisions at any time, key policies can be difficult to change once implemented due to institutional inertia and customer resistance. This observation underscores the fact that strategic issues should merit special consideration early in the planning process. Determining the organizational paradigm of the bus and rail system is possibly the most important issue. Two incompatible paradigms – such as contracted rail operations with incentives and penalties to encourage schedule adherence, and a privately-operated feeder bus network without schedules – will make fare coordination, scheduling and real-time decision-making tougher. Likewise, an integrated fare policy can encourage customers to take the most efficient route rather than one that merely avoids transfers. A well-planned network structure can enable an agency to improve resource utilization by shifting buses from routes that duplicate rail to ones that serve new markets.

At the same time, tactical and operational decisions can also influence the effectiveness of an intermodal network, as well as customer perception. For example, scheduling ample time for customers to transfer between modes can lower the chances of missing connections due to service delays. Holding and other real-time intervention strategies can also increase transfer reliability. While this thesis covers mostly strategic intermodal planning, it also briefly discusses some tactical and operational issues affecting transfers since this is a major – and often controversial – component of many multimodal systems.

After designing and preparing an integration plan, an agency must then present it to the public since the law requires public notification of major service changes. At this point, planners have an opportunity to explain and justify changes and possibly cycle through another iteration with customer suggestions. They should also develop a plan for the staged implementation of service changes. Finally, after the rail line opens, the operator should evaluate services and modify them if necessary.

## 2.3 Objectives

A preliminary step in the bus-rail integration planning process is to establish key objectives. As indicated in the planning process flowchart above, one should consider the strengths and weaknesses of existing transit, travel patterns and trends in the metropolitan area, as well as financial and political realities when establishing objectives for an integration plan. One should also identify target markets where transit can become a feasible or competitive travel mode. While planners will need to tailor objectives for individual systems, some general objectives will apply in nearly all cases:

- Attract new riders

A primary goal of a new rail system is to attract new transit riders, especially since heavy political pressure exists to meet ridership expectations. Merely shifting riders from the bus to the train is unlikely to justify a major investment. A prudent restructuring of bus services can also increase ridership on the bus system by facilitating access to the train and between destinations not along the rail line.

- Retain existing ridership

The opening of a rail line should not cause the existing bus system to decline. Some riders will certainly shift from bus to rail and that would benefit both the passenger and operator. However, for both social and political reasons, bus route restructuring for the train should not drive existing bus riders away from transit. Therefore, the bus-rail integration planning process must balance the desire to achieve the first objective with the need to retain existing ridership.

- Maximize *effective* use of the rail system

Since rail infrastructure is expensive and is a sunk cost, clearly a transit agency must capitalize on its investment. In terms of labor costs, higher-capacity vehicles can allow rail to transport passengers more economically than buses along high-demand corridors.

- Ensure political support for future rail extensions

Because of high cost and implementation time, rail systems are built over decades, line segment by line segment. Maintaining political support for continuing to expand the rail system is usually essential to long run success. Often critics have assailed new rail segments for under-utilization, high construction costs, favoring “choice” riders and other demographic groups, and for disrupting existing bus systems. Whether or not they have legitimate grounds for such complaints, they have (ironically) succeeded in allying anti-tax and anti-transit forces with bus riders in some cities. Their attacks have sometimes resulted in diminished public support for and/or abandonment of further rail construction. On the other hand, a well-integrated transit system that meets today’s diverse transportation needs can win support not only from regular transit patrons, but also from non-riders and occasional users. Having a large support base is critical for future transit expansion. Thus, any integration plan must provide high-quality service to solidify the broad constituency needed to expand rail transit.

- Improve Productivity

No major North American public transit system turns a profit. However, a prudent allocation of resources that boosts ridership and takes advantage of the relative economic and technological strengths of bus and rail modes can help improve overall productivity.

## **2.4 Criteria**

After establishing broad objectives, transit agencies should also develop criteria to measure how well integration proposals fulfill these target goals. Criteria can fall into broad service, customer, financial, productivity and external categories, and possibly others depending on the situation. Of course, these categories as well as the criteria themselves can vary, reflecting values of each organization and the particular circumstances of the metropolitan area. Below is one possible set of criteria:



## Service Criteria

- Network coverage and connectivity – By establishing where customers can travel, the route network is the basic building block of a transit system. Planners should consider how route restructuring proposals affect the ability of passengers to travel throughout the urban area. Network coverage refers to the areas easily accessible to transit. Connectivity refers to how well rail and bus lines interface to allow passengers to reach a variety of destinations. In some cases, bus reallocation from the rail corridor to other parts of the region can improve an agency’s ability to serve new customers.
- Route Directness – Circuitous routing or trips that involve many transfers can discourage ridership. On the flip side, a transit agency cannot provide direct service for everyone given the multiplicity of travel patterns in any region. Changes to integrate bus and rail services should balance the desire to offer customers direct service with other goals including network connectivity and operational efficiency (i.e. eliminating service duplication).
- Service Frequency and Span of Service – While service frequency is a function of demand along a given transit route, it is also a primary factor influencing people’s mode choice. When evaluating service integration proposals, it is important to consider how changes can affect service frequency or span of service. For example, resource allocation from bus lines that parallel rail to overcrowded routes or ones that operate in underserved areas can make transit more attractive to new customers.
- Operational Impacts – The introduction of a rail line and associated bus service modifications may have large impacts on overall system reliability. Operational reliability is an important criterion to consider when formulating integration proposals. For instance, shortened bus routes circulating around neighborhoods tend to have better schedule adherence than radial express routes travelling along congested highways. Meanwhile, rail systems potentially have better service reliability than typical bus routes because they operate in exclusive rights-of-way rather than in general traffic.

### Ridership Criteria

- Ridership impacts: New rail lines and associated bus modifications clearly affect ridership. Better service levels and fare coordination generally result in higher patronage, but resource limitations constrain system growth. When evaluating service changes, planners should also attempt to determine how they might affect new and existing customers differently. Since it is usually easier to lose riders quickly than to attract new ones, appropriate integration strategies should balance the need to attract new customers with retaining existing ones.
- Equity concerns: Changes in a transit system that occur when a new rail line opens do not always affect all population groups in the same way. For example, the rail system may introduce a transfer for certain transit-dependent bus riders, but may succeed in attracting “choice” riders from their cars. Of course, the definition of equity is nebulous: it may mean that all people receive the same level-of-service or that disadvantaged people with fewer resources receive additional transit service. Nevertheless, planners should be particularly sensitive to how their integration strategies affect people with different levels of income and mobility.

### Financial & Productivity Criteria

- Marginal costs and revenue: Each service modification (or fare policy) proposal will impact operating costs and revenue, often in a non-linear manner. For example, it costs more to provide service during rush hours than at other times; not only does an agency have to size its fleet for the peak, but it may also have to pay spread premiums to drivers whose shifts extend over a long workday. In addition, different service levels and fare policies can dramatically impact ridership, which affects revenue. Various analytical models can help agencies estimate marginal costs and revenue for a given service change.
- Service effectiveness: Service effectiveness, a productivity measure of how well the public utilizes provided service (e.g. passengers per vehicle hour or per vehicle mile), helps to demonstrate the social contributions of a given service modification. Boosting ridership (relative to service) can help improve service effectiveness and

can reduce subsidies per passenger, since higher ridership levels translate into greater revenues. Of course, cutting back service but trying to retain as many riders as possible can also improve service effectiveness, but this typically leads to a downward spiral of service cuts, higher fares, and lost ridership. The lag between service modifications and ridership increases (or decreases) is of major importance and requires explicit acknowledgement to avoid confusing short-term and long-term impacts.

- **Cost efficiency:** Cost efficiency is another productivity measure that describes the unit cost of providing service, independent of ridership. Common cost efficiency measures include labor cost per vehicle hour or per vehicle mile. Cost efficiency is one of the primary considerations in selecting an operating model (e.g. directly-operated service); one of the primary arguments for contracted operations is that private carriers can achieve better cost efficiency than the public sector. When designing an intermodal network, cost efficiency differs for bus and rail.
- **Cost effectiveness:** Cost effectiveness is a commonly used productivity measure that relates costs, revenue, and ridership, as well as encapsulates both service effectiveness and cost efficiency. Specifically, it compares the monetary social cost of providing service (subsidy) with transit's beneficiaries (number of passengers). Net cost per passenger is a common measure of cost effectiveness.

Since transit agencies must always balance the desire for high service levels with available financial resources, productivity measures such as net cost per passenger are often used to evaluate service modification proposals. While productivity criteria are clearly important to keep an agency financially stable, it probably should not be the primary concern during the transition to a new rail system. During this period, a critical objective is to get people to try the new rail system and become regular customers. Changes in travel patterns, new system capacity added by rail, fare incentives to attract new customers, and other factors can lead to "inefficiency" (at least as perceived in the short run.) Using productivity as the primary evaluation criteria for integration policies may lead to decisions that discourage system usage.

## External Criteria

- **Political Risk:** In some cases, it may make sense not to pursue a strategy that meets other service, ridership, financial, and performance criteria if it is not politically acceptable. For example, eliminating express bus routes on the rail system's opening day may draw unfavorable attention. Rail skeptics may feel that the agency is forcing bus passengers onto rail, while bus operators may complain out of fear they could lose their jobs. Similarly, opening a rail line and increasing fares simultaneously can embarrass the agency even if it brings additional revenue. Clearly, political acceptability is an important evaluation criterion for any integration strategy.

## **2.5 Approaches**

This section outlines some general approaches a transit agency can take to fulfill the objectives outlined in section 2.3. While presented as distinct models, these approaches are not mutually exclusive. Some appropriate strategies may use a combination of approaches.

- **Minimalist Approach**

The minimalist approach makes few service changes. Only minor and obvious modifications are made, such as changing bus routes that run close to rail stations to stop at the stations. Limiting changes would primarily satisfy existing customers under the presumption that many people choose where to live based on transit availability. A bus-rail integration plan developed for the Boston's northwest Red Line extension notes, "It was felt to be poor marketing strategy to jeopardize the current ridership in the hopes of gaining new ridership with a radically revised service delivery strategy. Current riders can be lost immediately, while a substantial amount of time is required to build up new ridership" (MBTA, 1985).

However, this approach may lead to an inefficient use of resources and miss opportunities to tap new markets. For instance, an agency may decide not to reduce any bus service that parallels a rail line. This would directly impact rail utilization and perhaps result in an oversupply of service along the corridor. Meanwhile, the agency might also have to forgo redistributing bus resources to under-served communities, or

redesigning routes to facilitate new trip patterns. Thus, the opportunity cost of this decision also may include lost potential ridership on the entire system.

- Feeder Approach

The feeder approach prioritizes bus accessibility to the rail system. Bus routes that travel anywhere near the rail alignment are transformed into feeders that deliver passengers to the rail station. In the short term, this strategy will likely maximize rail ridership by shifting existing bus riders to rail. Higher ridership would help project an image of “success” and reinforce rail as the system’s symbolic centerpiece.

One disadvantage of the feeder approach is that it requires transfers for many former “one-seat” bus riders. Some people may also find it easier to drive to a park & ride lot instead of taking a feeder bus. Fortunately, schedule and fare coordination can help mitigate these impacts. Perhaps more seriously, the feeder approach may greatly inconvenience passengers whose origins and destinations are not near the rail line. Truncating bus routes at rail stations may result in lengthy trip diversions as well as added bus-to-bus transfers. This may lead to the perception that the investments in rail transit are at the expense of the bus system.

- Integrated Systems Approach

The integrated systems approach strives to create a system that takes advantage of the strengths of bus and rail modes by considering their respective operational and financial effectiveness and efficiency. As importantly, it emphasizes providing the most efficient travel options for customers, whether by rail, bus or a combination of both. Unlike the other approaches, it explicitly balances the desire to build rail ridership with the needs of current patrons. In the long run, this strategy may possibly attract more rail *and* bus customers. Depending on the rail corridor characteristics, a reallocation of bus services to decrease headways or introduce new service to other areas could achieve significant ridership gains. In the short term, however, this strategy may not necessarily result in as much rail ridership as the rail-oriented approach.

Over the long run, which strategy should an agency choose when altering bus routes to accommodate a new rail line? The answer in current practice often depends on many factors including the political environment and financial resources. It typically differs based upon whether the same or separate authorities operate the buses and trains. For example, a bus-only agency interested in retaining its customer base may choose the minimalist approach, continuing parallel express bus service that competes with the rail services of another agency. Among multimodal agencies, political pressures to achieve rail ridership projections commonly result in a rail-oriented “feeder” network design approach. Unfortunately, this may greatly inconvenience customers whose travel patterns do not naturally “fit” the new rail line, leading to the perception that the agency is trying to force bus passengers onto the train to make it “look good”.

While the minimalist and rail-oriented approaches seem like quite natural responses to the bus-rail integration issue given a specific institutional, cultural and physical environment, in the long run an integrated systems strategy may be preferable. Admittedly, geographical and financial constraints may make this option more feasible in some cities than others, and indeed easier along certain segments of a particular rail alignment. Nevertheless, framing the bus-rail integration issue in terms of designing an efficient system for both the operator and public offers several advantages:

- Compared to the rail-oriented feeder approach, an integrated systems strategy takes a broader view of intermodal planning. Not only does it address bus feeder access needs, but it also explicitly acknowledges the complexity of today’s travel patterns. Heavy demand and potential transit-friendly development opportunities along a corridor can justify building a new rail system; however, transit can also play a role in many other travel corridors that exist today in metropolitan areas. An intelligent network design can transform a purely feeder-based route scheme into a more comprehensive one.
- Unlike the minimalist approach, an integrated systems strategy takes a proactive view of network design. It encourages an agency to design services to improve trip speed and reliability, coordinate schedules, achieve operating efficiencies, and expand customer markets where possible by reallocating (and expanding) bus resources. An

integrated systems strategy can incorporate elements of both the minimalist and rail-oriented approaches for specific locations. For example, planners may not need to make many changes to integrate services at a station that has historically served as a bus hub. The existing route structure would continue to accommodate current bus riders, while the buses would effectively make the train accessible from outlying areas.

- Over the long run, an integrated systems strategy has greater potential to build transit ridership. An integrated system can give people confidence that transit can work for them, even if the higher-profile train cannot initially take them where they want to go. This translates into greater support for rail expansion and for public transportation in general as an alternative to driving.

- Incremental Approach

While an integrated systems approach makes sense over the long run, it can clearly inconvenience some people in the short term if it causes them to alter their travel patterns. In addition, transit planners may have difficulty accurately predicting the outcome of service changes associated with an integrated system despite careful analysis and modeling efforts. Since new rail systems are often under intense scrutiny during and shortly after opening, an incremental strategy of implementing bus service changes is worth considering.

Specifically, an agency might pursue a minimalist approach initially with relatively minor service alterations on opening day. Current bus riders will not be forced to alter their travel patterns, at least initially. Bus drivers are more likely to feel comfortable if there is clearly no threat to their jobs. In addition, this strategy may include temporary fare discounts on the rail system to entice people to try the new system. A few months later, initial scrutiny fades and the agency has time to assess the impacts of the rail system on travel behavior. Some bus riders will have certainly switched to rail to take advantage of a higher level of service, and the agency could then justify major bus service modifications and fare changes. It is important to explain this strategy to the public openly. Agencies must clearly state that in the future, bus services

may be redeployed, not curtailed, and that low fares are introductory discounts for the transitional period only.

While the incremental approach can stabilize bus ridership and insulate an agency from some political criticism, two major obstacles impede implementation. First, service duplication consumes additional operating resources, but is not likely to increase ridership substantially. Secondly, rail ridership cannot reach its potential without support from the bus network. Nevertheless, it may make sense to “buy” stability and insulation from political criticism. For this approach to work, an agency must accept that inefficiency is necessary during the transition phase. Although this may seem like a waste of resources, the marginal cost of providing some excess service over a relatively short period is small compared to the rail system’s capital cost. In addition, an agency must explicitly emphasize to the riders, the general public, the media, and others that actual ridership cannot reach expectations until all the support services are in place.



## **Chapter 3: Bus-Rail Integration Planning Principles**

This chapter introduces some basic planning principles for integrating buses with new rail lines. After outlining desired level-of-service characteristics from the customer's perspective, it then addresses some strategic, tactical, and operational issues using the analytical framework presented in section 2.2. It focuses primarily on strategic, long-term questions but also mentions the tactical and operational issues that are fundamental to high-quality service delivery.

### **3.1 Desired Level-of-Service Characteristics**

The success and utility of new rail systems depend critically upon effective integration with the existing transit services. Generally speaking, any intermodal system will need to offer a consistent and high quality level-of-service in order to retain existing ridership and attract new customers. Some of the most important service attributes include:

- **Service Frequency** – Reducing out-of-vehicle waiting time enhances passenger convenience particularly in an intermodal network that relies on transfers. While budget constraints may limit an agency's ability to provide short headways on all routes, schedule coordination on low frequency routes can partially compensate for lower service levels.
- **Schedule Reliability** – Services should operate according to published schedules. Customers should know the expected trip time, as well as when to leave so as to minimize transfer wait time.
- **Integrated Fares** – An intermodal system should offer a fare structure that makes transferring between modes convenient. Lack of fare integration and varying fares across modes often contribute to perceptions that bus and rail operators do not coordinate with each other.
- **Vehicle Comfort and Accessibility** – Vehicles must be clean, comfortable, and climate-controlled. The interior design should also be able to accommodate large passenger volumes quickly and comfortably. In addition, they should provide accessibility to people with disabilities, as mandated by the Americans with

Disabilities Act. Improvements such as low-floor vehicles can also make a system more user-friendly.

- Route Structure - Ideally the bus and público route structure should provide access to the rail line while retaining convenient service for non-rail customers, particularly for local and crosstown trips

### **3.2 Organizational/Operating Paradigms**

When designing and building a new rail line, planners must determine an appropriate operating paradigm for the organization. Sometimes the public agency running buses assumes responsibility for the rail system; at other times, an entirely new agency is formed. Table 3-1 presents the major options, highlighting the advantages and disadvantages of each. This choice not only impacts cost efficiency, but also the overall effectiveness of intermodal integration. For example, two fundamentally different paradigms, such as the unregulated and contracted operations models, will make coordination between systems difficult.

The great majority of North American transit systems employ the publicly-operated model, although there is also increasing use of contracting, particularly for demand responsive service and commuter rail operations. Both paradigms depend upon public financial assistance, although the contracted operations option uses competitive bidding among private sector firms in an attempt to realize cost savings. With the exception of Tren Urbano in San Juan, all North American heavy and light rail operations use the publicly-operated model. Furthermore, regional agencies almost always operate both the bus and rail systems. Independent suburban bus systems may also serve rail stations in some of these cases. A few rail operations, such as BART in San Francisco, are completely separate from bus systems

Table 3-1: Major Operating Paradigms

	Description	Advantages	Disadvantages
Unregulated/ Deregulated	Privately operated, few barriers to entry or exit, little government oversight	Competition among operators ostensibly encourages better service at a low cost; government does not have to subsidize operations	Unprofitable routes, low density areas, and off-peak services neglected; coordination difficult; High demand areas over-served; overfilled vehicles to maximize revenue; driving “competitively” may jeopardize passenger safety and lead to maintenance neglect
Regulated Competition	Privately operated, but with some government regulation pertaining to safety, maintenance, fares, etc.	Similar to unregulated/ deregulated model; government regulation can help meet some societal objectives	Similar to unregulated/ deregulated model; government regulation may cause operators to fail
Threatened Competition	Government threatens competition by using renewable contracts with private operators, but avoids direct street competition	Potential to produce cost-efficient, high-quality service	Threat of competition may be illusory, which diminishes the model’s effectiveness; potential corruption and non-competitive bidding
Private Monopoly	A single private company operates public transport with some government regulation	Potential for better service coordination; government can more easily impose mobility, equity, environmental and other broad objectives; organization motivated to earn a profit	Private monopolists less likely to fulfill fundamental societal objectives for public transit, favoring infrequent and overloaded services; less incentive toward cost efficiency and service quality because they are insulated from competition
Public Monopoly	The public sector directly operates public transport services	Theoretically able to best serve public transport’s accessibility, equity, and other societal objectives; potential for better service coordination; long-run stability with less risk of financial failure	Less incentive to achieve cost-effectiveness, grow ridership, or penetrate new markets; pressure to avoid increasing subsidy may result in service cutbacks rather than cost streamlining
Contracting Out	Public authority delegates operating responsibility to private companies through competitively-bid contracts	Potential for improved cost efficiency through the bidding process; public authority still able to specify service quality and levels to meet societal objectives	May not reduce costs if bidding process is not competitive, especially with a lack of qualified bidders; contractor may not focus on customers or “cut corners”; monitoring of private company performance can be costly and difficult

Source: Salvucci et al. (1997)

Within the same region, different transit agencies and operating models can sometimes be compatible. In Los Angeles and Washington DC, for example, publicly operated multimodal systems provide most transit service but coexist with contracted out suburban bus operations. A few multimodal transit agencies, such as Denver’s RTD and Boston’s MBTA, operate some services with public employees and others with

contracted workers. From a customer's standpoint, these two models can work together since the public authority retains control over schedules, routes, and fares.

Even within the same organization, however, integration can be difficult. In general, different transit agencies and operating models within the same region can further stymie coordination efforts. In the San Francisco Bay Area, for example, there are over two-dozen transit providers ranging from the nation's eighth largest system to mini-operations with just one or two routes. With divergent interests, agencies may not always agree on service duplication, fare integration, and schedule coordination policies. Widely different operating paradigms can further complicate matters in cities with comprehensive bus and rail systems. In Miami and New York, for example, privately operated jitney services categorized as "regulated competition" operate alongside busy public bus corridors. Jitneys are hard to coordinate with rail, or for that matter with regular buses and other jitneys, since they charge separate fares without transfer privileges and do not adhere to fixed schedules. In fact, Miami's transit agency experienced a public backlash when they allowed jitneys to replace some bus routes when their rail system opened. (For more information on San Francisco and Miami, please refer to the appendix.) Experience from other cities suggests that planners should carefully weigh the organizational options for new rail systems in relation to pre-existing transit systems. These early but critical decisions set the tone for other integration policies.

### **3.3 Fare Coordination**

Fare coordination is extremely important in a system that relies on transfers to maximize the destination opportunities available to customers. Substantial literature already exists regarding fare coordination, particularly in the areas of fare policy and fare collection technology. With regard to intermodal fare integration, Barr (1995) developed a framework for analyzing specific fare integration strategies. Rather than repeating previous research, the work here briefly discusses how fare coordination policy may influence network structure decisions and passenger willingness to accept service changes in conjunction with a new rail line.

From an operator’s standpoint, a rail system provides opportunities to reconfigure the bus system. Although these changes can improve efficiency and network effectiveness from a systemwide perspective, some trips may require an additional transfer. In addition, new riders who begin or end their trips away from the rail corridor may need to ride buses to access stations. The fare policy should encourage customers to use the most efficient route(s) possible to reach their destinations, whether they are travelling by bus, rail, or both.

Table 3-2: Transfer Policies for Major Intermodal Systems

City	Rail Fare	Bus Fare	Same Operator?	Transfer Policy
Atlanta	\$1.50	\$1.50	Yes	Free transfer
Baltimore	\$1.35	\$1.35	Yes	No transfers; \$3 day pass
Boston	\$.85+	\$.60	Yes	No transfers; \$5 (visitor’s) day pass
Buffalo	\$1.25	\$1.25+	Yes	Free transfer
Chicago	\$1.50	\$1.50	Yes	\$.30 transfer; \$5 (visitor’s) day pass
Cleveland	\$1.50	\$1.25	Yes	Free transfer, or \$4 day pass
Dallas	\$1.00	\$1.00	Yes	Free transfer, or \$2 day pass
Denver	\$1.25 pk, \$.75 base	\$1.25 pk, \$.75 base	Yes	Free transfer, or \$3 day pass
Los Angeles	\$1.35	\$1.35	Yes	\$.25 transfer
Miami	\$1.25	\$1.25	Yes	\$.25 transfer
New York	\$1.50	\$1.50	Yes	Free transfer, or \$4 day pass
Philadelphia	\$1.60	\$1.60	Yes	\$.40 transfer, or \$5 day pass
Pittsburgh	\$1.50+ peak \$1.25+ base	\$1.25+	Yes	\$.25 transfer
Portland	\$1.15+	\$1.15+	Yes	Free transfer, or \$3.60 day pass
Sacramento	\$1.50	\$1.50	Yes	Free transfer, or \$3.50 day pass
St. Louis	\$1.25	\$1.25	Yes	\$.10 transfer, or \$4 day pass
Salt Lake City	\$1.00	\$1.00	Yes	Free transfer, or \$2 day pass
San Diego	\$1.00+	\$1.75+	Yes	Transfers cost the difference between rail and bus fare, or \$5 day pass
San Francisco	\$1 \$1.10+ \$1.10+ \$1.10+	\$1 \$1.35 \$1.10	No	Free transfer (MUNI light rail to/from bus) \$.50 transfer (BART to/from MUNI) \$1.15 transfer (BART to/from AC Transit) No transfers (BART to/from SamTrans)
San Jose	\$1.25	\$1.25	Yes	No transfers; \$3 day pass
San Juan	-	-	No	Undetermined
Washington	\$1.10+	\$1.10	Yes	\$.25 rail-to-bus; no bus-to-rail transfers
Calgary	\$1.60	\$1.60	Yes	Free transfer, or \$5 day pass
Edmonton	\$1.60	\$1.60	Yes	Free transfer, or \$4.75 day pass
Montréal	\$1.90	\$1.90	Yes	Free transfer
Toronto	\$2.00	\$2.00	Yes	Free transfer, or \$7 day pass
Vancouver	\$1.50+	\$1.50+	Yes	Free transfer, or \$6 day pass

Source: Agency web sites

Table 3-2 summarizes the intermodal fare policies of major North American multimodal systems. The majority of transit operators offer free or heavily-discounted transfers, unlimited-ride day passes, or a combination of both. In general, having a single regional transit provider overseeing all modes greatly facilitates fare integration. A major

exception is Boston, where customers pay different bus and subway fares with no transfer privileges. Although individual subway and bus fares are among the lowest in the United States, the lack of transfers raises the price for intermodal trips and makes the rail and bus systems appear independent.

Separate transit providers within a region often resist fare integration efforts because of potential revenue loss. In the long run, such fare policies can encourage inefficient and duplicative network structures that benefit neither party. Appendix A describes such a situation in the San Francisco Bay Area. In this case, BART, the regional heavy rail operator, and AC Transit, the bus system serving the area east of San Francisco, provide only a nominal discount on a combined bus and rail fare. Meanwhile, AC Transit's transbay commuter buses to San Francisco cost much less than intermodal trips (Bay Area Transit Information website). This fare policy increases the demand for duplicative service and encourages AC Transit to provide it. In fact, AC Transit's *Transbay Comprehensive Service Plan* states that in the future, "the District may need to initiate peak-hour bus service even in areas well-served by BART" (AC Transit, 1998). To justify this policy, AC Transit cites BART's capacity constraints, but BART's internal documents indicate that the agency is attempting to address this issue by increasing system throughput (BART, 1999). While transbay customers benefit from additional transportation choices, the opportunity cost of such decisions is high: in 1996, AC Transit slashed owl, weekend, and evening buses in communities with no other transit alternatives (Pimentel, 1999).

Even within a single intermodal agency, a lack of fare coordination can cause problems. In Washington, DC, the Washington Metropolitan Area Transit Authority (WMATA) encountered opposition when it extended the Metro system to Anacostia, a low-income neighborhood. Buses that used to run into the central business district were truncated at the Anacostia station. Although riders received a substantial discount when transferring from rail to bus, they paid two full fares in the opposite direction. Customers were justifiably concerned with the financial impacts of transferring since they had paid a single fare prior to the rail extension. To respond to these concerns and to avoid having to restore duplicative bus service, WMATA management ultimately reduced fares by about 40% on selected Anacostia bus routes, which in effect lowered the transfer fee

(Erion, 1998). In contrast, recent improvements in intermodal fare policies have resulted in huge ridership increases. In July 1999, WMATA simplified bus fares and reduced rail-to-bus transfers to \$0.25. These transfers used to cost between \$0.25 and \$2.25 or simply were not available, depending upon time of day, direction, and jurisdiction. These efforts contributed to an immediate ten percent ridership jump (WMATA Press Release, Oct. 20, 1999). Appendix A provides additional background information and details.

New York City is perhaps the best North American example of how fare coordination can boost ridership and increase customer convenience. Historically, New York City Transit had offered free subway-to-subway and bus-to-bus transfers, but no discounted intermodal transfers. This resulted in a de facto two-zone fare structure for customers who rode both the bus and subway. In the 1990s, the transit authority implemented an automated fare collection (AFC) system on all buses and rail stations using the *MetroCard*, a magnetic swipe card. In July 1997, it introduced free transfers between subways and buses, including buses operated by private carriers. It later initiated bulk-ride discounts and unlimited-ride 1-day, 7-day, and 30-day rolling passes.

Between January 1997 and June 1999, New York experienced double digit ridership increases mainly as a result of these fare incentives. Specifically, weekday subway and bus ridership increased 12.5% and 40.8% respectively. Weekend ridership also grew by 17.6% and 37.2%, indicating that the *Metrocard* has also encouraged off-peak usage. By comparison, New York City employment rose 4.9% during this period. While some of the growth can be attributed to a real fare decrease for intermodal trips, fare elasticity only accounts for part of the increase. Today there are about 500,000 intermodal trips systemwide (many of which were already occurring before the fare incentives), but weekday ridership on buses alone grew by about 600,000 trips between June 1997 and June 1999 (Hirsch, 2000).

A follow-up study prepared by the transit authority, “The Effects of Fare Incentives on MTA New York City Transit Ridership”, argues that convenience and flexibility of fare payment also helps explain the *Metrocard*’s success. Growth has resulted from “a reduction in the marginal cost of certain trips to zero, including induced trips made by passengers holding unlimited-ride *MetroCards* [i.e. off-peak and non-work trips] and feeder bus trips made by existing subway passengers using the new free

intermodal transfer.” Introducing free intermodal transfers also appears “to have shifted some passengers from a two-bus trip to a subway-bus” trip (Hirsch, 2000). In other words, most customers now choose the most efficient and quickest path (i.e. often one that involves the subway) rather than a slower all-bus trip that used to avoid a transfer fee. Moreover, the significant increases in bus ridership (around 40%) suggest that fare incentives did not merely shift customers from bus to rail, but actually induced more bus usage. *Metrocard* has fueled an upward spiral of higher ridership and more service: between 1997 and 1999, revenue seat miles increased 10% and 11% on buses and subways respectively. The current number of peak buses is now 20% higher than in 1996 (Hirsch, 2000).

Of course, financial considerations limit an agency’s ability to provide transfer discounts. In New York’s case, fare revenue decreased slightly (-3.7%) and the farebox recovery ratio dropped about five percentage points (Tucker and Stuart, 2000). Nevertheless, planners designing new rail systems should still consider a coordinated fare policy. When a rail line opens, it is especially important to offer transfer discounts and perhaps artificially low introductory fares to entice people to try the new system. Particularly with a new rail line, mandates or external pressures to achieve a high cost recovery ratio can result in cutting corners on service or maintenance and missed ridership potential. This may lead to a downward spiral of higher fares, more service reductions, and deferred maintenance, which ultimately makes it more difficult for transit – both buses and new rail systems - to fulfill important social goals and compete with the automobile.

Given the recent experiences in New York and Washington, DC, it seems reasonable to conclude that simplifying and lowering the cost of intermodal (and intramodal) transfers can attract new patrons to the system and encourage existing customers to ride more frequently. By making vehicles look fuller, the large off-peak ridership growth in New York’s case may have also had the side impact of increasing customer perceptions of security. This, in turn, encourages people to utilize transit not only for commuting, but also for other activities and can reduce the need to own multiple cars. As importantly, induced demand on bus routes that serve rail stations lessens the



pressure to build park-and-ride lots and permits better bus frequency, which also benefits passengers on these routes who rely on buses exclusively.

### 3.4 Network Structure

A new rail line presents many opportunities to modify bus routes in order to avoid service duplication, expand into new areas, etc. For simplicity, the analysis of bus integration proposals often focuses on individual route impacts. This section, however, considers the effects of bus restructuring efforts on the entire network and evaluates strategies for their implementation.

#### 3.4.1 Background Information

It seems fairly self-evident that a route network is a primary factor in determining which travel patterns transit can serve effectively. A new rail line and other significant transit investments may provide opportunities not only to directly boost “choice” ridership, but also to redesign the existing bus network to make it more responsive to diverse travel needs. Many transit systems, particularly in older metropolitan areas, historically evolved to serve radial travel patterns between central business districts and outlying neighborhoods and suburbs. Clearly, a strong downtown and a compact urban environment are most conducive to effective transit services and foster a symbiotic relationship between frequent service and high ridership. In contrast, transit has a much more difficult time competing with the automobile in the suburbs, particularly for suburb-to-suburb trips. Abundant free parking, high car ownership, higher incomes, automobile-oriented land uses, and other factors discourage transit usage. Table 3-3 illustrates this point by breaking down public transport’s mode share for work trips in the United States by home and work locations. While transit captures approximately 14% of trips within the central city and 6% between suburbs and the city, it performs poorly in the suburb-to-suburb market with just a 2% mode share.

Table 3-3: Public Transport Mode Share in the United States (1990)

Location	Work in Central City	Work in Suburbs
Live in Central City	14%	6%
Live in Suburbs	6%	2%

Source: Pisarski (1996).

At the same time, transit's most competitive market (commuting within the central city) no longer dominates. Table 3-4 shows that suburb-to-suburb commuting comprises almost 44% of work trips in the United States, eclipsing all other categories. Although some cities have rebounded in recent years, decentralized and low-density development trends remain strong. Table 3-5, which breaks down the total commuting growth between 1980 and 1990 by home and work locations, shows a clear suburbanization trend. Over this period, the American workforce increased by about 18.5 million. Of this total, suburb-to-suburb travel captured 58% of this growth while travel within central cities captured just 10%. The traditional suburb-to-city and reverse-commute had a healthy share of this growth given their size, however, indicating potential opportunities for transit.

Table 3-4: Basic Metropolitan Commuter Flows in the United States (1990)

Location	Work in Central City	Work in Suburbs	Total
Live in Central City	24,330,000 (30.1%)	5,970,000 (7.4%)	30,300,000
Live in Suburbs	15,260,000 (18.9%)	35,350,000 (43.7%)	50,610,000
Total	39,590,000	41,320,000	80,910,000

Note: Numbers include those commuters who work within the metropolitan area where they live.

Source: Pisarski (1996).

Table 3-5: Share of the Increase of Metropolitan Commuter Flows (1980-1990)

Location	Work in Central City	Work in Suburbs
Live in Central City	10%	12%
Live in Suburbs	20%	58%

Note: Between 1980 and 1990, the number of American workers grew by 18.5 million, from 96.6 million to 115.1 million.

Source: Pisarski (1996).

It is important to note that Tables 3-3, 3-4, and 3-5 focus on commuting patterns only, not on non-work travel where transit is generally even less competitive. The tables also show aggregate data for the entire United States, but figures can vary greatly by geographical location. Older East Coast cities with extensive transit networks and relatively strong central business districts, for example, generally have much higher transit mode shares than Sunbelt cities that boomed after the Second World War. Since many new rail systems serve predominantly automobile-oriented cities such as Dallas, Denver, Los Angeles, San Diego, Salt Lake City, Sacramento, Atlanta, and San Jose, examining cost-effective ways to adapt intermodal networks to low-density environments

is relevant and worth considering (even if a long-term objective is to foster “transit-oriented” development).

For reasons discussed earlier, however, transit almost inevitably performs worse in low-density areas than in concentrated urban centers. With limited resources, the opportunity costs of capturing new markets can be high. For example, expansion in suburban areas may come at the expense of cities where the additional resources would likely produce higher returns in terms of ridership and cost-effectiveness. Service dilution in urban areas can make cities less attractive places to live, which may ultimately encourage further suburbanization.

Nevertheless, rudimentary transit service already exists in many low-density areas of North American metropolitan regions, but is often underutilized. In larger cities, service may consist of local and commuter express buses to and from the central business district and community shuttles. Many of the recently-built rail lines penetrate such areas as they radiate outward from the central business district. This suggests that a new rail investment may provide opportunities to reallocate bus resources and/or boost bus service to meet induced rail feeder demand to improve system utilization. Consequently, the intermodal network may be able to serve existing or untapped travel markets better. Section 3.4.3 discusses these concepts in more detail.

Reverse commuting to suburban office parks or “edge cities” is a specific example of a potential niche market. Abundant parking, circuitous street layout, good highway access and other impediments make it hard for transit to compete with automobiles. Running frequent, direct express buses from a single employment center to points throughout the metropolitan area is unlikely to be either cost-effective or productive because of low demand densities. However, if an employment site is located near a rail station, it may be possible to operate a bus shuttle that connects with rail service. Since the shuttle operates short distances, schedule reliability would be generally easier to control and it would require relatively few resources to offer reasonable service levels (compared to a long route).

Realistically, these efforts will not produce huge mode share gains for transit without fundamental changes in land use and automobile pricing policies. Portland, Oregon, demonstrates that they can make an impact, however. When light rail was

extended to the western suburbs, the transit agency used these concepts to convert a primarily radial bus network with a heavy commuter express emphasis into one focused around key rail stations. As a result of these changes, transit's mode share of afternoon peak-direction trips rose from 13% to 20% along the corridor; even more impressively, the afternoon reverse-commute transit usage more than tripled from 4% to 14% (Tri-Met and ODOT, 1999). Appendix A describes Portland's experience in more detail.

### **3.4.2 A Priori Considerations**

As discussed in section 3.4.1, a new rail line gives transit agencies an opportunity to redesign bus services to create an intermodal network that meets existing ridership and anticipated demand. In terms of service reallocation, a common question that arises is whether to retain or discontinue a bus line that parallels the rail alignment. In Appendix B, a mathematical model is developed to analyze this situation. This model incorporates cycle time, headways, service reliability, passenger loads, and other factors that can influence such a decision. Its basic premise (and limitation) is that the decisions about route changes can primarily be reduced to operational and financial impacts.

The results of the model suggest that it may make sense to truncate or reduce parallel service under one or more of the following conditions:

- (1) Load factors/capacity are much higher for the train than the bus. This seems fairly self-evident given the technological differences between the two modes.
- (2) The difference in cycle times for the pre- and post- rail bus route is large, especially relative to the cycle time for the train. Longer-distance buses also tend to have poorer reliability, especially compared to the train. Clearly, bus routes that duplicate rail services for a long distance are better candidates for truncation than those that do not. This assumes a demand profile for the train where most people are travelling to the central business district; an agency could short-turn trains to better match capacity with the load profile.
- (3) A small number of people would have to transfer from bus to rail.
- (4) The marginal cost to run a train is relatively low per passenger, and the marginal cost to run a bus is relatively high.

While the model presented in Appendix B offers some help, it cannot address many aspects of this complex choice. For example, it does not model the larger network impacts of route design policy or the distinction between commuter-oriented and regular buses. It also does not handle some of the political subtleties that surround these decisions; for instance, the low marginal costs of operating rail service relative to its high infrastructure costs may encourage agencies to maximize rail usage and level-of-service. In contrast, the presence of separate bus and rail operators can result in duplicative bus service even when it is slower, less efficient, or less reliable. This and the following sections supplement Appendix B by providing a more comprehensive analysis to assist in decision-making. Namely, they discuss the relationships among network structure, transfers, schedule coordination, and service planning.

### **3.4.3 Basic Network Structures**

Prior to the introduction of a new rail line, a transit system may offer one or a combination of several basic network structures. These networks are a function of road network geometry, the location and relative strengths of the central business district and secondary activity centers, employment and residential densities, and other variables. Some common networks include:

- **Grid** – As the name implies, this network looks like a grid with two sets of parallel routes intersecting at right angles. Grid networks serve a variety of travel patterns either directly or with a single transfer. Since it is mathematically impossible to time connections at all interchange points, a grid network functions most effectively when routes run on short headways.
- **Radial** – This network features sets of routes that radiate from the central business district (CBD). Since it offers direct, one-seat rides for CBD trips, it works well with a strong urban core relative to peripheral activity centers. Depending on the extent of bi-directional service, this network can also facilitate reverse-commuting. However, suburb-to-suburb trips are often inconvenient if they involve circuitous routing through the CBD.
- **Modified Radial** – In a modified radial network, crosstown and circumferential routes supplement radial trunk lines. They support some suburb-to-suburb and non-CBD

intraurban trips as well as radial travel. The level of service provided on both radial and crosstown lines usually declines as distance from the CBD increases. This network is most effective in central areas where shorter headways reduce transfer time.

- Nodal – In a nodal network, routes converge at hubs (often called “transit centers”) located at major activity centers. These resemble radial networks, but on a much smaller scale. They serve many origin-destination patterns within a local area without a lengthy diversion through the CBD. At these hubs, it is possible to coordinate arrivals and departures to minimize transfer time. Physical facilities at transit centers are usually more amenable to transfers, compared to grid or radial networks where passengers switch vehicles at street intersections.

Transit services can also be classified by stopping patterns. In addition to basic local bus service that makes frequent stops, larger cities often include limited-stop and express buses to speed travel along busy corridors. A limited stop route overlaps a corresponding local route, but only stops at major intersections and transfer points. Express buses usually connect residential neighborhoods and/or park-and-ride lots with downtown employment centers, by running non-stop along highways. In a few instances, some agencies are also beginning to identify niche markets where they can successfully implement suburb-to-suburb express service.

These network classifications provide a natural framework for assessing the service and operational impacts of opening a new rail line. This analysis first focuses on the simple case of integrating rail with local buses and then investigates the more complex situation of parallel express buses.

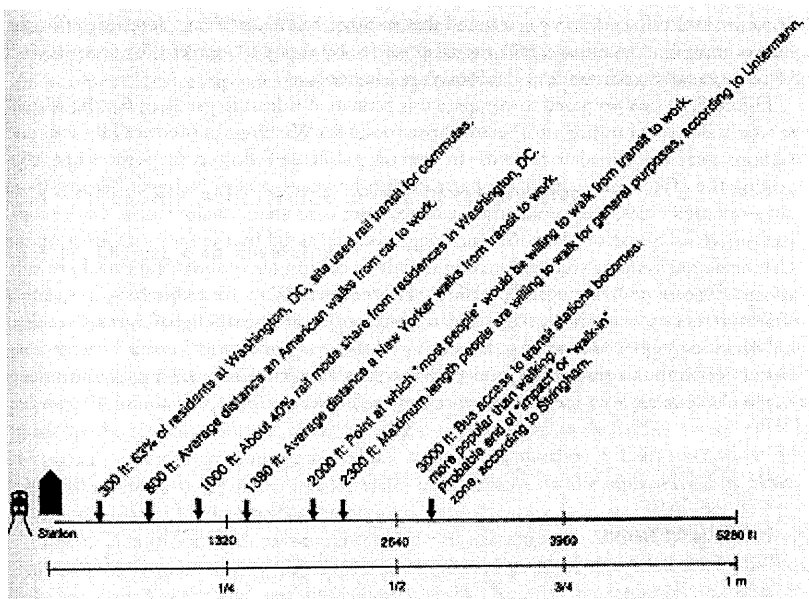
#### **3.4.4 Rail impacts on local buses**

In a network with local buses – whether grid, radial, modified radial, or nodal – a new rail line will typically parallel an existing bus route. Since the two services physically overlap, the issue of reducing or possibly eliminating bus service arises. While buses and rail may operate in the same corridor, however, they may actually serve different markets and thus it may not make sense to eliminate the bus route. (For

simplification, this analysis ignores the fact that riders may prefer one mode over the other for vehicle comfort, image, or other reasons.) Compared to buses, trains make fewer stops, travel on their own right-of-way, and can carry larger loads per operator. Thus, rail serves as a high-capacity, longer distance mode. In contrast, parallel bus routes better handle local and intermediate travel – trips that begin or end beyond easy walking distance from a rail station. The rail system will likely draw some passengers away from buses, particularly people who travel longer distances. Thus, it will usually make sense to adjust the level-of-service on parallel bus routes to reflect lower demand.

The question then becomes one of whether bus and rail serve similar enough markets to warrant discontinuation of the bus route. Given these considerations, rail station spacing is perhaps the most important factor in this analysis. Clearly, the market distinction between bus and rail services diminishes as the distance between rail stations drops. What is the distance threshold at which parallel bus service becomes appropriate? Of course, this depends upon land uses, climate, sidewalk availability and quality, as well as other factors. Empirical evidence supports the self-evident hypothesis that the inclination to use rail declines as the walking distance from a station increases. Figure 3-1 summarizes previous research findings on this topic.

Figure 3-1: Station Access Behavior



Source: Bernick and Cervero, 1997

Beyond a station-spacing of about ½ mile, bus transit is generally needed to access rail and, presumably, to fill in the service gaps between stations. “Most people” are willing to walk about 2,000 feet, or 3/8 mile, from transit to work (Bernick and Cervero, 1997). In a one-dimensional linear corridor, it appears that station spacing of somewhere between ¾ and 1 mile, or twice the “maximum” walking distance to either station, could theoretically serve all demand. In practice, however, transit corridors are two-dimensional which effectively reduces this distance because people from side streets must walk further.

Table 3-6: Parallel bus service in selected North American rail corridors

City	Rail Corridor	Approximate Station Spacing	Approach
Boston	Mass Ave. (Red Line)	1 mile	Parallel local buses
Buffalo	Main St.	½ to 1 mile	Parallel local buses
Chicago	Milwaukee Av. (Blue Line)	¾ mile	Parallel local buses
Los Angeles	Vermont Av. (Red Line)	1 mile	Parallel local and limited stop buses
	Wilshire Blvd. (Red Line)	½ to 1 mile	Parallel local buses (discontinued limited stop buses)
	LA-Long Beach (Blue Line)	1 mile	Parallel local buses (discontinued freeway express buses)
Philadelphia	Broad St. (Orange Line)	½ mile	Parallel local buses
Portland	Burnside St.	½ to 1¼ miles	Parallel local buses on streets about ¼ mile to either side of rail alignment
San Francisco	Mission St. (BART)	1 to 1½ miles	Parallel local, limited, and peak-hour express buses
San Jose	First St.	½ mile	No parallel buses except in downtown area
Toronto	Yonge St.	¼ to 1¼ miles	Full-time parallel buses along portion of route with distant station spacing, peak-hour and overnight buses along entire route
	Bloor-Danforth Sts.	¼ to ½ mile	No parallel buses except for overnight hours

Source: Transit agency system maps

Table 3-6 illustrates how a handful of North American transit agencies handle the question of whether or not to offer local bus service that parallels a rail line. In general, agencies tend to operate parallel bus service when the distance between rail stations exceeds ½ mile. (In fact, few of the systems surveyed had rail station spacings less than the ½ mile threshold for operational and construction cost reasons.) At that point, destinations directly along the rail line are within about a five-minute walk, or ¼ mile, of



a station. This suggests that agencies should strongly consider retaining some parallel bus service to address local needs when rail stations are more than a ½ mile apart. This parallel service does not necessarily have to be on the same street as the rail line, but should be within close proximity.

A new rail line will also impact other local buses beyond those along the same corridor. In a radial or modified radial network, it may be prudent to split long radial routes under certain circumstances. In this situation, the inner portion would retain direct service to the CBD while the outer portion would be rerouted to the rail system. Since this strategy introduces transfers for outlying riders, it would be advisable only if it produces tangible benefits such as:

- (1) customers would enjoy faster trips on rail, despite the transfer
  - (2) the split would “balance” loads on the inner and outer portions of the route
  - (3) it would increase bus service reliability, as cycle times decrease with shorter routes
- As a variation of this strategy, radial routes could be rerouted to, but not truncated at, rail stations. Faster rail travel times would still encourage CBD-bound travelers to transfer, but intermediate traffic would not be inconvenienced.

In a grid network, rail might alter the overall route structure very little. With the exception of a few parallel lines immediately adjacent to the rail line, bus routes can continue providing broad coverage. Transfer traffic from rail will help support intersecting parallel routes. This in turn may lead to shorter headways, increasing the grid’s effectiveness. Customers will also benefit from fast, frequent line-haul rail service. Depending on the city’s geography, it may be possible to switch from a pure grid to a grid and nodal combination that focuses buses on key rail stations. Since a grid system already relies on transfers, the new rail line is not likely to “force” new transfers on passengers.

In a nodal network, integrating buses with a new rail line is relatively simple if rail stations are located at or near existing bus hubs. Since passengers are already accustomed to switching buses to reach their destination, transferring between buses and rail is usually not a significant change. In Portland and other cities, transit agencies relocated or established timed transfer centers adjacent to suburban light rail stations several years prior to rail service (see Appendix A). Not only did this prepare the public

for intermodal transfers, but made the system more responsive and also improved the bus system in the interim. The nodal network is also consistent with the vision of rapid transit and a polycentric urban form described in Section 3.4.5. In this paradigm, key rail stations become bus transit centers surrounded by clustered development. At these centers, it is also possible to coordinate schedules between buses and trains so customers can transfer with minimal additional waiting time. To make these connections reliable, an agency may have to develop real-time holding strategies for delayed trains.

Thus, introducing a new rail line into a local network of buses is relatively straightforward. In grid and nodal networks, many bus routes can remain intact. Passengers who can use the rail line benefit from a higher level-of-service; meanwhile, service changes will not disrupt non-rail travel patterns. In radial and modified radial networks, customers on the outer portions of local radial bus lines may have to transfer, but the train's faster and more reliable service can mitigate this inconvenience, particularly with coordinated schedules.

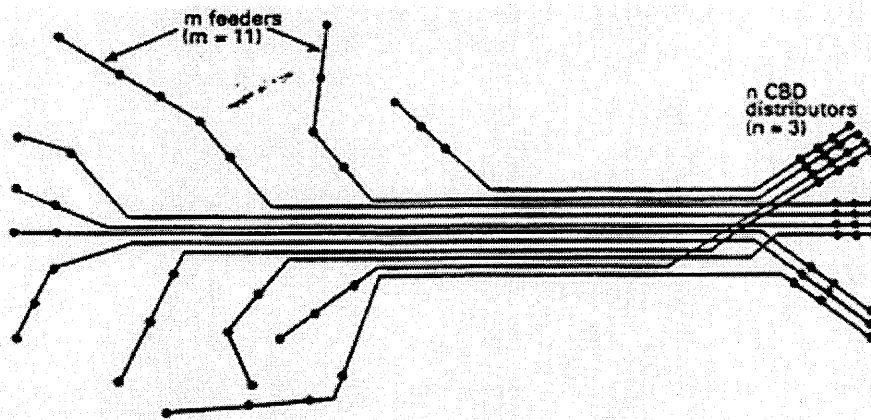
### **3.4.5 Rail impacts on express buses**

When radial express buses parallel a rail line, however, the transition may be more difficult. Express buses usually offer a direct peak-period ride from the home or a nearby park-and-ride lot to downtown without intermediate stops. Since express buses use taxpayer-supported highways, they are also an inexpensive way to extend high-speed transit service to the suburbs. Due to these characteristics, they often attract "choice" riders who live in the suburbs and work in the city. If a transit agency were to truncate the line at the nearest rail station, sometimes the added transfer time can be greater than train travel time savings. These observations seem to suggest that a transit agency should retain parallel express buses since they offer a premium level-of-service. Furthermore, modifying these services may be politically unpalatable and may look like a way to artificially boost rail ridership. For these reasons, many rail skeptics criticize transit agencies for converting express bus routes into rail feeders.

Of course, converting express buses into rail feeders may not always negatively affect riders. While most transit agencies charge premium fares on express buses, they usually offer comparable local bus and rail fares with intermodal transfer discounts (see

Table 3-2). Thus, a combination local bus and rail trip fare is often lower than the express bus fare although this would not apply to the few intermodal systems using zonal fare structures (e.g. Pittsburgh and Portland). In addition, service reliability may improve if buses no longer have to fight traffic on congested roadways leading into the central business district.

Figure 3-2: A Schematic Radial Express Bus Network



Source: Vuchic (1981)

By focusing strictly on avoiding transfers, however, other important issues such as network connectivity, frequency, and service efficiency may be overlooked. Radial express buses usually serve only the peak-period downtown-bound suburban commuter effectively. They do not facilitate multiple trip patterns even though they can consume a disproportionately large amount of operating resources. Figure 3-2 illustrates how commuter buses along a generic corridor struggle to accommodate even a limited number of transit patterns. Direct service between  $m$  neighborhoods and  $n$  distinct CBD destinations requires  $mn$  individual routes. The  $mn$  routes typically cannot support short headways since no passenger or trip consolidation occurs and the demand between any particular neighborhood and the core destination is likely to be low. Ridership on individual routes is further limited because there are few if any intermediate stops along the trunk section, which is usually a highway. Express routes seldom operate during the off-peak when demand is much lower. In addition, express routes generally do not serve local needs well even though they originate in residential neighborhoods because of their

radial orientation and limited schedules. Thus, a transit agency may also need to operate a redundant basic local bus network to enhance overall mobility.

Busways and HOV highway lanes that may exist in a potential rail corridor tend to encourage this network structure. Pittsburgh's two busways, for example, resemble trees with about twenty branches each. Although busway service itself is frequent (but uncoordinated), peak-hour headways on individual routes can exceed 45 minutes. During the off-peak, buses commonly run every 1 to 2 hours, if at all. This level of service attracts few customers. Frequencies are relatively poor because the network is not designed to serve multiple trip patterns. Even simple non-CBD travel can be difficult. For example, customers often cannot travel between two adjacent neighborhoods on opposite sides of the busway without transferring between infrequent routes. With dozens of long suburb-to-CBD expresses and no trunk-line consolidation, Pittsburgh devotes so many resources to support this network that it only offers limited "general mobility" routes in the busway catchment area (Port Authority Transit website).

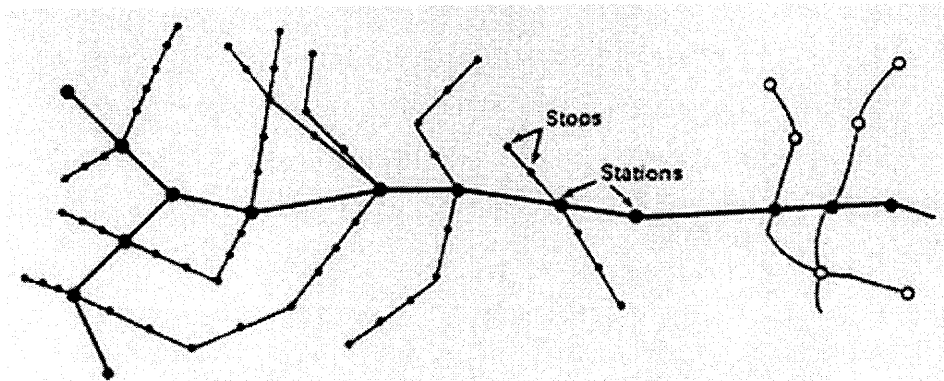
Houston's HOV/Transitway system, one of North America's most extensive commuter bus networks, represents a variation on the same theme. METRO Transit's express buses run on reversible HOV highway lanes, linking peripheral park-and-ride lots and downtown Houston primarily during rush hours in the peak direction. Local and express buses capture approximately thirty percent of all downtown work trips, a spectacular figure given Houston's sprawl and well-developed highway system. Despite the transitway's large capital cost, however, its physical design inhibits network connectivity since there are no intermediate stations or even reverse-peak lanes. Transitway routes bypass urban communities and major "edge cities", miss many reverse-commute and off-peak ridership opportunities, and connect to few local routes outside downtown. One of Metro's documents, the summary of the Downtown-to-Astrodome (rail project) Major Investment Study, indirectly assesses the shortcomings of the HOV/Transitway system in the context of Houston's development patterns:

"The transportation program of the future will need not only to provide increased capacity, but to add new dimensions: bi-directional service will be needed in key corridors, to address the increase in work destinations in the suburban areas... METRO will need to provide for these 'reverse direction' trips, as well as suburb-to-suburb travel, circulation within multiple activity centers, and expansion of

non-traditional service. At the same time, it is essential to preserve and strengthen the vital core of the region through timely [bus and rail] transit investment.” (Metro, 1999)

A report on “Transit and Urban Form” (TCRP Report 16, 1996) characterizes transit in Houston as two distinct bus systems – local and express. The demographic differences between them are striking: only a quarter of local bus patrons are “choice” riders, while more than ninety percent of express customers have cars and indeed drive to park-and-ride lots. Few transfers occur between them and express buses capture just 8% of total unlinked bus ridership (TCRP Report 16, 1996). This is a lower percentage than for “comparable” new rail systems with far less geographical coverage, although this issue involves network structure more than vehicle technology. Clearly, infrequent or nonexistent off-peak and reverse-commute service as well as a lack of system connectivity discourages ridership. In short, while Houston’s commuter bus network has attracted choice riders, it is very limited in scope and has not integrated well with the rest of the transit system.

Figure 3-3: A Schematic Transit Network with Connectivity

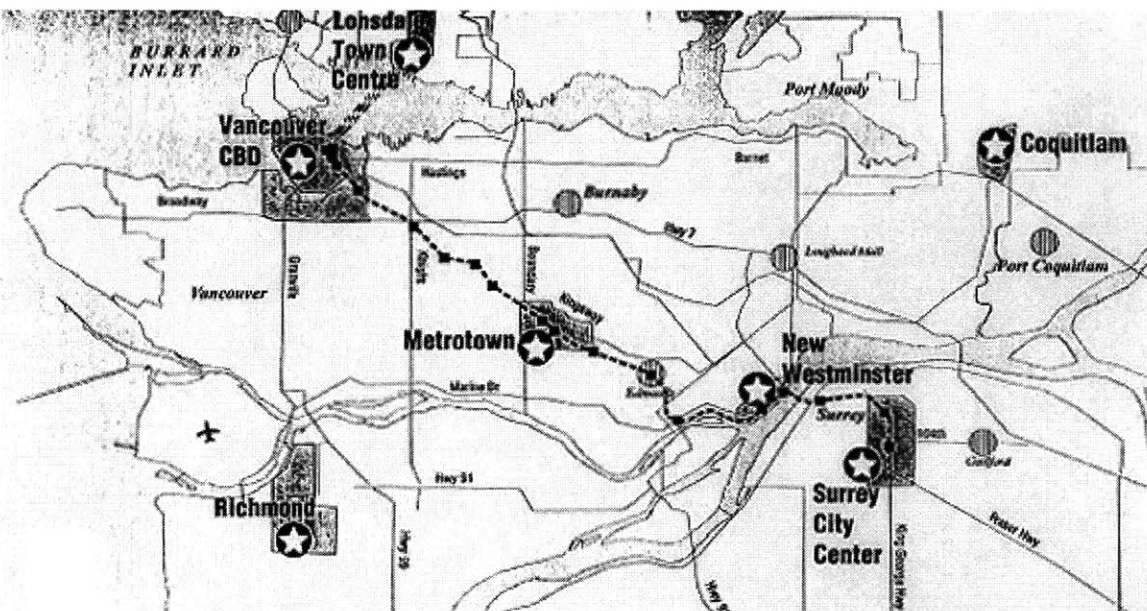


Source: Vuchic (1981)

Opening a rail line along a corridor previously served by express buses presents opportunities to improve system connectivity, frequency, and reliability. Specifically, converting expresses to rail feeders that also serve local needs can benefit both the customer and the transit operator. Figure 3-3 illustrates this strategy. In contrast to Figure 3-2, it shows a network of local bus routes that connects with a high-speed, high-frequency rail trunk line with intermediate stops. There are fewer, shorter bus routes, each of which supports multiple travel patterns (shopping, school, reverse-commuting,

not just commuter traffic). Thus, they can operate more frequently with longer service hours. Schedules are also more reliable since buses do not have to travel all the way into the city. Of course, this strategy may result in the loss of some former express riders who no longer enjoy specialized service; however, this general network has the potential to increase ridership much more because it serves diverse travel patterns while still facilitating the suburb-to-downtown commute. In the suburbs, where demand usually does not warrant short bus headways, the transfer points can become timed-transfer locations that facilitate suburb-to-suburb travel that would otherwise be served ineffectively. Over the long run, these transfer points have the potential to encourage more concentrated development.

Figure 3-4: Network Connectivity and Supportive Urban Form in Vancouver



Source: TCRP Report 16, “Transit And Urban Form”, 1996

Figure 3-4 illustrates such a network structure in Vancouver, British Columbia. Four of Greater Vancouver’s seven major regional centers, which feature a concentration of employment, shopping and other land uses, are linked by the high frequency SkyTrain rapid rail system. The SeaBus ferry connects SkyTrain and Downtown Vancouver with another node in North Vancouver. All of the regional centers, including those not adjacent to SkyTrain or SeaBus, also serve as major bus terminals. Trains and buses converge and exchange passengers at these hubs. This route structure, coupled with

clustered development around major rail stations and a ban on highways within the city of Vancouver, has resulted in a higher transit mode share than in similar U.S. cities.

Realistically, over the short term, it is unlikely that new rail systems will develop an urban structure that supports network connectivity to the extent found in Vancouver. However, implementing a “general” network in conjunction with a new rail line can help transit serve markets that standard radial bus systems have difficulty accommodating. In terms of cost effectiveness, new local bus routes may actually be less productive than the radial express routes they replaced. However, radial express routes and local routes clearly have different characteristics. A radial express route charges a higher fare and operates only during peak-hours when transit in general is more heavily utilized, while a truncated local line charges a base fare and runs during times with lower vehicle loads. Similarly, overall system productivity may decrease because the rail line also operates longer service hours.

Nevertheless, this restructuring strategy may still improve operating efficiency. Despite their low service levels and limited coverage, radial express bus routes require a disproportionately high number of vehicles and deadhead hours per trip operated because of their long cycle times and limited service hours. Since buses travel long distances along congested streets and highways, drivers often can only complete one or two peak-period trips. Depending on the transit agency work rules and the availability of part-time workers, these peak-hour runs can result in expensive driver spread penalties and make-up time. Thus, a transit agency can lower peak equipment requirements and reduce expenses for the bus fleet by converting an equivalent number of peak service hours to off-peak service hours. In turn, more midday, evening, and weekend service can help build more discretionary ridership.

In Portland, the opening of an 18-mile light rail extension resulted in significant performance and operational changes for buses. The bus network now emphasizes route connectivity and supports multiple travel patterns during both peak and off-peak periods rather than direct, but infrequent express routes. Despite some major frequency and coverage increases, weekday revenue hours did not increase significantly because buses were reallocated from radial to local routes. Weekend revenue hours grew substantially, in contrast. Discontinuing express lines also freed a disproportionately large number of

buses for redistribution during the peak and decreased the substantial deadheading associated with these lines. The peak vehicle requirement actually decreased, while the base vehicle requirement increased. This relieved pressure on the bus system during the busiest periods, utilizes the fleet better throughout the day, and potentially reduces driver spread penalties. As mentioned previously, this effort resulted in large increases in peak and reverse-peak modal splits.

Washington, DC demonstrates how a rail system can successfully interface with a busway to offer customers the advantages of both bus and rail modes. Commuter buses from the Virginia suburbs traverse the Shirley Busway, two reversible high-occupancy vehicle/bus lanes in the median of the Interstate 395, on their way towards Washington. Instead of continuing into the city, however, buses terminate at the Pentagon just across the river. From there passengers can connect to the subway to reach employment centers in Virginia and the District of Columbia. Although this arrangement requires transfers, it has expanded destination opportunities for customers, improved operating efficiency, and allows more resources to be focused on local bus service. The Shirley Busway services allow passengers in suburban neighborhoods to reach the subway quickly; from there, the subway acts as a circulator around the sprawling central business district and peripheral suburban centers. If the Shirley Busway services were to continue directly into Washington, additional peak-hour bus resources would be required just to maintain existing headways, and many customers would still have to transfer to reach peripheral destinations. Please refer to Appendix A for details about the Portland and Washington cases.

Other empirical evidence from throughout the United States supports the same theory: intermodal networks that rely on transfers can serve more travel patterns (and potentially many more passengers) than express buses alone. In fact, it is worth noting that cities with large transit mode shares – New York, Toronto, Montréal, Chicago, Philadelphia, San Francisco, Washington, and Boston – rely on network connectivity rather than route directness. In New York, for example, express buses carry around 40,000 weekday riders, just 2% of all bus boardings and 0.8% of the city's five million unlinked system trips. These express buses run primarily between Manhattan and Staten Island, the most remote borough without a link to the subway. In contrast, there are



approximately ½ million bus-bus and ½ million bus-subway transfers, as well as many uncounted subway-subway transfers (Hirsch et al, 2000). High frequency bus and subway lines that allow passengers to reach anywhere in the city with just one or two transfers contribute to the system's success. Section 3.3 describes how ridership skyrocketed after transfers became more convenient with the elimination of intermodal transfer charges and introduction of unlimited-ride passes.

In short, transfers are often a crucial component of the bus-rail integration strategy. An effective system that serves multiple travel patterns must emphasize the connectivity between routes and modes, not merely directness. Furthermore, transfers are not the only level-of-service variable that influences mode choice. Since the introduction of transfers may permit bus route consolidation, service frequency can increase on individual routes with the same financial resources. In turn, better frequency can boost ridership. Recalling the positive experience of the implementation of a timed-transfer network in Norfolk, Virginia, Becker and Spielberg (1998) argue:

“It is axiomatic in our [the transit] industry that transfers are bad. [Norfolk]'s experience suggests that it is bad transfers that are bad. Well-designed timed transfers benefit transit customers. Because travel is dispersed, there is, in fact, no other practical way for a fixed route transit service to handle the dispersed patterns of travel in today's multicentered metropolitan areas. The transit industry needs to rethink service development from route design to network design with a focus on reducing the negative perceptions of transfers.”

In other words, the question (at least in the long term) should not necessarily be whether to eliminate transfers altogether, but rather how to make transfers as convenient as possible. When opening a new rail line, it is especially important to make the transition period easy for customers who may have to transfer.

### **3.5 Transfers and Schedule Coordination (Tactical)**

From the above discussion, the introduction of a transfer represents the most visible negative impact of bus-rail integration. As with any transportation system, the interchange points are often a greater source of problems than the links themselves. Multiple transit operators, fare surcharges, uncoordinated schedules, unreliable running times, and uncomfortable waiting conditions can all exacerbate this “transfer penalty.”

Clearly, minimizing the inconvenience of transfers can help make an intermodal system more attractive.

In a study on transfer penalties in the Boston metropolitan area (CTPS, 1997), researchers identify the waiting time at the transfer point as a critical deterrent to transit usage for home-based work trip making. Specifically, the study concluded that for the Boston region, (1) the transfer penalty is worth several minutes of equivalent in-vehicle time, (2) transfer waiting time is more onerous than initial waiting time, and (3) transfer waiting time is over twice as onerous as in-vehicle time. Since Boston has unique geography and a large transit ridership base, the study does not attempt to draw general conclusions applicable to other cities. However, it does suggest that the transfer penalty might be even higher in places where transit enjoys less of a competitive advantage than Boston.

Liu et al. (1997, 1998) employ both a stated preference and simulation model to determine a generic value for the transfer penalty. In their stated preference study, they found that the penalty for an automobile-to-rail transfer (i.e. park & ride) is worth approximately 15 minutes of travel time, 5 minutes for a rail-to-rail transfer, and about 8 minutes averaged for all transfer types (Liu et al, 1997). In the simulation study, they use a binary logit mode-choice model to quantify the differences in transit mode shares with and without transfers. In their analysis, adding a single rail-to-rail transfer only slightly decreased transit mode share (by less than half a percentage point). In contrast, adding an automobile-to-rail transfer (i.e. a trip where patrons had to drive instead of walk to stations) decreased transit mode share from 12% to 6%. The difference between the two situations, they hypothesize, is due to the fact that a park & ride trip is a mode change that requires extra time to find a parking space, to walk from the parking space to the station entrance, and perhaps to purchase a new ticket. In contrast, rail-to-rail transfers can occur within a sheltered station environment, in many cases across a platform.

Despite these perhaps negative findings about transfer penalties, Liu et al (1998) suggest alternative strategies rather than abandoning transfers altogether in order to avoid disrupting network structures. Specifically, they call for limiting the number of transfer points through the “extremely judicious planning and placement of intermodal transfer

facilities within transit networks.” The other approach they suggest is to make transfers more pleasant through coordinating route schedules, increasing service frequency, minimizing walking distances at transfer points, and improving schedule reliability. They further suggest that intermodal transfer facilities may actually be positive because they can potentially accommodate trip-chaining and promote urban development (i.e. with on-site commercial activities.)

Given the previous discussion, it is safe to assume that at least some transferring will be necessary in any intermodal network or, for that matter, any transit system with intersecting routes. Clearly, an agency should focus on making transfers as convenient as possible, mainly by decreasing transfer waiting time. (Offering safe, sheltered waiting facilities at intermodal transfer points can also reduce the negative impacts of transferring.) Transfer waiting time is a function of the headways of the passenger’s initial and connecting vehicles. Tables 3-7 and 3-8 are matrices of transfer wait times broken down into four cases, which are based on the headways (short or long) of the initial and connecting routes. Table 3-7 identifies issues from the passenger’s perspective while Table 3-8 highlights operational issues. While the distinction between “short” and “long” headways is admittedly vague, in general new rail systems operate on “short” headways (every 15 minutes or less during base periods and even better during the peak). Headways on intersecting bus routes vary based on demand levels, but typically outlying routes have longer headways (30 to 60 minutes is not uncommon) than ones in the urban core.

**Table 3-7: Transfers Issues from a Passenger’s Perspective**

From\To	Short Headway on Connecting Vehicle	Long Headway on Connecting Vehicle
Short Headway On Initial Vehicle	Short and convenient	Can be convenient if passenger schedules trip properly and the schedule is reliable Large waiting penalty for missed connections
Long Headway On Initial Vehicle	Short and convenient	Generally inconvenient, except for timed transfers at key locations; not common for intermodal transfers due to high rail frequency

Table 3-8: Transfer Issues from Operator’s Standpoint

From\To	Short Headway on Connecting Vehicle	Long Headway on Connecting Vehicle
Short Headway On Initial Vehicle	Inconsistent headways or headway multiples can cause uneven loading and/or overcrowding, leading to vehicle bunching	Possible overcrowding on short headway route if many long headway routes leave simultaneously from a common transfer point
Long Headway On Initial Vehicle	Possible overcrowding on short headway route if many long headway routes have simultaneous arrivals at common transfer point	Difficult to coordinate Possible Timed Transfer Connections if routes operate on consistent headway multiples

Source: Tables adopted from Vuchic and Musso (1992)

Case I: Short Headway to Short Headway

Case II: Long Headway to Short Headway

Cases I and II address the situation where passengers transfer to a short headway route. In an intermodal network with high-frequency rail service, the bus-to-rail transfer would fall under these categories. Case I would also include the rail-to-bus transfer if the connecting bus runs on a short headway. From the passenger’s perspective, switching vehicles should be relatively convenient because expected waiting times are small for the connecting route.

On short headway routes, passengers are more likely to arrive randomly to wait for their vehicle than to depend upon schedules. The expected waiting time, assuming a random and independent passenger arrival process, is given by the equation

$$\overline{WT} = \frac{\bar{h}}{2} \left[ 1 + \frac{\text{var}(h)}{\bar{h}} \right]$$

where  $\overline{WT}$  = mean waiting time,  $\bar{h}$  = mean headway

“Bunching” (i.e. irregular headways) creates service gaps followed by closely spaced vehicle arrivals. Assuming that passengers arrive independently and randomly, the chances are higher that people will arrive during the service gap (and wait longer) than during the time when vehicles are close together. Thus, expected waiting time is a function not only of the mean headway, but also the variance of the headway. Even though short headways on a connecting route theoretically should be convenient for the passenger, good operations control is clearly necessary to minimize transfer times.

If headways are inconsistent on the initial vehicle and a large number of intermodal transfers take place at a specific interchange point, uneven loading can

quickly occur on the connecting vehicle. In the rail-to-bus direction, passenger fluctuations at the transfer point can lead to bus bunching down the line, deterioration in service quality and increases in average waiting time. In the other direction, trains have an easier time absorbing passenger surges due to their greater capacity. However, they are not immune from similar loading problems and consequently train bunching (although headways are constrained by the minimum safe stopping distance). During peak times, it makes sense to spread bus arrivals at rail stations evenly to avoid overwhelming specific trains.

### Case III: Short Headway to Long Headway

Of the four cases, transferring from a short headway route to a long headway route presents the most opportunities for active intervention, both during the planning phase and during operations. This typifies many rail-to-bus transfer situations in multimodal systems, where trains usually run frequently at all times of the day but buses (especially in suburban areas) may run only once an hour. It also generally arises when low-frequency commuter-oriented express buses are converted to rail feeders. The expected transfer time is given by the equation

$$\overline{TT} = (p_{make})(t_{transfer}) + (1 - p_{make})(\overline{headway})$$

where  $\overline{TT}$  = expected transfer time  
 $p_{make}$  = probability that a passenger makes a connection  
 $t_{transfer}$  = scheduled transfer time  
 $\overline{headway}$  = mean headway of connecting vehicle

For simplification, this equation assumes that

- (1) passengers can always board the first available vehicle
- (2) neither the originating nor connecting vehicle leaves early
- (3) passengers board the originating vehicle that most conveniently “connects” with the second vehicle
- (4)  $p_{make}$  and  $t_{transfer}$  incorporate the time it takes physically to move from one vehicle to another
- (5) The second vehicle is on time

Note that the expected transfer time may overestimate a passenger’s expected waiting time at the transfer location should the originating vehicle arrive late. Clearly, a transit agency should aim to minimize the expected transfer time to reduce passenger

inconvenience. Short of reducing headways on the low frequency route, this equation suggests two approaches:

- (a) reduce the scheduled transfer time
- (b) increase the probability that passengers make their connection

This equation suggests that customers weigh waiting times uniformly, regardless of whether or not they make or miss a connection. However, passengers may become more agitated if they miss their connection and have to wait for the next vehicle, especially if they arrive only a few minutes (or seconds) after the connecting vehicle departed. Thus, a more plausible representation may be

$$\overline{TT} = (pmake)(t_{transfer}) + (1 - pmake)(\overline{headway})(agitation\ factor)$$

Clearly there exists a strong relationship between the probability of making a connection (*pmake*) and the scheduled transfer time (*t<sub>transfer</sub>*). The longer the scheduled connection time, the greater the chances of making the transfer successfully. If most trips on the originating vehicle arrive “on-time”, however, the larger the connection, the longer passengers will have to wait before their connecting vehicle leaves. More specifically, we may surmise that *pmake* varies depending upon the run-time reliability of both routes.<sup>1</sup> If we assume for the moment that the connecting vehicle runs on schedule, then

*pmake* can be written as  $\int_{-\infty}^{\mu+Z_{TT}\sigma} r(t) dt$

where  $r(t) dt$  = the unit run-time probability distribution for the first vehicle

$\mu$  = mean run-time for the first vehicle

$Z_{TT}$  = number of standard deviations the transfer time represents

$\sigma$  = run-time standard deviation for the first vehicle

To lessen customer anxiety by reducing the transfer burden, an agency will want to minimize expected transfer time by selecting a scheduled transfer time that minimizes the following function:

$$\overline{TT} = \left( \int_{-\infty}^{\mu+Z_{TT}\sigma} r(t) dt \right) (t_{transfer}) + \left( 1 - \int_{-\infty}^{\mu+Z_{TT}\sigma} r(t) dt \right) (\overline{headway})(agitation\ factor)$$

---

<sup>1</sup> Holding is an example of a real-time operational strategy to help passengers make their connecting vehicles if their initial vehicle is delayed. For more information, please refer to the article “Optimal Holding Times at Transfer Times” (Hall, Dessouky, and Lu, 1999).

Unfortunately, this formula may not have an “easy” solution and may require empirical estimation. Clearly, more variable running-times (“fatter”  $r(t)$  distributions) make it more difficult to limit expected transfer times. Fortunately, rail rapid transit will typically have better reliability than buses if it includes adequate operations control since it operates in a separate right-of-way. These conditions therefore facilitate the common transfer case from a high-frequency train to a low-frequency bus.

A typical network in a major metropolitan area has many potential transfer points. This fact precludes optimal scheduling in nearly all locations except for possibly the busiest transfer points; in some cases a transit agency may have to resort to random connections. In addition, to make this “optimal” scheduling work, rail and bus routes should each run at a multiple of a common headway to ensure schedule consistency throughout the day. For example, if trains operate every 14 or 16 minutes instead of every 15 minutes, it is much more difficult to coordinate with buses that run at 15, 30, or 60-minute intervals. Since adjusting headways by just one or two minutes can alter vehicle requirements, agencies must weigh customer convenience (and corresponding ridership changes) with the marginal costs of improving schedules. In particular, they should be particularly sensitive in the case where the new rail system introduces a transfer for former “one-seat” bus riders.

Even if a connecting bus operates infrequently, active schedule intervention may not be necessary if trains run “very frequently” (such as during peak hours). From the customer’s perspective, the important question is when to arrive at the station in order to make a rail-to-bus connection. To estimate the necessary lead time for the connection, one can sum the rail travel time and the rail headway, and then pad the result to ensure enough time to transfer physically between vehicles and to guard against a minor delay. Clearly, solid operations control that maintains consistent rail travel times and headways (not necessarily equivalent to on-time schedule adherence) is necessary for this heuristic approach to work regularly. Finally, transit agencies should inform passengers of the estimated running and waiting times through public schedules.

#### Case IV: Long Headway to Long Headway

When both the initial and connecting routes run infrequently, it is difficult to coordinate schedules to minimize the waiting times for all possible transfers. Some transfers may be quick while others may involve lengthy waits. Transit systems that rely heavily on connectivity and transfers to maximize destination opportunities available to customers – such as grid networks – do not function well with low service levels. In general, however, new rail systems (excluding commuter rail) operate frequently during most periods of the day. Thus, this case applies less to intermodal transfers than to bus-to-bus transfers on an infrequent network.

New rail stations often provide an opportunity to develop transit hubs where bus routes converge, particularly if they are located near major activity centers. In such situations, it may be possible to establish timed-transfers for routes with low frequencies. Sometimes called a “pulse” system, buses on different routes are scheduled to arrive and depart simultaneously, with a layover period to allow passengers to transfer conveniently in all directions. Coordination with rail service may also be desirable but not necessary if trains operate frequently.

Several logistical difficulties may arise when attempting to implement timed-transfers in an intermodal system. Only a limited number of locations can offer timed transfers. Due to the many connection points within the network, it is mathematically impossible to schedule timed-transfers everywhere without seriously lengthening running times. To ensure consistent vehicle meets, routes must have the same headway or an even multiple of a common headway (e.g. 30 and 60 minutes). An effective timed-transfer network also requires high on-time performance; customers who miss connections by even a few minutes must wait a full headway. Finally, a timed transfer system may increase vehicle requirements. Coordinating schedules at the transfer point may require excessive layover/recovery times and preclude interlining opportunities. Given these limitations, a pulse schedule system may make sense if bus-to-bus transfers constitute a significant fraction of all passenger movement at the interchange points.

Some cities have attempted to implement timed-transfer networks in areas with relatively infrequent transit service. With the extension of light rail to its western suburbs, Portland established three new transit centers at key rail stations. To facilitate both bus-



to-bus and bus-to-rail transfers, buses arrive and depart simultaneously with a few minutes of layover time to let passengers change vehicles. Some bus routes operate as often as every 15 minutes during the off-peak, but half-hourly or even hourly headways are more typical. Since trains run frequently, intermodal coordination is not absolutely vital; however, buses are consistently scheduled to leave a few minutes after the train departs from the station. An integrated, three-zone fare structure with free transfers also helped make the system equitable for passengers who had to transfer to complete their trips (Tri-Met website).

In contrast, in Washington DC, the lack of schedule coordination has tended to worsen the transfer waiting time problem. Specifically, transferring from rail to bus can become inconvenient during off-peak hours when vehicles arrive less frequently. On Saturdays, for example, trains run relatively frequently (every 12 minutes) but do not consistently meet with buses that operate 20, 30, or 40-minute headways (WMATA website). Uneven headways make it difficult to coordinate schedules and minimize waiting times for all transfers. Please refer to Appendix A for more details about Portland and Washington, DC.

### **3.6 Political Considerations and Implementation Strategies**

As discussed earlier, transit agencies often face criticism for truncating or eliminating bus service along rail corridors. A prudent customer-oriented and political strategy would be to redistribute bus resources to underserved areas and/or untapped markets. Improvements may include longer service hours, better frequencies, and/or more comprehensive network coverage. As mentioned earlier, the rail line introduction presents a unique opportunity to redesign the network to be more responsive to a variety of travel patterns. A transit agency can only realize these gains if it makes a commitment to balance bus cutbacks along the rail line with improved frequencies, service hours, coverage, etc. elsewhere. Simply reducing bus service without demonstrating any tangible benefits for bus customers may lead to political troubles and lost ridership. It certainly will not generate and might jeopardize public support for future rail extensions.

Two basic obstacles impede the immediate implementation of this type of network. First, agencies may be financially constrained, especially after completing rail

projects, and may be tempted to cut rather than reallocate bus service. Secondly, bus reallocation means that some people gain new bus service while others “lose” it. People are likely to vehemently oppose transferring and real or perceived bus service reductions, even if they are offered an alternative on the new rail system. In contrast, people who might potentially benefit with improved bus service as a result of resource reallocation probably will voice little support for changes because they already rely on other transit routes or different modes. Thus, a transit agency runs the risk of quickly losing existing customers without their immediate replacement by new riders.

Two case studies examined in Appendix A (Los Angeles and Miami) illustrate this general theme. In Los Angeles, the Metropolitan Transportation Authority ran into difficulties when it was developing a bus integration plan for the Red Line subway extension to Hollywood. Instead of continuing to run radial express buses past major intermediate destinations along a congested freeway, the agency had planned to truncate these lines at the rail terminal in Hollywood. At the same time, the move would have freed bus resources to help the agency reduce overcrowding on core bus routes. Riders would have also enjoyed lower fares, since they would have ridden two local-fare services instead of an express route. Due to political pressures and vocal opposition from riders and bus advocates during public meetings, the authority decided not to pursue changes until subsequent subway extensions are completed (Richards, 1999).

In Miami, Metro-Dade Transit implemented major bus service changes in conjunction with the opening of Metrorail in the mid-1980s. The integration plan “was marketed as a service improvement when in reality it was a massive service cut.” Many areas lost evening and weekend service and some routes were transferred to private sector jitneys, which lacked comfortable vehicles and fare coordination with publicly-supported transit operations. The public demanded and ultimately won restoration of most services. In the process, however, the agency suffered negative publicity and several top officials lost their jobs (Fialkoff, 1990).

Given the experiences in these (and other) cities, it seems that sudden changes can result in real or perceived negative impacts. As discussed in Section 2.5, an incremental approach to service changes may be appropriate in some situations. Deferring significant route changes until several months after the rail line’s opening day allows rail ridership to

stabilize and gives an agency an opportunity to observe actual travel patterns. Meanwhile, an agency should provide incentives to persuade bus customers to switch to rail during the interim period. For example, an agency can reroute express buses through rail stations so customers have the option of transferring to the train or remaining on the bus. To offset the additional operating costs of providing the duplicative bus service, the agency can raise fares for “through” bus passengers but charge local fares with free transfers for people who decide to use the bus-rail combination. If riders respond to this pricing incentive, then the agency could justify route truncation; otherwise, at least passenger fares will cover more of the costs of operating an inefficient network.

## **Chapter 4: The San Juan Case**

San Juan, Puerto Rico, is now constructing the Tren Urbano heavy rail system to provide people with alternatives to the automobile which is often subject to heavy traffic congestion. As mentioned in Chapter 1, Tren Urbano presents both an opportunity and a challenge to transform the region's struggling bus and públicos systems into a coordinated, high-quality intermodal network. Using the analytical framework in chapter 2, the discussion of integration issues from chapter 3, and case studies from cities with new rail lines in Appendix A, this chapter evaluates options for modifying San Juan's bus and público system in conjunction with Tren Urbano.

### **4.1 Background Discussion**

Given the current state of San Juan public transit, the city faces some tough but surmountable challenges in developing an effective integrated system. Different vehicle standards, service levels, fares, and organizational arrangements make the task more difficult than in typical North American metropolitan areas. Active intervention by the public sector, particularly through financial assistance and público restructuring efforts, can help produce the service quality to attract new riders.

Left alone, San Juan will have three organizational models when Tren Urbano opens in 2002, each representing a different stage in the evolution of transit industry operating practices. At the more rudimentary end, the público "system" relies on individual profit-motivated drivers organized into route associations. Commonly known elsewhere as jitneys, these services are often important in developing countries, capitalizing on low car ownership levels, captive ridership, and lower expectations for service quality. In contrast, the AMA bus system directly operates fixed route bus service, the model most commonly found throughout the United States. Metrobús and Tren Urbano employ contracted operations, a model some North American transit agencies have successfully employed for fixed-route bus and paratransit services. It relies on competitive bidding to control costs and improve service quality. Tren Urbano will become the first North American heavy rail system to contract operations.

North American transit properties commonly use either the publicly-operated monopoly or contracting out model, or both. Even cities with single multimodal

operators face integration difficulties. Metropolitan areas with separate agencies controlling bus and rail operations grapple with additional fare, route, and schedule coordination issues. In addition to the challenges of integrating distinct bus and rail systems, the existence of an unfunded and declining público system in San Juan complicates matters even further. The inability to control thousands of individually-owned públicos makes it hard to achieve the service quality necessary for effective integration with Tren Urbano.

Table 4-1: Service Characteristics of San Juan’s transit systems

Operator	Tren Urbano	Metrobús	AMA Buses	Públicos
Operating Arrangements	Public agency with contracted operations	Contracted operations	Public agency with public employees	Private Individuals
Fares	\$1	\$0.50	\$0.25	Varies (\$0.35-\$0.65)
Span of Service	7 days/wk, morning to late night	7 days/wk, morning to early evening	7 days/wk, morning to early evening	Monday-Saturday, daytimes only
Service Headways	4 min (peak) 12 min (off-peak)	6-12 min (weekdays), 12-20 min (weekends)	8-30 min (peak & base), 15-60 min (weekends)	Variable but frequent (peak), irregular to non-existent (off-peak)
Schedule Reliability	Good	Good	Fair but improving	Generally unreliable during off-peak
Vehicle Comfort	Comfortable	Somewhat comfortable, with air conditioning	Somewhat comfortable, with air conditioning	Uncomfortable, poor seating arrangement, no air conditioning
Accessibility	ADA compliant	Working to become ADA compliant	Working to become ADA compliant	Not ADA compliant
Public Image	Positive	Positive	Fair	Mixed

Source: Wensley, 1999.

Table 4-1 compares key service variables for San Juan’s transit systems. The different operating arrangements and their associated economic implications have contributed to significant disparities in service quality among San Juan’s transit providers. For instance, compared to the públicos, the publicly-supported AMA system is more likely to balance cost and revenue considerations with passenger convenience. In fact, AMA undertook significant route restructuring in early 1998 to improve reliability and consolidate service onto fewer, but higher frequency and more direct routes that connect at transit centers. Ridership responded with a 20% jump, reversing a decades-long decline. AMA is also planning to run later in the evening to match Tren Urbano

service hours. Investment in AMA has also brought other improvements. New air-conditioned buses, a more comfortable in-vehicle atmosphere, and improved wheelchair accessibility have made the service more attractive. Metrobús has also done well, aided by financial assistance and a contracted service structure that has encouraged improved service quality. The introduction of frequent, reliable service along two main corridors has helped to stabilize falling ridership. Compared to AMA, Metrobús charges a premium (double) fare yet enjoys more support from the public. Continuing to bring progressive transit ideas to San Juan, Metrobús has recently introduced low-floor buses (Wensley, 1999).

Of course, Tren Urbano is the most significant and visible transit investment in San Juan's history. When it opens in 2002, it will provide a high level-of-service with trains operating every 4 to 12 minutes until midnight seven days a week. Vehicles will offer rapid and comfortable transportation, while stations will provide a safe and pleasant waiting environment. A financial commitment by the government to building Tren Urbano and upgrading AMA operations offers the promise of an integrated, high-quality system.

In contrast, the lack of support for the público system in automobile-dominated San Juan has resulted in a system in decay. Público mode share dropped from 9.2% in 1964 to 7.7% in 1976 to 4.8% in 1990, while automobile usage has skyrocketed from 62.7% to 90.7% over the same period (Lau, 1997). The automobile's growing popularity has contributed to the downward público spiral because públicos are increasingly stuck in traffic. Declining ridership, low revenue, and a lack of financial support encourages público owners to "cut corners" on capital improvements and operating expenses for survival. For instance, in contrast to the publicly operated systems, públicos run irregularly during the off-peak and generally offer no service evenings and Sundays. To maximize revenue, the driver departs only when the vehicle is full, however long that may take. Aged vehicles, deferred maintenance, lack of air-conditioning, and a poor physical seating arrangement also contribute to an unfavorable image. Given this perceived and actual disinvestment, the públicos not surprisingly attract few "choice" riders. Since públicos cover many neighborhoods that lack conventional bus service,

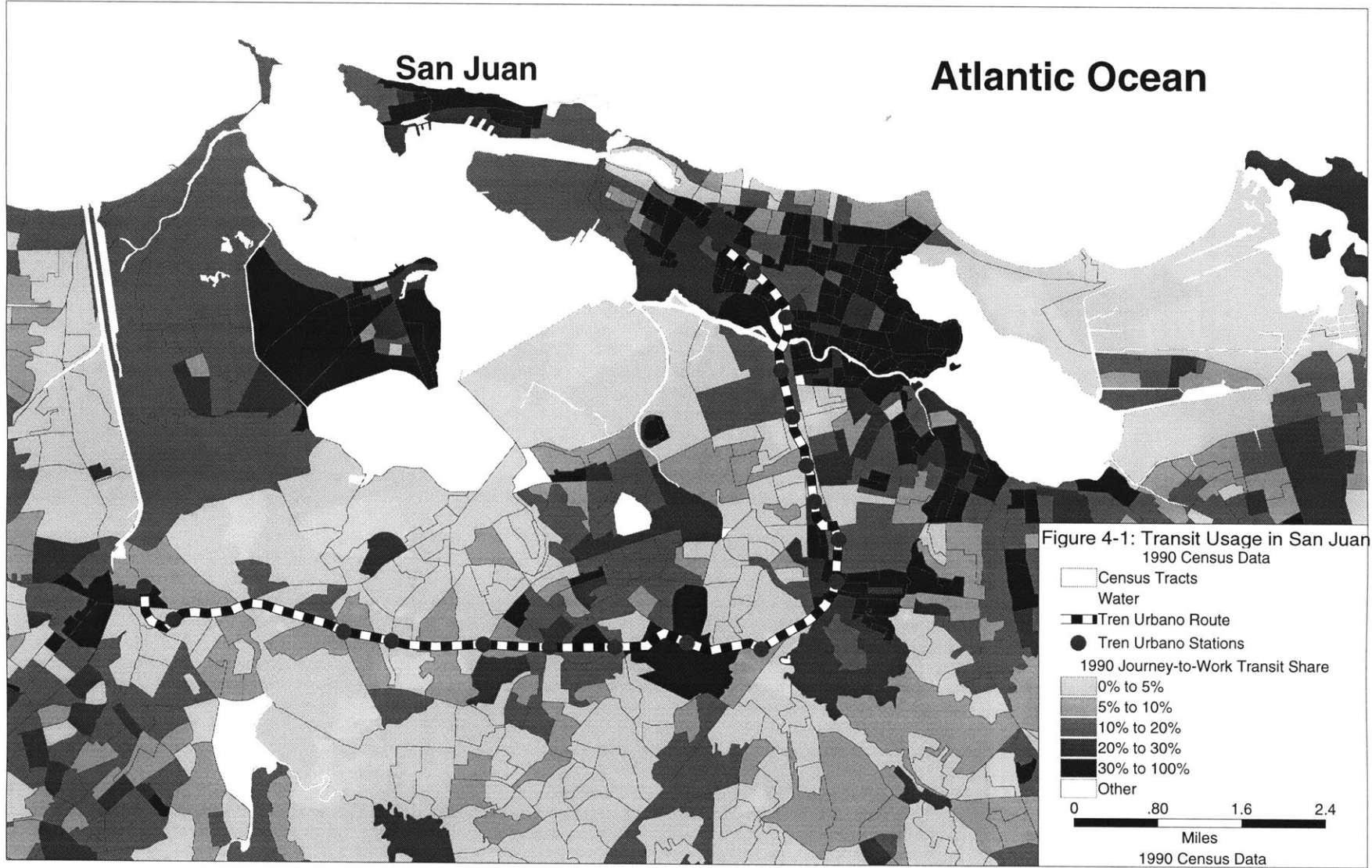
allowing the system to atrophy further could leave transit-dependent riders with significantly reduced mobility.

In short, the San Juan experience to date suggests that public investment and innovative operating arrangements in AMA and Metrobús have improved transit services. It has also shown that laissez-faire policies with respect to the públicos have resulted in decline and poor service quality. Coordinating bus and público services has not received much attention in the past since each served distinct geographical areas with relatively little overlap, and the services are planned and regulated by different agencies. In the future, however, Tren Urbano ridership will rely heavily on both bus and público access. San Juan's intermodal system will only be as strong as its weakest link; all elements must function properly for the entire system to work.

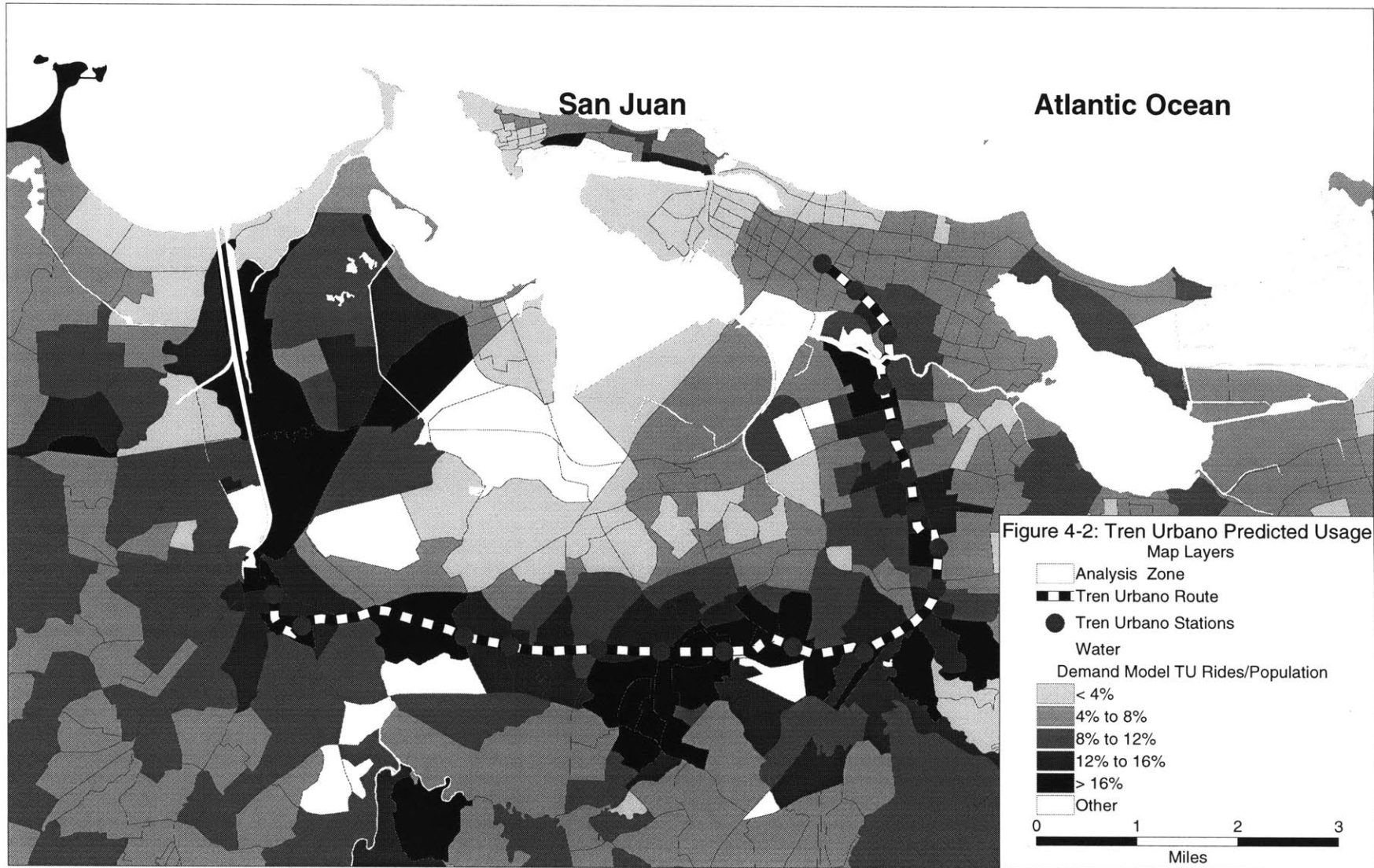
Comparing the service characteristics of San Juan's transit systems reveals various areas for potential improvement. For instance, fares vary from mode to mode with no discounts for transfers, even among vehicles under the same operator. Span of service, service headways, and vehicle comfort also differ, with a noticeable decline for the públicos. Potential "choice" Tren Urbano customers who value comfort and schedule regularity are unlikely to be satisfied with público feeder services. Without adequate station accessibility, people may decide not to take public transit at all, despite the quality of Tren Urbano itself. Consequently, públicos in their present state may stunt Tren Urbano ridership, inevitably diminishing support for further expansion.

#### **4.2 Spatial geography of bus, público, and Tren Urbano riders**

The mismatch between Tren Urbano, bus, and público riders presents another challenge to effective multimodal coordination. While Tren Urbano will attract some existing bus and público customers from parallel routes, many riders will continue on their current travel patterns simply because the initial phase of Tren Urbano will not serve their destinations. In other words, the bus and público systems will continue to play important roles in San Juan even though Tren Urbano will emerge as the visual and symbolic backbone of transit. Figures 4-1 and 4-2 demonstrate this point. Figure 4-1 shows the concentration of AMA and público riders by census tract, as measured by the percentage of 1990 work trips taken by transit. Figure 4-2 shows the expected







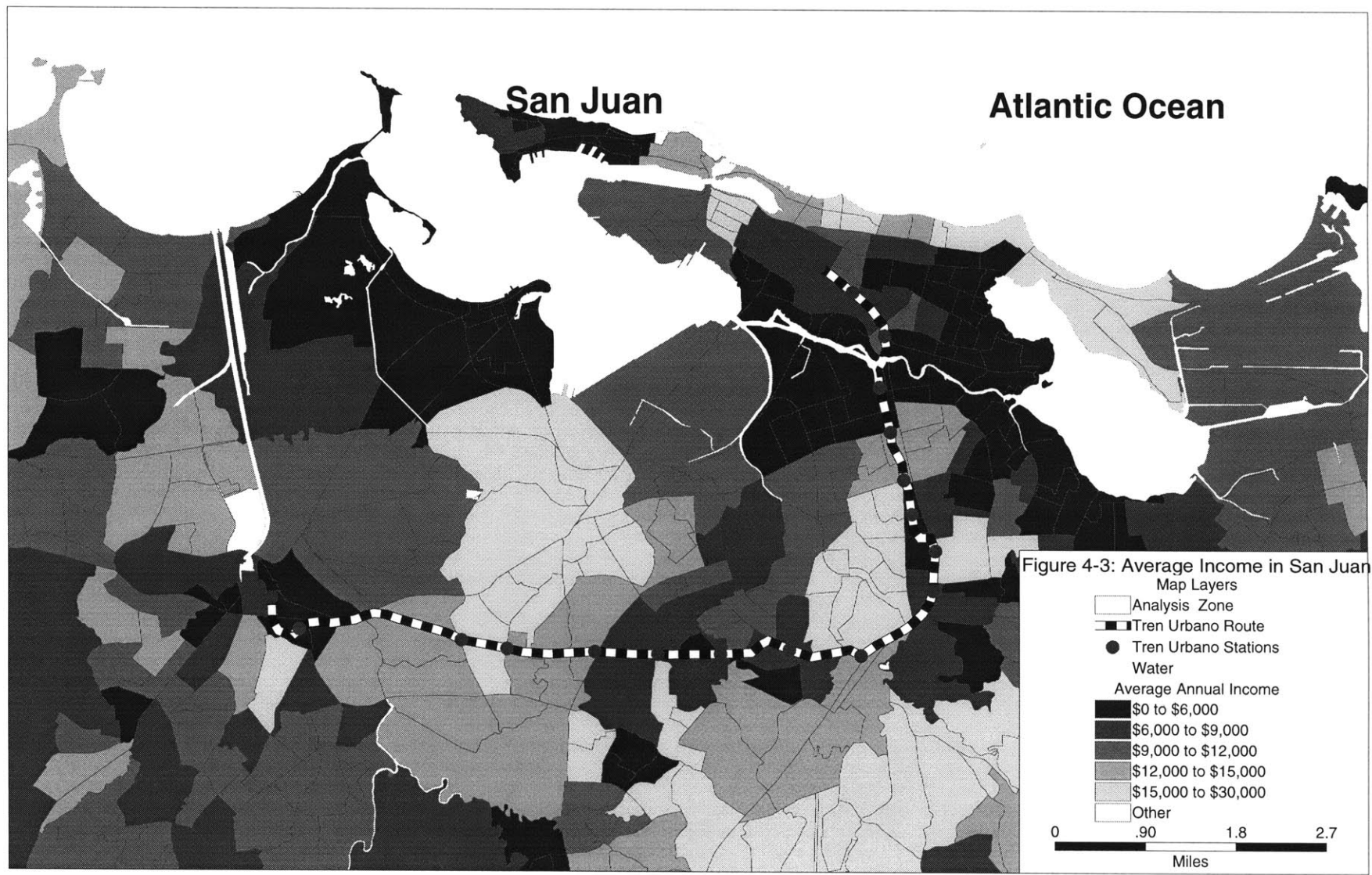
geographical distribution of future train riders expressed as a percentage of total population, as forecast by the demand model used in the Tren Urbano Environmental Impact Statement. While these maps are not directly analogous (one examines mode share of adult work trips while the other looks at total population), they strongly suggest that demographic and spatial differences exist between future Tren Urbano customers and current público and bus riders.

In San Juan, many of the predicted areas of high Tren Urbano demand generally do not correspond with bus and público-dependent areas. As expected, the Tren Urbano demand model predicts that train riders will mostly live adjacent to the alignment. In contrast, transit-dependent riders are concentrated in the Isleta, Santurce, Barrio Obrero, Cataño, and Río Piedras. Excluding people who work at home, transit carries over 30% of work trips in some neighborhoods. Smaller concentrations of transit riders live in western Carolina and in the area wedged between Expreso las Americas/Plaza las Americas, F.D. Roosevelt, Centro Médico, and the Guaynabo border. Público usage is heaviest in Bayamón, the mountainous region to the south, parts of Carolina, and the area between Barrio Obrero and Laguna San José.

Examining the distribution of income (Figure 4-3) in San Juan shows the relationship between transit dependency and ridership on buses, públicos and Tren Urbano. Many areas that the demand model predicts will have high rail ridership also share relatively high personal incomes and car ownership levels, suggesting Tren Urbano should attract “choice” riders. Some of these areas include the San Francisco area south of Centro Médico, Cupey and Guaynabo. In contrast, areas where a large portion of the population has no access to an automobile correspond to the neighborhoods with high bus and público ridership. Considering the socioeconomic characteristics of these areas, it is likely that most bus and público riders cannot afford a car.

### **4.3 Implications**

San Juan faces some familiar and other unique challenges compared to other metropolitan areas that have recently introduced rail systems. Like many cities, it is introducing a rail line within a context of a car-dominated environment and a bus network



with a transit-dependent ridership base. It must also overcome possible impediments to effective system integration as a result of having separate bus and train operators. Consequently, San Juan must not only focus on attracting “choice” riders to Tren Urbano, but also improve the service quality for existing customers who may or may not be able to use the train. Buses must continue to be a primary component of San Juan’s public transit system and not merely serve a feeder role for Tren Urbano. Coordination efforts with the buses should focus on network design, operations planning, and fare policy. Marketing efforts are also necessary to inform the public about changes to the bus system as well as to attract new riders quickly to Tren Urbano.

San Juan must also salvage its troubled público system. Unlike some other cities with jitney operations, for-profit público operations can no longer thrive in a city where transit usage has plummeted as a result of increasing affluence and generally pro-automobile policies. Revenue starvation has resulted in deferred maintenance, irregular or non-existent service, and uncomfortable vehicles. Few público drivers have the means or incentive to improve services or purchase new vehicles, let alone comply with federal requirements such as full vehicle accessibility under the Americans with Disabilities Act. Fortunately, the existing público network already complements the future Tren Urbano system, with major terminals located near key stations. Furthermore, with the arrival of Tren Urbano, públicos can concentrate on connecting neighborhoods to nearby rail stations, rather than running along congested arterials into San Juan. Thus, efforts for improvement should focus on handling the institutional and financial issues that are critical to bolstering público service quality.

#### **4.4 AMA and Metrobús Analysis**

As discussed above, coordination efforts between Tren Urbano and the two publicly-funded bus systems (AMA and Metrobús) should address network design, operations planning, and fare policy. Organizational differences may also impact integration, particularly concerning fares. For reasons discussed earlier (see Section 2.5), this analysis applies an integrated systems approach for long term bus-rail integration planning in San Juan. In summary, in the integrated systems approach, the route design tries to take advantage of the relative strengths of the bus and rail modes. This approach explicitly balances the desire to build rail ridership with the needs of

current riders. More specifically, this analysis focuses on two key customer groups: (1) people using Tren Urbano for all or part of their trip and (2) people who rely solely on AMA buses and Metrobús. This strategy is particularly relevant given that there appear to be significant demographic and locational differences between these two groups. One must emphasize that this integrated systems approach offers ideas for long-term bus service based on current ridership patterns; in the short run, an incremental strategy is appropriate during the transition to Tren Urbano in order to soften the impacts of potentially large changes.

The “Report on the Tren Urbano Feeder System” (Multisystems, 1999 [3]) presents some preliminary ideas for integrating AMA and Metrobús routes with Tren Urbano. This analysis builds upon this work by evaluating some of its key proposals using the analytical framework developed in chapter 2. Given this approach, some goals and questions associated with the feeder system plan include:

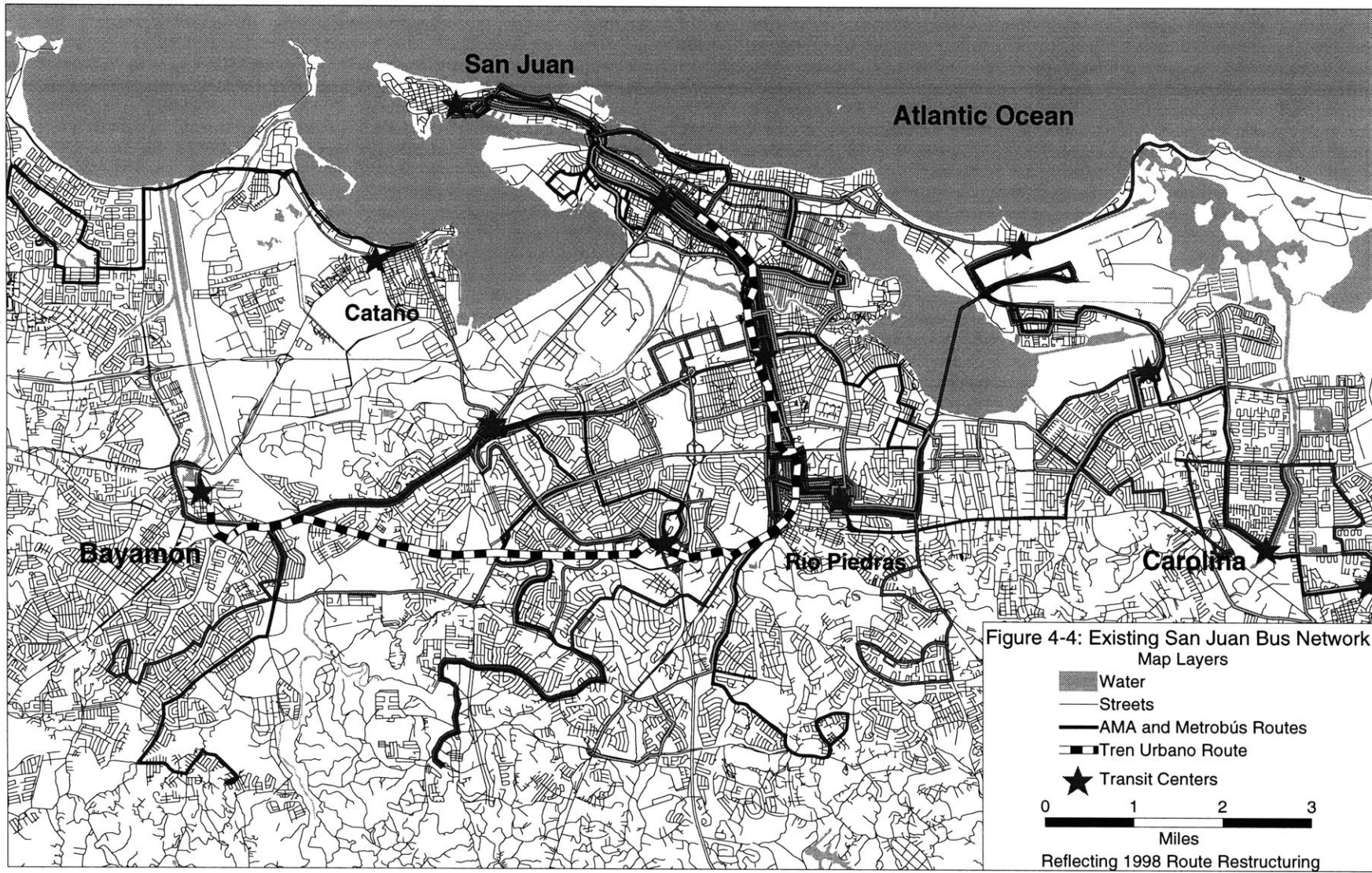
- Maximize effective rail system utilization: Are bus routes that remain in the Tren Urbano corridor serving different markets than the train? Does the plan avoid duplication and instead redistribute resources to underserved areas?
- Retain existing ridership: Do the proposed changes avoid seriously inconveniencing existing bus riders? Do they introduce lengthy or costly transfers? Do they address existing overcrowding issues?
- Attract new riders: Does the train offer the level-of-service necessary to attract “choice” customers? Do buses provide the coordinated service necessary to extend the rail system’s reach?
- Improve operator efficiency: Within the Tren Urbano corridor, are passengers encouraged to use the higher capacity and quicker rail mode? Do changes that could disrupt existing commuting patterns result in cost savings that offset potential lost ridership and revenue?
- Ensure political support for future rail extensions: Does the plan value both existing and potential customers?

### *General Analysis and Recommendations*

In several respects, San Juan is in a better position than other cities that have transitioned from bus to multimodal systems. Specifically, the 1998 system restructuring consolidated routes to provide more frequent service and connected them at transit centers. As illustrated in Figure 4-4, Many of these transit centers are conveniently located adjacent to Tren Urbano stations (for example, Hato Rey, Bayamón, and Centro Médico). The system design allows passengers to travel fairly directly throughout the San Juan area with at most one or two transfers. At the same time, the public has grown more accustomed to transfers, a key element of any successful intermodal network. Thus, even if the bus system were left alone, it would still partially fulfill the objectives of feeding Tren Urbano and providing general mobility.

The most recent Tren Urbano Feeder Bus Plan (Multisystems, 1999 [3]) also proposes an overall service expansion. The peak-hour pullout will increase from 201 to 252 buses once Tren Urbano opens. Maximum base headways will drop from 30 minutes to a very respectable 20 minutes. In addition, buses will run 20 hours daily to match Tren Urbano's span of service. This represents a significant improvement over current conditions where nearly all AMA and Metrobús service ends at 9 pm. Relative to comparable North American operations, the proposed San Juan bus (and train) network will offer excellent headways with long service hours. The plan does not, however, propose major service coverage expansion (specifically into público territory) or increases in route density within San Juan. Cost estimates of the new service were not readily available.

Taken as a whole, the plan builds upon dramatic improvements in the AMA and Metrobús systems in recent years. Extra buses will shorten average waiting time and relieve overcrowding. More evening service will make the system more attractive to off-peak customers. The funding and political support for better bus service demonstrates a commitment to retaining and expanding the existing bus customer base, in addition to attracting riders to Tren Urbano. In short, the opening of Tren Urbano will not be used to justify bus service cutbacks. Politically this should diffuse complaints that Tren Urbano is consuming a disproportionate share of public transportation resources.



Of course, the plan is cognizant of the importance of prudent resource allocation because of the financial realities of operating public transit. For example, better frequency in some areas may be offset by a reduction in buses that duplicate the rail corridor. To better utilize train capacity, other routes are slated to be rerouted to feed rail stations. The plan also proposes some major changes to the core route structure in central San Juan.

Appendix C evaluates some of the proposals presented in the Tren Urbano Feeder Bus Plan using the evaluation criteria discussed in Chapter 2. To narrow the scope of this analysis and concentrate on the system's most critical parts, this thesis concentrates on a few key high-frequency trunk bus routes. These ones merit special attention because they transport the majority of passengers on the AMA and Metrobús systems. Seven out of approximately 30 routes now carry over 60,000 of a total systemwide weekday ridership of almost 100,000 (see Table 4-2). These buses currently handle both regional as well as local travel and currently serve customers whose travel patterns may not necessarily require a ride on Tren Urbano. Superimposing these routes onto a map of bus usage in San Juan showing mode shares reveals how important these buses are to transit-dependent neighborhoods (see Figure 4-5).

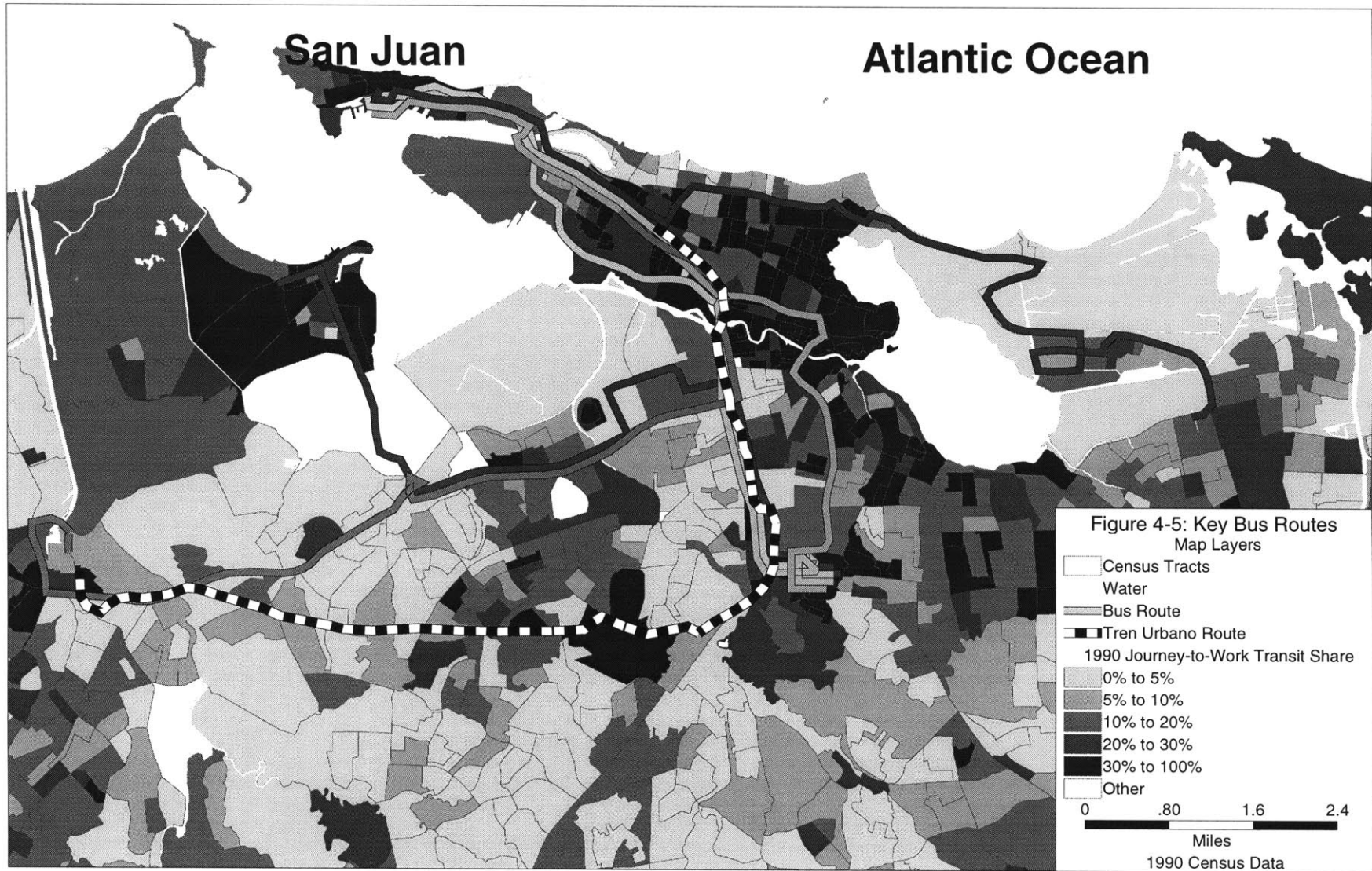
Table 4-2: Key High Ridership Bus Routes in San Juan

Route	Daily Riders	% of AMA and Metrobús Total	Areas Served
Metrobús I & Metrobús Exp.	15,300	16.1%	Viejo San Juan, Isleta, Santurce, Hato Rey, Río Piedras
Metrobús II	8,900	9.4%	Santurce, Hato Rey, Plaza Las Americas, San Patricio, Bayamón
A3	7,080	7.5%	Cataño, San Patricio, Plaza Las Americas, Hato Rey, Río Piedras
A5	9,691	10.2%	Viejo San Juan, Isleta, Santurce, Calle Loíza, Isla Verde, Carolina
A6	6,882	7.3%	Río Piedras, Carolina
A9	12,455	13.1%	Viejo San Juan, Isleta, Santurce, Barrio Obrero, Barbosa, Río Piedras
"A" & Metrobús routes	60,308	63.7%	

Source: Multisystems SJMA Bus Ridership, January-April 1998

The Tren Urbano Feeder Bus Plan investigates the possibility of either splitting or truncating several key routes (e.g. Metrobús I, Metrobús II, A9). Some potential modifications involve reorienting routes to feed Tren Urbano, while others are intended





to address load factor and reliability issues. Specifically, this analysis investigates proposals to:

- Shorten the A9 route, which now runs between Río Piedras and Viejo San Juan. The northern terminus would be relocated to either Santurce or Isla Grande instead of Viejo San Juan. Completely unrelated to Tren Urbano, this change would ostensibly seek to address even passenger loads but would introduce a bus-to-bus transfer for some passengers.
- Split Metrobús II, which now runs between Santurce and Bayamón. Metrobús II connects the endpoints of Tren Urbano, but takes a different route and serves separate markets. The plan investigates the possibility of splitting the route at its midpoint in San Patricio and creating two separate routes. The western half would become a feeder route between Bayamón and the Centro Médico area with reduced service levels. The eastern half between San Patricio and Santurce would remain unchanged.
- Eliminate the portion of Metrobús I that parallels Tren Urbano. Metrobús I, which runs along San Juan's central spine from Viejo San Juan and Río Piedras, would no longer run between Santurce and Río Piedras. However, other bus routes (Metrobús II and route A3) would continue to provide local service along this portion.

Appendix C uses the service evaluation criteria defined in section 2.4 and recent ridership and origin-destination data to analyze these proposals. It finds that the current key route structure serves existing and the anticipated future demand well. Buses not only provide trunk service along major arterials, but also feed Tren Urbano at major stations. As such, they meet both local travel and Tren Urbano accessibility needs. In most cases, increasing frequency and extending service hours (rather than drastic route restructuring) would be sufficient to accommodate anticipated changes in demand due to Tren Urbano. Major changes – such as truncating route A9 or Metrobús II – might greatly inconvenience existing customers without producing appreciable Tren Urbano ridership gains. In fact, they may even cause ridership to drop. In this sense, the integrated systems and incremental approaches are also minimalist ones. Actually, most of the major changes needed to integrate AMA and Metrobús services with Tren Urbano

already occurred during the 1998 system restructuring. By introducing a bus system designed around network connectivity and transfers several years prior to rail service, this effort has already eased the transition to Tren Urbano.

While the San Juan's core bus network may not need major changes, it does make sense to modify Metrobús I service (both local and express) to avoid duplication with Tren Urbano. Reducing or discontinuing Metrobús I service that parallels Tren Urbano would not severely impact the service quality for existing customers. Spaced approximately ½ mile apart, Tren Urbano stations are generally within walking distance of the vast majority of Metrobús I riders. In addition, other bus routes that parallel portions of the Tren Urbano alignment (i.e. route A3 and Metrobús II) would continue to provide local service. To ease the transition to Tren Urbano, it may make sense simply to reduce bus service levels on opening day, but defer route discontinuation until several months later after observing ridership patterns. The fact that Metrobús I is the best public transit success in San Juan warrants extra caution in truncating or even reducing service levels.

Although a reduction in Metrobús I service may seem negative, it could actually benefit customers. By avoiding service duplication, buses could be redeployed to the portion of Metrobús I that remains (between Santurce and Viejo San Juan). Additional service along this corridor should help accommodate the additional demand generated by passengers transferring from Tren Urbano. Shorter headways will also reduce transfer waiting times. In addition, there is a possibility of expanding Metrobús service elsewhere. The Metrobús concept – competitively contracted operations that provide frequent, reliable service using exclusive bus lanes – has proven successful and is popular. This concept deserves further exploration, particularly in future Tren Urbano corridors (e.g. Río Piedras-to-Carolina and Airport-to-Santurce).

Finally, the success of the planned intermodal network will depend upon a coordinated fare policy. Having separate rail and bus operators in San Juan presents a major impediment to fare integration. Currently, AMA and Metrobús rides cost 25 and 50 cents, respectively, with no free transfers issued within or between systems. Tren Urbano trips are expected to cost \$1.00. (Público fares vary but are generally higher and

do not include free transfers either.) So far, no specific intermodal or intramodal fare arrangements have been determined.

Service changes that introduce transfers need mitigation such as reduced or free transfers in order to minimize the cost impacts on riders. Otherwise, fares could more than double. For example, a trip from UPR to Viejo San Juan that now costs 50 cents on Metrobús I could cost up to \$1.50 (the sum of Tren Urbano and a connecting Metrobús ride). With this de facto fare increase, ridership could drop and opposition to Tren Urbano could rise. In contrast, improved fare coordination in New York and Washington, DC has resulted in increased ridership (see section 3.3). Prior research provides some concrete ideas for fare integration between Tren Urbano and San Juan bus and público operators (see Barr, 1997).

#### **4.5 Público Analysis**

In terms of network structure, integrating the públicos with Tren Urbano is relatively simple. Relatively few route changes would need to occur because San Juan's two largest público terminals, Bayamón and Río Piedras, are located close to Tren Urbano stations. From these terminals, públicos also provide extensive service coverage in Bayamón, Carolina, the highlands south of San Juan, and other target areas for Tren Urbano feeder service. However, the públicos in their current state will not be able to meet the anticipated demand generated by Tren Urbano. First, público service is primarily geared toward transporting shoppers, workers and students to activity centers in Bayamón and Río Piedras, not to other destinations along the rail alignment. The existing fleet will not provide sufficient capacity to serve the new rail feeder market. In addition, the públicos' relatively poor service quality and vehicle conditions are unlikely to attract many "choice" riders to Tren Urbano.

Thus, integrating the públicos with Tren Urbano involves two related challenges: overcoming the institutional barriers that now impede service quality and creating attractive supplemental services to meet induced demand. Meeting these challenges also requires sensitivity towards público drivers and their leadership. To ensure long-term stability and growth for transit in San Juan, one must avoid the perception that new or improved Tren Urbano feeder services – and Tren Urbano itself – are trying to drive the

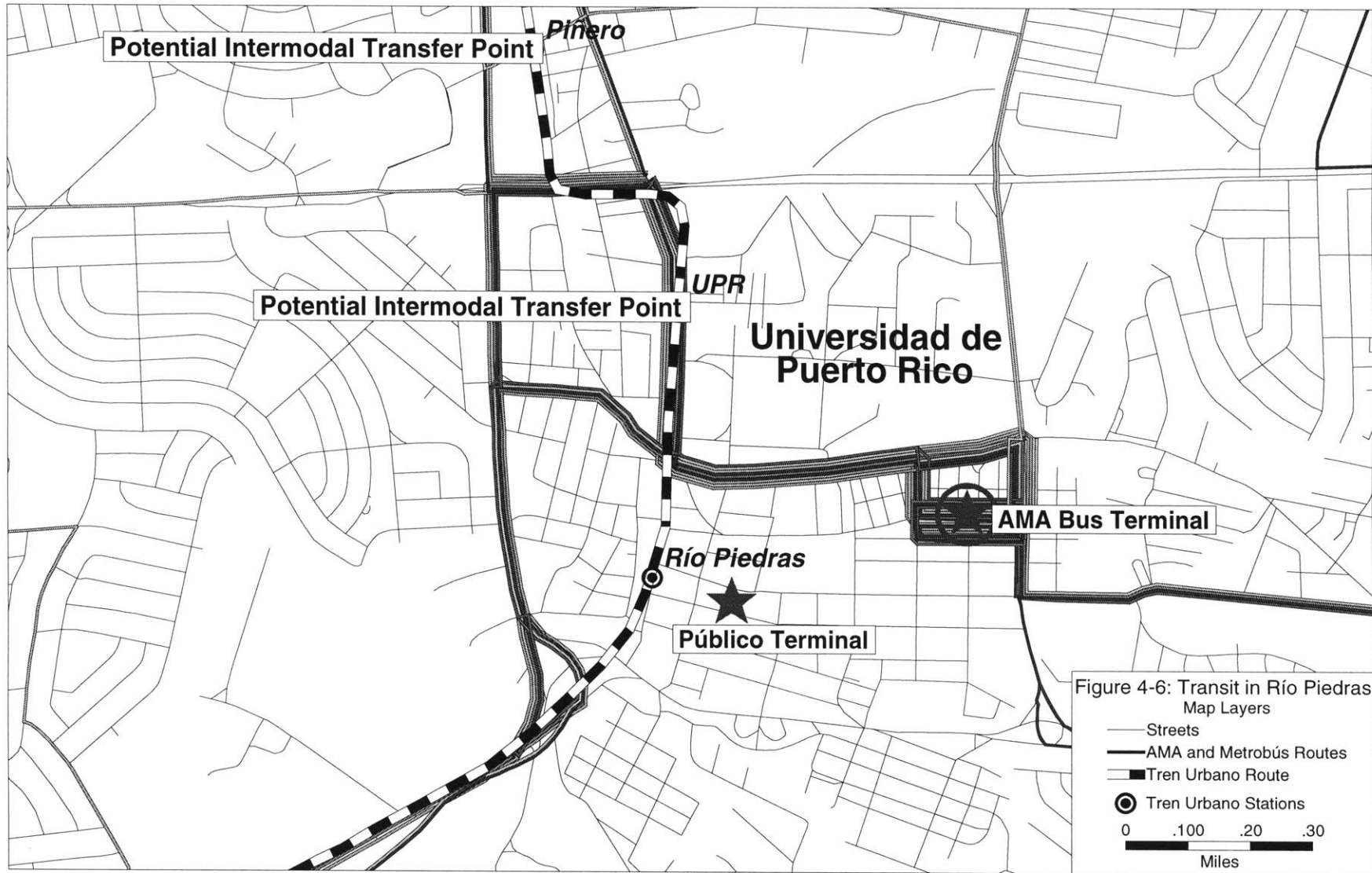
públicos out of existence. Since the organizational structure of feeder operations plays a major role in an integrated system's overall "success," this analysis primarily evaluates alternative operating arrangements for both new and existing services. This research investigates options for three areas with very different characteristics: Río Piedras, Bayamón, and the region's periphery.

#### **4.5.1 Río Piedras Area**

In Río Piedras, the públicos currently face some competition from less expensive and more consistent AMA buses, particularly on routes that link the area with Carolina. When Tren Urbano opens, further AMA improvements will be necessary to transport passengers from outlying areas to rail stations. Service enhancements could include fare integration, higher frequency, and potentially a "bus rapid transit" line along the PR 3 highway corridor between Río Piedras and Carolina. Although transit would become more attractive overall, competition from AMA could lead to público ridership losses. Consequently, público drivers might perceive Tren Urbano (and AMA) as more problematic than beneficial.

With the anticipated increases in transit demand due to Tren Urbano, AMA service expansion in the Río Piedras area is clearly important. Nevertheless, an initial strategy of avoiding direct competition with the públicos could help diffuse potential conflicts. The geography of the Río Piedras area actually makes it possible to avoid the overlap of AMA bus and público services, while still allowing AMA to provide the necessary feeder capacity to Tren Urbano. Currently, several público terminals are scattered throughout the Río Piedras district, with a major on-street layover area around a plaza located just two blocks from the Tren Urbano station entrance and the Paseo de Diego shopping district. In contrast, the major AMA bus terminal (Capetillo) is located about a half mile to the east of the Río Piedras station (see Figure 4-6). The congested, narrow, one-way streets in central Río Piedras favor small público vans over large AMA buses.

Considering the physical constraints, the públicos can be expected to gain riders because of Tren Urbano. In order to provide fully accessible and scheduled service to Tren Urbano, it makes sense to route AMA buses to adjacent Tren Urbano stations.



Specifically, Carolina-bound AMA buses that currently terminate at the Capetillo facility could be extended along the south side of the University of Puerto Rico campus to the UPR station or even further north to the Piñero station. This approach accomplishes several goals: AMA buses would avoid traffic on narrow streets enroute to Tren Urbano. At the same time, they would also serve the UPR market better by running closer to the center of campus. Meanwhile, AMA buses would not confront the públicos around the plaza in Río Piedras. Circumventing the públicos altogether would make it easier politically for AMA to increase service to meet demand. One would expect the scheduled AMA service to capture most of the Tren Urbano riders, particularly if fare policies allow for free or heavily discounted transfers between AMA and Tren Urbano. However, AMA buses will not directly encroach into the públicos' primary market; namely, travel between outlying areas and the Río Piedras business district, and undoubtedly the públicos will capture some of the Tren Urbano feeder market.

#### **4.5.2 Bayamón Area**

Unlike Río Piedras, the públicos face little direct competition from AMA in the Bayamón area. Only one AMA and one Metrobús route currently serve the area and both are oriented toward the central spine of the region. In contrast, a dense network of público routes radiates outward from several major terminals in central Bayamón, which are approximately a third of a mile from the Tren Urbano station. Meeting the accessibility needs of Tren Urbano in this area presents a unique challenge. On the one hand, judging from present operations, it would be difficult to rely on the públicos to provide the high-quality service needed to attract choice riders. On the other hand, introducing an entirely new feeder network would increase operating costs substantially and could encounter stiff opposition from público operators, who might feel threatened by perceived or real competition. This section explores possible operating arrangements for feeder services in the Bayamón area. Of the basic options reviewed in section 3.2, there are three major approaches that merit further consideration.<sup>2</sup>

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<sup>2</sup> For additional information, please refer to “Strategies for Improving Jitneys as a Public Transport Mode” (Lau [1997])

#### **4.5.2.1 Minimalist approach**

The simplest way to handle the públicos would be to leave them in their present state. At least in the short term, the públicos would continue to serve communities with few other transportation alternatives at no direct government expense. Jitneys generally thrive in cities with cheap labor, inadequate or costly conventional transit services, and high transit dependence. Captive riders also have low expectations for service regularity, comfort, or safety (Takyi, 1990). While Puerto Rico may have had favorable conditions for públicos in the past, it is rapidly moving away from such an environment. In many areas of San Juan, wages and the standard of living have improved substantially. Reliance on automobiles has also grown correspondingly. Expectations for service quality have also risen with Metrobús, improvements in AMA bus services and in anticipation of Tren Urbano.

Given San Juan's unfavorable transit environment, it is not surprising that the for-profit público enterprise has been unable to produce a quality system that attracts choice riders. In fact, it may be unreasonable to expect profit-motivated individuals to run a transport system that fulfills important but not remunerative social mobility objectives. Some of these objectives may include expanding service coverage, assisting with national "Access to Jobs" and "Welfare-to-Work" programs, and providing mobility to seniors and individuals with disabilities. Once Tren Urbano opens, some público drivers may attempt to migrate to the most lucrative, high ridership routes. Considering the alarming shrinkage of the publico system as a whole, customers on less profitable routes might lose most or all of their service.

Service irregularity is perhaps the fundamental impediment to adopting a minimalist público strategy. Although público drivers belong to route associations, each retains its own passenger revenue. This arrangement motivates público drivers to fill their vehicles before leaving the terminal or collect additional payment from other passengers for any empty seats. Fluctuations in passenger arrival rates inevitably result in inconsistent terminal departures. It also results in long and irregular waiting times during the off-peak. On Sundays and evenings, little público service exists because drivers do not feel that potential passenger revenue will offset expenses. Attracting riders



to Tren Urbano depends upon both the availability and reliability of público service, since many trips will require intermodal transfers. The status quo, a free-enterprise transport “system” driven by individual profit-motivation, will likely result in passenger frustration.

High-quality flexible transit services can still supplement scheduled, fixed-route public transit. However, their high cost structure (and service irregularity) precludes them from becoming practical substitutes for a comprehensive transit system. Demand-responsive operations that carry relatively few people per vehicle and serve scattered origins and destinations are inherently cost-inefficient, whether operated by the private or public sector. To stay afloat, they must charge high fares, consume huge subsidies, or limit service availability. Common examples in the United States include taxis and paratransit. In San Juan, the for-profit “Taxi Turísticos” charge \$8 to \$16 for a one-way trip along the Airport-to-Viejo San Juan corridor (Puerto Rico Compañía de Turismo, 1998). Few residents can afford to ride them regularly. Subsidized paratransit offers door-to-door service with advance reservations at much lower fares. However, they are extremely unproductive with farebox recovery ratios of under 10% and individual trips requiring subsidies of \$20 or more, according to National Transit Database (FTA, 1999). For this reason, only people with conditions that prevent them from riding conventional transit services can usually take advantage of paratransit.

Assuming that no large operational changes occur, Tren Urbano should have generally positive short-term effects on the públicos in Bayamón as in Río Piedras. The terminals in these communities are located within walking distance of Tren Urbano stations. Existing riders are already accustomed to público service quality. In contrast, público routes that parallel Tren Urbano could experience sharp ridership drops since the train will provide faster, more reliable service at only a slightly higher fare. However, there are only a handful of público routes (notably the Bayamón to Río Piedras line) that directly compete with Tren Urbano. These routes could even gain ridership by serving as local distributors, carrying passengers from areas between stations to Tren Urbano.

Regardless of Tren Urbano, however, the públicos will continue to have trouble in the long term without external intervention. Economic factors, poor service quality, and growing automobile usage will result in further ridership erosion. At the same time, the

heavy investment in a new rail system may cause some critics to blame the government for supporting large-scale projects at the expense of driver “entrepreneurs”. Meanwhile, poor accessibility will prevent Tren Urbano from reaching its ridership potential, and a lack of wheelchair accessible feeder service to Bayamón stations could be an ADA compliance problem (see Appendix D). Ultimately, any negative publicity for Tren Urbano will diminish support for future extension.

San Juan can learn from other cities that have relied on jitneys as rail feeders. When Miami opened its Metrorail system in the mid-1980s, for example, the transit agency allowed private jitneys to connect rail stations with neighborhoods in the northwest part of the metropolitan area. This decision enabled the agency to cut costs by curtailing bus service. As in San Juan, vehicles were uncomfortable and the jitneys provided service only during busy, profitable times. Drivers were also averse to fare integration, since that would directly reduce their income. However severe public resistance to the changes developed, eventually resulting in a political fiasco that included the removal of some top transit officials and the restoration of most bus service (Fialkoff, 1990) (see Appendix A.2).

#### **4.5.2.2 Contracted operations approach**

In the contracted operations model, the public transit authority contracts some or all operations to private companies. Also known as “contracting out”, this model involves both the public and private sectors. The public agency determines routes, fares, schedules, and vehicle characteristics, while private contractors bid to operate the service. Thus, this strategy transfers the daily operational responsibility from the agency to the contractor. Since few cities have the density and ridership to make transport services profitable, this model does not eliminate the need for subsidy. Rather, it allows the private contractor to incorporate an implicit profit margin into its bid price. This profit-making potential, coupled with competition in the bidding process from other private firms, motivates the contractor to achieve operational efficiency and better service quality for a reasonable price.

The contracted operations strategy does raise some serious concerns. First, bidding must be competitive in order to improve upon the standard publicly-owned and

operated transit system. Monetary barriers to entry, such as requiring contractors to provide their own equipment and maintenance garages, can limit the number of bidders and thus reduce competition. Secondly, the model requires public agencies to undertake the bidding process every few years, sometimes a difficult undertaking with transitional problems. For instance, if the previous contractor leaves involuntarily, it may purposely allow service to deteriorate to embarrass the public agency.

In order for this model to succeed, a public agency also must monitor the service provider to ensure that it is fulfilling the contract specifications. In theory, incentives and penalties encourage the contractor to meet or exceed service quality expectations. Without oversight, a contractor may believe that it will receive payment regardless of performance. This may lead to skipped runs, deferred maintenance, or other cost-cutting behavior that hurts both the public agency and its customers. Thus, this model depends upon careful structuring and a commitment to enforce its provisions. As mentioned previously, two examples of contracted transit operations in San Juan include Metrobús and Tren Urbano.

### *Political Considerations*

Political considerations will play an important role in determining the contract structure and specifications. In the past, públicos could survive because they carried captive riders and mostly served different territory than AMA. Maintaining the status quo likely would lead to a further drop in mode share; their poor service quality motivates riders to switch to automobiles as soon as they have the financial means. More reliable and frequent AMA service has already siphoned away público riders along the Bayamón to Santurce and Carolina to Río Piedras corridors.

Tren Urbano and a feeder service bidding process could place público owners in an uncomfortable position. On the one hand, if they do not change, they will have to compete with contracted Tren Urbano feeder services. Their decline may accelerate as riders likely will prefer the contracted service's reliability and comfort. On the other hand, they can try to win a Tren Urbano feeder service contract. Success would mean a complete paradigm shift for público drivers. For example, they would need to adhere to a schedule and work evenings and Sundays. Fares would no longer provide daily, cash

income; instead, drivers would earn wages and pay the appropriate taxes. In addition, drivers would lose personal use of the vehicle and have to learn how to accommodate customers with disabilities.

Given the need to offer high-quality transit accessibility to Tren Urbano, it does not make sense to encourage público drivers to operate the contracted feeder services. While it may not be feasible to exclude públicos from contract negotiations, the contractor must deliver quality service. Judging from their current operating practices, they may be ill-prepared or unwilling to transition to the contracted service model. Furthermore, the públicos still fill an important transportation niche in San Juan. Contracting out new Tren Urbano feeder routes to público drivers would allow them to abandon their existing markets. For both equity and political reasons, Tren Urbano should not lead to service degradation.

Despite the steady decline of the públicos, drivers and their route associations still wield considerable political power. In addition, públicos have historically met the transport needs of many Puerto Ricans and employed many people. In recognition of their functional and political importance, the government and PRHTA (Puerto Rico Highway and Transportation Authority) still need to “negotiate” with público operators and leaders. The PRHTA must avoid the perception that it wants to hasten the públicos’ decline by introducing publicly-supported Tren Urbano feeder services. To demonstrate its commitment to the existing públicos, it could build new passenger waiting shelters, reserve exclusive lanes to expedite services, provide low-interest vehicle loans, etc.

### *Contract Specification*

Considering the above discussion, the contract specifications should primarily encourage bids from high-quality service providers. Emphasizing high, enforceable standards from the beginning is especially important to make a good first impression and attract new riders to Tren Urbano. Some relevant contract points include:

- Geographical Scope and Contract Size

While the contract model could eventually cover público services throughout the island, the government needs to start small to control costs. Initial attention should focus

on público routes in subregions such as Bayamón, for example, which are adjacent to key Tren Urbano stops. Separate contracts could be established for each subregion, or for individual routes or small groups of routes. A more extensive geographical area would minimize the contract overhead and favor larger and more organized bidders. This in turn may improve the chances of obtaining higher quality service since it would encourage bids from established transport companies.

Theoretically, a large-scale contract would still enable some públicos to consider competing in the bidding process. The públicos maintain a well-defined, hierarchical structure; most drivers belong to union-like route associations to which they pay dues in exchange for legal protection and other benefits. A few politically powerful cooperatives and federations in turn “control” these route associations (Lau, 1997). However, público associations would still have to compete with outside professional transportation providers.

- Service Level Requirements and Changes

A competitive procurement specifies basic service requirements to help contractors determine their bid price and size their fleet and workforce. Of course, demand variation can make forecasting service requirements difficult, especially over the length of the contract. The situation for new operations like Tren Urbano is even more uncertain than for established systems. The anticipated Tren Urbano feeder requirements are derived from a demand model that relied on assumptions about long-term economic conditions, traffic congestion levels, population growth and many other variables. In reality, ridership may not materialize at the expected levels, or may overwhelm the system from the beginning.

The contract will need to include provisions for incremental service changes. Though the uncertainty may increase bid prices, potential contractors will know that they may have to adjust service in the short-term. Preferably the contract should also begin with conservative (relatively low) service requirements. It may be difficult to get the service provider to agree to less compensation even if service levels drop.

- Gross Cost v. Net Cost Reimbursement

In a gross cost contract, the transit agency pays the contractor a fixed amount to provide the service and receives all fare revenue. In a net cost contract, the contractor receives a smaller payment from the transit agency but retains the fare revenue. Since ridership fluctuates, the net cost approach motivates them to provide better service so that they can capture more revenue. A gross cost contract lessens the risk for the contractor, which may lead to more bids and greater competition.

The gross cost structure initially may result in more reliable service. At least during a specified “break-in” period after Tren Urbano opens, the primary goal of the supplemental minibus network should be to develop ridership by providing reliable but not necessarily high-productivity service. Allowing contractors to keep fare revenue would motivate them to wait for their vehicle to fill before departing from the terminal. In other words, the service provider would continue to equate every empty seat with lost revenue and thus the operating procedures could degenerate into the status quo. Although incentives for schedule adherence might encourage them to change, in practice it may be difficult and costly to enforce contract regulations.

A “shared revenue” scenario represents a compromise between these two options. In this situation, the public agency partially reimburses the contractor for fares collected. A graduated scale, where contractors earn a higher percentage of revenue as ridership grows, encourages them to provide the consistent service needed to attract more customers. However, it also increases the contractor’s financial risk and may drive up bid prices. Simply filling vehicles, the current operating practice, will not necessarily generate more ridership or revenue. Since this behavior results in uneven headways, particularly during the off-peak, it discourages ridership.

- Vehicle specifications and ownership

A typical público van is approximately fifteen years old, lacks air conditioning, and has an inefficient seating arrangement that hampers easy entry and exit. It is also inaccessible to people with wheelchairs. New, accessible vehicles will be needed not only to comply with federal ADA requirements, but also to attract customers who expect

quality feeder services to deliver them to Tren Urbano. For a detailed discussion of accessibility requirements, refer to Appendix D.

A modern accessible bus fleet that supplements Tren Urbano will require a substantial capital investment. The standard lift-equipped minibus, also known as a “cutaway”, sells for about \$50,000. Low-floor vans that avoid wheelchair lift maintenance, and dramatically reduce dwell times for wheelchair customers, and enhance accessibility for all passengers, cost much more. For example, the “ELF” (short for “Exceptional Low-Floor Flexibility”) costs at least \$100,000.<sup>3</sup> If the government required bidders to provide their own accessible vehicles, it would implicitly limit competition to large-scale, established companies and increase bid prices. However, the contractor would also be more motivated to maintain the vehicles. Realistically, público route associations would have little chance of winning this type of competition, unless they form partnerships or joint ventures with other, well-financed entities.

It would also be in the best interests of the government to avoid the público system’s long run demise. The deteriorating condition of the present público fleet illustrates that owners can hardly afford to maintain their aging vehicles, let alone purchase modern low-floor vans or minibuses with wheelchair lifts. While some traditional públicos may succeed in carving their own niche, many may cease operations when faced with government-supported high-quality competition. Extending vehicle loans and seeking exemptions from ADA regulations may help the públicos survive.

#### **4.5.2.3 Hybrid Approach**

The hybrid approach combines elements of current público operations and the pure contracted services model. “Base” contracted services would run approximately every half-hour during all hours of operation on all routes. Licensed “Tren Urbano Públicos,” run as individual for-profit service, would supplement the base services at the driver’s discretion. The licensed públicos would not follow schedules; however, it is likely that they would provide relatively frequent service during the busiest travel hours in order to capture the most passenger revenue. To prevent them from “skimming”

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<sup>3</sup> Source: Overland Custom Coach, Thorndale, Ontario, Canada

passengers from the publicly funded base services, however, the licensed públicos would be forbidden to leave a station close to a scheduled base service departure. Standard, non-licensed públicos could not compete directly with either service; they would be denied entry to Tren Urbano stations.

The owners of licensed públicos would not receive direct assistance for operating expenses or government assistance for vehicle procurement. However, Tren Urbano would reimburse them for transferring passengers. Even with this indirect support, it is uncertain whether becoming licensed públicos will prove financially attractive for current público owners. According to the Americans with Disabilities Act (ADA), any new fixed-route, public transit vehicle purchased after 1991 must be accessible to individuals with disabilities (refer to Appendix D). Unfortunately, these well-intentioned guidelines make the capital cost prohibitive (\$50,000 or more) for the average público driver. One cost-reduction tactic would be to attempt to waive ADA requirements by arguing that these regulations would force drivers of the licensed públicos out of business (Amador and Wensley, 1999). Another possibility is to attempt to define the supplemental services as “demand responsive.” Specifically, drivers could deviate from fixed routes to pick up or drop off passengers. According to ADA regulations, a demand responsive system does not require accessibility if, “when viewed in its entirety, [it] provides a level of service to [individuals with disabilities] equivalent to the level of service provided to the general public.” In this case, the base service and possibly paratransit would arguably provide an “equivalent” level of service.

Table 4-3 describes the service characteristics for a preliminary hybrid model developed for the Bayamón area. Costs were estimated using the ridership forecasts from the Tren Urbano Environmental Impact Statement. These estimates rely on the assumption that base contract service costs approximately \$35 per hour and that licensed Tren Urbano Público drivers would receive a \$0.50 reimbursement for each transferring customer (Multisystems, 1999 [3]).



Table 4-3: Proposed Bayamón Base and Licensed Público Characteristics

Characteristic	Base Service	Licensed Tren Urbano Públicos
Operator	Under contract	Público drivers
Proposed Fares	\$1.50 (combined público and TU fare); \$0.50 público fare	\$1.50 (combined público and TU fare); \$0.50 público fare
Span of Service	7 days/wk, matching Tren Urbano hours of operation	Determined by individual drivers, similar to current público hours of operation (assumed to be weekdays 5 am-7 pm)
Service Headways	30 minutes	Determined by individual drivers
Schedule Adherence	Yes	No
Accessibility	ADA compliant	Not ADA Compliant
Estimated Year 2001 Annual Ridership	3.0 million	4.8 million
Annual Revenue Hours	306,600	224,200
Assumed Contract Costs	\$35/revenue hour	\$.50 reimbursement per transferring passenger
Estimated Annual Operating Costs	\$10.7 million	\$0
Fare Revenues	\$1.5 million	-\$2.4 million
Estimated Net Cost	\$9.2 million	\$2.4 million

Source: Multisystems, Inc. [2], 1999.

Compared to the pure contracted operations model, the hybrid approach saves on contract costs as well as capital costs for the government. In the preliminary analysis of Bayamón públicos, the net cost per passenger was over \$3 for base contract service but only \$0.50 per Licensed Tren Urbano Público rider.<sup>4</sup> If only contracted services were to operate in Bayamón, annual net costs would be approximately \$16.1 million versus \$11.6 million under the hybrid scenario. The difference comes from the public accepting responsibility for the 224,000 service hours that are assumed to be privately operated under the hybrid scenario. This would require additional financial support of \$7.8 million annually (at a rate of \$35 per revenue hour), less \$2.4 million from fare revenues.

The hybrid model also has a few limitations, including:

- Schedule coordination: Licensed Tren Urbano Públicos are not required to operate according to a specified timetable. As long as drivers derive their income directly from fare revenue, they will be reluctant to leave the station until their vehicle fills.

<sup>4</sup> Since Licensed Tren Urbano Públicos likely would run only during the most profitable time periods, these numbers may exaggerate the benefits of this model. This hybrid model also assumes that público owners can acquire non-accessible vehicles, possibly an ADA violation. Requiring accessible vehicles will raise the entry cost for licenses, discouraging potential drivers from joining the program.

- **Passenger Skimming:** To maximize revenue, some licensed públicos may try to “skim” passengers by travelling directly in front of a base service vehicle, even if contract provisions prohibit this practice. Unfortunately, this behavior would require more public subsidies to support both the base service and Tren Urbano. Not only would the base service lose revenue directly, but Tren Urbano also would have to reimburse the licensed público driver. While Automatic Vehicle Location (AVL) technology or even human “starters” at rail stations can help “manage” público drivers, passenger skimming is very difficult to prevent in real operating environments.
- **Fare Integration:** Reimbursing drivers for individual transfer trips makes implementing unlimited-ride intermodal passes very difficult.
- **Regulating Private Entry and Controlling Base Service:** For the hybrid scenario to succeed, PRHTA must make clear that the públicos providing supplementary service do not “own” the Tren Urbano feeder market. Judging from past experience, however, it would be difficult to regulate private carriers once they gain a foothold along a given route. They might feel threatened by any attempt by the PRHTA to increase base service in response to demand. Without their cooperation, it will be difficult to coordinate bus service with Tren Urbano.

### *Summary and Recommendations*

The contracted operations model, the hybrid model, and the existing público system are in theory all driven by competition. Contracted operations, however, are more likely to produce a higher level of service. In summary:

- **Financial Assistance:** The financial assistance provided to contracted operations results in more comprehensive service, not just along high volume routes during peak hours. Financial support also enables periodic fleet renewal with comfortable, air-conditioned vehicles that also meet ADA requirements. Públicos only operate when and where drivers feel they can earn a profit. To stay solvent, most drivers have also decided not to upgrade their vehicles.
- **Organizational Scale and Structure:** The contract structure makes it easier to achieve the consistent, coordinated service needed to complement Tren Urbano. A private

entity operates the service, but the public agency specifies fare policy, routes and schedules. Públicos are more difficult to “control” because they are individually owned and operated, even though they belong to route associations and federations. Drivers leave a terminal when they have a full passenger load, not on a fixed schedule. Furthermore, since they derive their income directly from passenger fares, they may be reluctant to undertake intermodal fare integration with Tren Urbano.

- **Nominal v Real Competition:** Although the público is sometimes hailed as a “free enterprise”, competition-based transport system, público route associations basically act like cartels. At least in Bayamón, few público routes face direct challenges from AMA buses because they mostly serve different geographical territory. Público drivers queue at major terminals and are not supposed to “steal” customers from fellow drivers. Riders, most of whom are transit-dependent, have no viable alternatives. Currently San Juan realizes few benefits from the current form of private transport since little competition actually occurs. In the contracted operations model, on the other hand, the bidding process encourages competition, can require higher quality service, and favors cost-efficiency. Assuming that enough firms bid, providers that can meet the proposal specifications at a reasonable price have a better chance to win. Incentives, penalties, and the threat of contract termination all motivate an operator to fulfill the service requirements.

For reasons discussed previously, the pure contracted service model has the best chance of fulfilling an intermodal system’s desired qualities (service frequency, schedule reliability, integrated fares, vehicle comfort, and accessibility). Unfortunately, this model is also the most expensive; in Bayamón, for example, it would require financial support of approximately \$16 million annually, or \$5 million more than the hybrid approach. With the hybrid model, however, motivating the licensed Tren Urbano público operators to provide a high level-of-service may be as difficult as it is now.

To develop ridership as well as long-term public and political support, it might make more sense to adopt the contracted service model and simply “do it right” the first time. One or more of the following strategies could help contain costs:

- Larger vehicles – Increasing vehicle capacity on busy routes can reduce fleet requirements. Larger vehicles may cost more initially, but they save on ongoing expenses. However, larger vehicles also mean poorer service headways, a major ridership deterrent. In addition, they do not maneuver as well along narrow or hilly streets commonly found in San Juan.
- Shortening service hours and increasing base headways – Shortening service hours, particularly by limiting late-night and weekend morning service on low-demand routes, can trim expenses. Lengthening the base headways on low patronage routes can also reduce costs. Even with these cutbacks, service would still be far superior to present público operations, which run erratically and do not operate at all during the evening or on Sundays.
- Limiting service coverage – Under the current Bayamón service plan, the proposed feeder route density is extremely high in certain areas, with some lines being only a few blocks apart. In the Levittown neighborhood, some planned feeder routes also duplicate existing AMA bus service. Consolidating routes, particularly during the off-peak, could substantially cut vehicle and driver costs.
- Higher fares – Higher fares can increase the cost recovery ratio; however, they may also result in lower ridership. The actual revenue gains depend upon the fare elasticity, or the sensitivity of riders to fare changes.

None of these options sound favorable from a customer's perspective. However, limiting service hours (especially during the late evening) or coverage initially probably would have the least impact on customers since this service does not currently exist anyway. Nevertheless, the PRHTA should aim for incremental increases in off-peak services as ridership develops. Finally, one should not overemphasize cost-cutting measures for transit services that supplement Tren Urbano. First, the operating costs for feeder service are relatively small compared to Tren Urbano's capital costs. Secondly, Tren Urbano's success greatly depends upon drawing customers from areas that are not adjacent to rail stations. A relatively small expenditure on buses and públicos will allow many more people to take advantage of Tren Urbano.

Finally, introducing a contracted service in Bayamón could face political obstacles. Naturally, público operators and their associations will probably view any incursion into “their” territory as a threat. Unlike Río Piedras, the publicly-funded AMA transit system has not already established itself in the area. Nevertheless, pursuing a similar strategy of avoiding direct competition would help diffuse possible conflicts. This approach would involve market segmentation: the públicos would continue to provide transport between residential areas and the markets in Bayamón, while the contracted services would primarily enhance accessibility to Tren Urbano. To accomplish this objective, the contracted routes could initially be diverted from the Bayamón station to the Deportivo station, one stop to the east. Meanwhile, fare coordination between Tren Urbano and the contracted service as well as regulations that bar the traditional públicos from entering the Bayamón station would further reinforce the distinction between the two services. Alternatively, the contracted service could charge \$1, with free transfer privileges, effectively minimizing any siphoning off of current público riders.

This strategy would admittedly lead to some inefficiency. Customers headed toward central Bayamón (either to the commercial district or Tren Urbano) would not always be able to board the first vehicle that arrives at their stop. The routing to Deportivo would also depress the contracted system’s ridership because the station is located away from major commercial areas. For these reasons, it may make sense eventually to provide the contracted service to Bayamón station. Delaying this move until long after Tren Urbano’s opening day, however, may be necessary to facilitate the transition period to rail.

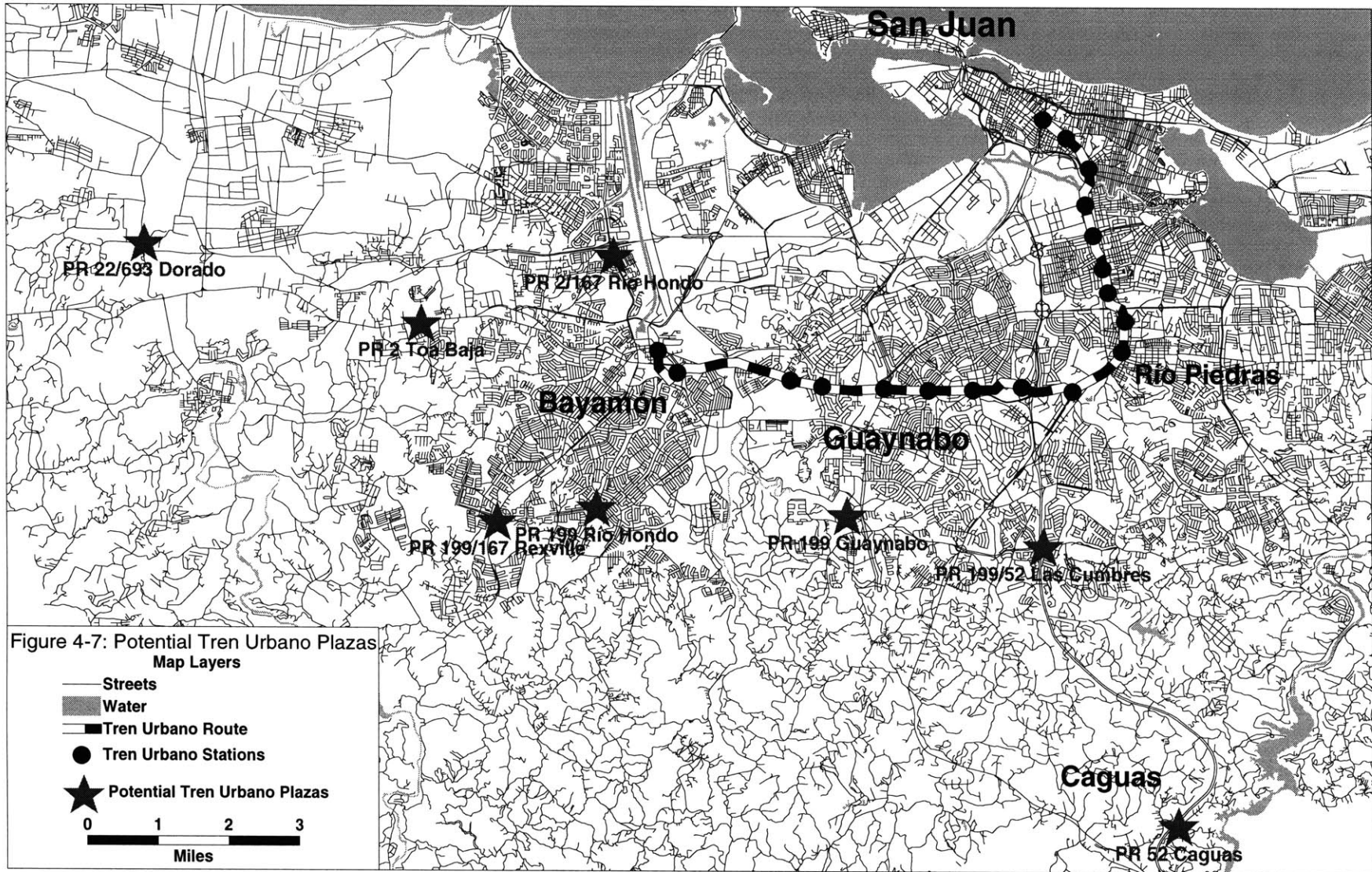
#### **4.5.3 Peripheral Areas and “Tren Urbano Plazas”**

Currently, San Juan’s públicos offer limited service to periphery of the metropolitan region. While potential Tren Urbano riders live in these areas, low densities, good highway access, and high automobile ownership make it difficult to provide high-quality feeder services. Without improved transit access to Tren Urbano, ridership may not reach its potential because there are relatively few park-and-ride spaces at rail stations to accommodate automobiles.

The “Tren Urbano Plaza” is an innovative concept designed to improve rail accessibility in suburban areas with relatively poor transit service. Tren Urbano Plazas would be located in outlying areas near major highways (Figure 4-7 shows a map of potential plaza sites). Each plaza would consist of a transit center with kiss-and-ride and park-and-ride facilities, as well as varying levels of commercial development depending on location. Express shuttle buses would operate non-stop between each plaza and a Tren Urbano station along dedicated high-occupancy vehicle lanes, offering faster travel times and better reliability than the car. For customer convenience, plaza shuttles would operate during both the peak and off-peak on weekdays, corresponding to Tren Urbano service hours. Shuttles would sport the Tren Urbano logo to encourage customers to think of the plaza as an integral component of the rail system. Finally, modest parking and concessionaire fees could help offset operating costs (Multisystems, 1999 [1]).

The Tren Urbano Plaza concept makes sense for several reasons. It effectively serves low-density areas with high car ownership rates. Instead of operating many long-headway routes in the suburbs, resources are consolidated into a few frequent, fast, point-to-point routes originating at strategically located plazas along key highways and close to suburban neighborhoods so as to intercept motorists who might otherwise forgo transit altogether. Passengers can reach many regional destinations quickly by connecting to Tren Urbano. The plazas would also provide excellent kiss-and-ride locations, close to suburban homes. Finally, Tren Urbano Plazas avoid the need to use space adjacent to rail stations – choice locations for transit-oriented development – with expansive parking and kiss-and-ride facilities.

The plaza concept serves an untapped, distinct market: suburban “choice” riders. With this product differentiation, it reduces the potential for political conflicts with the públicos. Federal transit officials have also endorsed the plaza concept. In June 1999, the Federal Transit Administration chose San Juan to participate in a nationwide “bus rapid transit” demonstration. Specifically, the 2.5-mile Río Hondo express shuttle route, which links the PR 199/Río Hondo Tren Urbano Plaza with the Bayamón station, will become one of ten funded projects nationwide (FTA, 1999).



## Chapter 5: Summary and Conclusions

A new rail line has the potential to strengthen a transit system by introducing quick, reliable, comfortable, and frequent transportation that attracts new riders and generates public support. A bus network that supplements the rail line can extend transit's reach and make the system more responsive to a variety of travel patterns. Although a new rail system can bring about long-term gains for transit, in the short term it introduces many changes that that may result in uncertainty for both passengers and operators. At the same time, external pressures to demonstrate "success" (often measured in terms of rail ridership) may cause agencies to divert their attention away from the equally important bus system. As both bus and rail are critical components of a successful intermodal system, agencies should focus on how both modes can work together.

This work has had two primary motivations: (1) to address intermodal integration issues generally with application to any North American metropolitan area developing a rail system, and (2) to make specific recommendations for San Juan, Puerto Rico, where the Tren Urbano heavy rail system is slated to open in 2002. It has developed a framework to analyze intermodal integration strategies, which considers some important factors (e.g. potential level-of-service, ridership, system productivity, and political impacts) in the decision making process.

Given the North American experience with intermodal integration, there is clearly a need to balance long-term system objectives with the short-term considerations of introducing a rail component to a transit network. An incremental approach to the issue may be appropriate, a strategy that few (if any) North American cities have pursued. Specifically, this approach suggests that a transit agency should initially focus on capturing riders through fare incentives and other promotions, while deferring large decisions with significant impacts (such as bus restructuring) beyond the rail system's opening day. This delay helps insulate the transit operator from potential political difficulties when it is in the spotlight and provides real data to justify proposed service changes. In the meantime, an agency must be prepared for some system inefficiency and unmet ridership expectations.



## 5.1 Review of Planning Principles

This thesis has also discussed general intermodal integration planning principles, supported by evidence from a handful of American cities with new rail systems.

### Fare Coordination

Fare coordination is extremely important in a system that relies on transfers to maximize the destination opportunities available to customers. The fare policy should encourage customers to use the most efficient route(s) possible to reach their destinations, regardless of mode. The majority of North American transit operators offer free or heavily-discounted transfers, unlimited-ride day passes, or a combination of both. In general, having a single regional transit provider overseeing all modes greatly facilitates fare integration. Given the recent experiences in New York and Washington, DC, it seems reasonable to conclude that simplifying and lowering the cost of intermodal (and intramodal) transfers can attract new patrons to the system and encourage existing customers to ride more frequently. These cities have experienced double digit ridership increases as a result of innovative fare initiatives.

### Network Structure

This thesis has investigated the impacts of new rail lines on the existing bus networks. While rail service may strengthen the transit system overall, it may inconvenience some existing riders. For example, passengers who used to have a “one-seat” bus ride may need to use a combination of bus and rail to reach their destinations. The transition period may be particularly difficult for express bus customers. Express buses usually offer a direct peak-period ride from the home or a nearby park-and-ride lot to downtown without intermediate stops. Due to these characteristics, they often attract “choice” riders who live in the suburbs and work in the city. If a transit agency were to truncate the line at the nearest rail station, sometimes the added transfer time may not offset any train travel time savings.

From a service perspective, however, the express bus network that sometimes exists prior to the opening of a new rail line is usually not comparable with an intermodal

system. Because each express route is tailored to a specific but limited commute pattern, it is very difficult for transit agencies to blanket an entire region with frequent, all-day express bus routes. It is even more of a challenge to offer high-quality express bus service to destinations outside the downtown core. In contrast, new urban rail systems introduce relatively fast, frequent, all-day service. Connecting buses, which provide local and rail feeder service, also often operate more frequently because they support a variety of travel patterns. As a whole, an intermodal network may provide better access to multiple points throughout a region. When deciding how to handle bus routes that parallel a new rail line, agencies must weigh the potential loss of some riders with potential improvements in network structure and opportunities to redeploy resources elsewhere. An incremental strategy of deferring major changes until after the rail line opens can help ease the transition period. After a transition period, real ridership data will be available and it should be possible to show clear benefits of service changes to all stakeholders. By committing to at least a zero-sum redeployment of bus services from routes that parallel the rail line to other areas and avoiding any cutbacks in bus service hours, bus providers can provide more frequent and expanded service elsewhere on the network.

### Transfers

Numerous studies (CTPS [1997], Liu et al. [1997, 1998]) identify transfer waiting time as a critical deterrent to transit usage. They have found that the “transfer penalty” is worth several minutes of equivalent in-vehicle time and is substantially more onerous than initial waiting time. Despite these negative findings about transfer penalties, at least some transferring will be necessary in an intermodal network or, for that matter, in any transit system with intersecting routes. This research suggests that agencies should focus on making transfers as convenient as possible, increasing feeder service overall to lower transfer waiting time and/or coordinating schedules.

### Case Studies

To support the planning principles and recommendations for San Juan, this research has investigated the intermodal integration experiences in five cities.

- Portland

Portland is an example of a highly coordinated bus and light rail system. In September 1998, the city extended its light rail line 18 miles to the western suburbs. While the integration of bus and rail service resulted in the loss of some direct radial bus service, it has facilitated non-radial trip-making and provided the resources to increase off-peak frequency and expand network coverage. As a result, transit's peak-period mode share along a parallel highway rose from 13% to 20% over a six-year period. As significantly, reverse-commute usage more than tripled (from 4% to 14%) in less than two years (Tri-Met and ODOT, 1999).

- Miami

When Miami opened its Metrorail line in the mid-1980s, it faced difficulties because it focused on cutting back bus service. The bus-rail integration plan "was marketed as a service improvement when in reality it was a massive service cut" (Fialkoff, 1990). Many areas lost evening and weekend service. Some routes were transferred to private-sector jitneys, which the transit agency viewed as an easy way to reduce costs. However, these jitneys – as in San Juan – were uncomfortable and lacked fare coordination with conventional buses, providing a lower level of service to customers. The public demanded and ultimately won restoration of most bus services. In the process, however, the agency suffered negative publicity and several top officials lost their jobs (Fialkoff, 1990).

- Los Angeles

Over the past decade, Los Angeles has developed a heavy and light rail network that carries in excess of 100,000 passengers per day, more than several of the better-publicized rail "success" stories (APTA, 1999). While the physical integration between buses and trains has gone relatively smoothly, many people believe that Los Angeles has two separate and unequal systems: an expensive rail network that caters to "choice" riders and an underfunded bus system for the transit-dependent. Bus overcrowding, ridership losses, and threatened fare increases came to reinforce this perception. While

some of the criticism may have been unwarranted, the damage has been done: the courts instead of the transit agency seem to have the final say on service levels and bus procurement. The agency has also suspended rail projects that would provide high-quality alternatives to driving and, ironically, would serve the transit-dependent (Klabin, 1996).

- Washington, DC

Overall, Washington's intermodal experience has been generally positive with buses and rail playing complementary roles. Recent fare simplification efforts, which reduced most transfer charges and bus fares, contributed to an immediate ten percent ridership jump (WMATA Press Release, Oct. 20, 1999). Washington also demonstrates how a rail system can successfully interface with a busway to offer customers the advantages of both bus and rail modes. Commuter buses using exclusive high-occupancy vehicle lanes terminate at a rail station just outside Washington, allowing passengers to transfer to the subway to reach many scattered destinations quickly and efficiently.

- San Francisco

The San Francisco Bay Area boasts one of America's most comprehensive transit systems, in terms of mode diversity and service coverage. However, the sheer network size and numerous transit providers hamper service and fare coordination. This thesis has examined one particular example: the transbay corridor between the East Bay and San Francisco served by both the BART rail system and AC Transit express buses. In general, the rail and bus networks have evolved to serve different markets. Trains provide line-haul service between major suburbs and the Bay Area's urban core; the bus offers one-seat rides to commuters who live far from train stations. Recently, AC Transit has become more aggressive and begun to concentrate on BART corridors. However, improvements to attract choice transbay patrons – including BART customers - have occurred while transit-dependent riders have seen many off-peak services disappear. In some ways BART's fare and parking policies exacerbate the coordination problem.

BART provides free parking at rail stations but offers only nominal discounts to those who transfer to or from buses.

## **5.2 Application to San Juan**

This thesis has developed and evaluated possible strategies for integrating San Juan's bus and público system with Tren Urbano. Given the current state of San Juan public transit, the city faces some tough but surmountable challenges in developing an effective integrated system. Different vehicle standards, service levels, fares, and organizational arrangements add complexity to the task. In particular, the inability to control thousands of individually-owned públicos makes it even tougher to achieve the service quality necessary for effective integration with Tren Urbano. Active intervention by the public sector, particularly through financial assistance and público restructuring efforts, can help produce the service quality to attract new riders.

The mismatch between Tren Urbano, bus, and público riders presents another challenge to effective multimodal coordination. While Tren Urbano will attract some existing bus and público customers from parallel routes, many riders will continue on their current travel patterns simply because the initial phase of Tren Urbano will not serve their destinations. In other words, the bus and público systems will continue to play important roles in San Juan even though Tren Urbano will emerge as the visual and symbolic backbone of transit.

### AMA and Metrobús Service

In terms of integrating bus and rail services in San Juan, this thesis focuses primarily on network design and fare policy. Major findings presented in this research include:

- **Key AMA Bus Routes:** This thesis evaluates proposals of either splitting or truncating several key routes in order to feed Tren Urbano or address load factor and reliability issues. A detailed analysis of origin-destination data, coupled with projected ridership patterns with Tren Urbano, finds that current key routes serve existing and future demand well. Routes not only provide trunk service along major arterials, but also feed Tren Urbano at major stations. As such, they meet both local travel and rail accessibility needs. In most cases, increasing frequency and extending service hours

(rather than drastic route restructuring) will be sufficient to accommodate anticipated changes in demand due to Tren Urbano.

- **Metrobús Service:** Eventually, reducing or even discontinuing Metrobus I service that parallels Tren Urbano should not severely impact the service quality for existing customers. Rail stations are generally within walking distance of the vast majority of Metrobús I riders as long as fare integration with free transfers is provided. In addition, other bus routes that parallel portions of the Tren Urbano alignment would continue to provide local service. By avoiding service duplication, buses could be redeployed to the remaining portion of Metrobús I (between Santurce and Viejo San Juan). However, the strong image of Metrobús I as San Juan's first public transit success suggests that restructuring should follow an initial Tren Urbano opening, and be based on observed ridership preferences.
- **Fare policy:** Currently, no fare integration exists within or between San Juan's transit systems. Nevertheless, fare coordination is necessary for a system designed around both intra- and intermodal transfers. In particular, service changes that introduce transfers need mitigation such as reduced or free transfers in order to minimize the cost impacts on riders. Otherwise, fares could more than double, ridership could drop, and the current strong support for Tren Urbano may weaken.

### Público Service

Currently, the existing fleet will not provide sufficient carrying capacity to serve the anticipated new rail feeder market. In addition, the públicos' relatively poor service quality and vehicle conditions are unlikely to attract many "choice" riders to Tren Urbano. Integrating the públicos with Tren Urbano involves two related challenges: overcoming the institutional barriers that now impede service quality and creating attractive supplemental services to meet induced demand. One must avoid the perception that new or improved Tren Urbano feeder services – and Tren Urbano itself – are consciously or unconsciously driving the públicos out of existence. This research investigates options for three areas: Río Piedras, Bayamón, and the region's periphery.

### *Río Piedras Area*

In Río Piedras, the públicos currently face some competition from less expensive and more consistent AMA buses, particularly on routes that link the area with Carolina. With the anticipated increases in transit demand due to Tren Urbano, AMA service expansion in the Río Piedras area is clearly important. Nevertheless, avoiding direct competition with the públicos could help diffuse potential conflicts. Considering the physical constraints of the street network and the difficulty of evicting públicos from the center of Río Piedras, it might make sense to leave the públicos alone and redirect AMA buses to adjacent Tren Urbano stations. One possibility is to route buses along the south side of the University of Puerto Rico campus to the UPR station, which would target the university and rail feeder markets. Passengers could walk to the commercial district, but buses would not directly compete with públicos there, and both modes would likely enjoy increased ridership from new Tren Urbano feeder market.

### *Bayamón Area*

Unlike Río Piedras, the públicos face little direct competition from AMA in the Bayamón area. Meeting the accessibility needs of Tren Urbano in this area presents a unique challenge. It would be difficult to rely on the públicos to provide high-quality service. At the same time, introducing an entirely new feeder network would increase operating costs substantially and could generate stiff opposition from público operators. This thesis investigates three major strategies:

- Minimalist – This approach leaves públicos in their present state, with no vehicle or service improvements to tap the Tren Urbano market.
- Contracted Operations – In this scenario, the Puerto Rico Highway and Transportation Authority (PRHTA) would initiate a set of contracted feeder routes. The authority would determine routes, fares, schedules, and vehicle characteristics, while private contractors competitively bid to operate the service.
- Hybrid - The hybrid approach combines elements of current público operations and the pure contracted services model. “Base” contracted services would run approximately every half-hour during all hours of operations on all routes. Licensed

“Tren Urbano Públicos,” run as individual for-profit service, would supplement the base services at the driver’s discretion.

The contracted operations model is the most likely to fulfill an intermodal system’s desired qualities. It would facilitate fare integration, avoid passenger skimming from licensed or traditional públicos, and enable all service to run on a schedule. Following a similar “público avoidance” strategy as in Río Piedras, the contracted routes could initially terminate at Deportivo station instead of Bayamón Centro, which is within walking distance of several público terminals. Alternatively, based contracted service could be provided to both stations, but with a \$1 fare with a free transfer. This fare policy would attract new Tren Urbano riders without directly competing for traditional público markets. Of course, this model is also the most expensive. Limiting service hours (especially during the late evening) or coverage initially to contain operating costs probably would have the least impact on customers since this service does not currently exist anyway.

To make this model succeed, bidding must be competitive in order to reduce costs and attract a high-quality contractor. A public agency also must monitor the service provider to ensure that it is fulfilling the contract specifications. Finally, this model depends upon careful structuring and a commitment to enforce its provisions. Table 2 outlines recommendations for Bayamón feeder service contract provisions.

Table 5-1: Recommendations for Bayamón Feeder Service Contract Provisions

Geographical Scope and Contract Size	A more extensive geographical area would minimize the contract overhead and favor larger and more organized bidders. This in turn may improve the chances of providing higher quality service since it would encourage bids from established transport companies.
Service Level Requirements and Changes	Given the uncertainty of feeder service ridership demand when Tren Urbano opens, the contract should preferably begin with conservative (relatively low) service requirements. It will need to include provisions for incremental service changes.
Gross Cost v. Net Cost Reimbursement	A “shared revenue” scenario, where the public agency partially reimburses the contractor for fares collected, encourages contractors to provide consistent service needed to attract more customers.
Vehicle specifications and ownership	The contract should require bidders to provide at least some of their own vehicles, which would implicitly limit competition to large-scale, established companies and increase bid prices. However, the contractor would also be more motivated to maintain the vehicles.



### *Peripheral Areas*

The “Tren Urbano Plaza” is an innovative concept designed to improve rail accessibility in suburban areas with relatively poor transit service. Tren Urbano Plazas would be located in outlying areas near major highway, and each would consist of a transit center with kiss-and-ride, park-and-ride facilities, and possibly commercial development. Express shuttle buses would operate non-stop between each plaza and a Tren Urbano station along dedicated high-occupancy vehicle lanes, offering faster travel times and better reliability than the car. Strategically located plazas along key highways intercept motorists who might otherwise forgo transit altogether. The plaza concept serves an untapped, distinct market: suburban “choice” riders. With this product differentiation, it reduces the potential for conflicts with the públicos.

### **5.3 Areas for Further Research**

This thesis has covered many broad intermodal integration issues. There clearly exists a need to explore many of these issues in greater depth. The following list highlights potential areas for further research, both in the general case and the San Juan context:

#### General

- Impact of new rail systems on transportation providers: Planners need to better understand how new rail systems influence private carriers as well as transit management, front-line workers and other employees. With this understanding, transit agencies can take steps to reduce potential conflicts (e.g. job security issues). Within this context, it would also be useful to identify strategies to involve the private sector more in service provision to achieve cost efficiencies.
- Cost and demand modeling: This thesis primarily employed a qualitative approach to assess various integration strategies. For instance, the discussion about network structure involved general concepts rather than detailed modeling, supported by some general data from the case studies. A simple, but limited model involving operating costs and ridership was developed to describe the situation. Additional research into

cost and demand implications different strategies could help better estimate the financial impacts of service changes.

- **Intermodal facilities:** The physical design of intermodal facilities can influence people's willingness to use transit. Possible research areas include the safety and comfort of waiting areas and the provision of real-time vehicle departure information. Station parking policies and availability are also important because they influence rail ridership, usage of feeder buses and other modes, station construction and maintenance costs, and surrounding land uses.
- **Cross-sectional analysis of cities outside North America:** Many cities with multimodal transit systems on other continents boast high transit mode shares. Research into what makes these systems successful (both exogenous and endogenous factors) can help North American planners identify additional integration strategies for new rail systems.
- **Intermodal integration in low-density environments:** As noted in chapter 3, operating effective intermodal transit systems in automobile-oriented suburbs is a tremendous challenge. Given the importance of suburbs, it would be useful to conduct additional research into how to integrate buses with new rail systems, particularly commuter rail, which has grown rapidly in the past few years. In contrast to typical light and heavy rail lines, commuter rail is tailored to long-distance, peak-hour, peak-direction travelers and runs infrequently (if at all) during the off-peak. In most cases, this level-of-service makes rail more reliant on automobile rather than bus access.
- **Marketing:** Often, existing bus services lack a strong image compared to a new rail system. Additional research identifying ways to market supplemental bus services – particularly as an extension of a rail line – can not only generate ridership, but encourage people to think of bus and rail as one system.

San Juan specific:

- **Institutional issues:** Significant cultural differences exist between San Juan and other American cities (including the case studies). Research on unique institutional issues by people familiar with Caribbean and Latin American customs and culture would help planners tailor successful integration strategies used in other cities to San Juan.

In particular, the públicos merit special attention since they are unique to Puerto Rico, have had a long historical presence on the island, and pose the greatest challenge to effective service integration with Tren Urbano and conventional bus services.

- **Route Analysis:** While this thesis examines some major bus routes in the San Juan, several key transit corridors with high ridership potential require a more extensive analysis. Some of these present opportunities for the implementation of “Bus Rapid Transit” as an interim step to full Tren Urbano service. Examples include the Viejo San Juan/Santurce and the Río Piedras/Carolina corridors.
- **Transfers:** As in other systems, transfers will be a key component of San Juan’s intermodal transit network. To improve the methodology for evaluating service alternatives, further research needs to be done to quantify the impacts of transfers (e.g. trading off faster rail service and possibly shortened headways on improved bus feeder routes with transfer wait times).
- **Extensions:** After Phases I and IA of Tren Urbano are complete, there are proposals to extend rail service to Carolina, the Airport area, Viejo San Juan, and Caguas. Work is needed to determine how to integrate bus and público services with these extensions.
- **Intercity bus service:** Currently, públicos provide the major intercity transit service between San Juan and the rest of Puerto Rico. To make Tren Urbano play a greater regional carrier role, planners need to determine how to integrate rail with these intercity públicos, or other possibly new services using standard over-the-road coaches.
- **Other modes:** Other ways of accessing Tren Urbano stations include taxicabs and automobile dropoffs (“kiss-and-ride”). These modes can supplement bus feeder services, particularly during off-peak hours and in remote areas. Better accessibility to Tren Urbano can allow family members to share cars (instead of leaving a car idle at a park-and-ride lot), creating a more transit-dependent culture. Additional research can help identify ways to encourage alternative modes (for example, neighborhood taxis).

- Marketing: Marketing of new and expanded transit service is extremely important in San Juan, where transit does not have a strong positive image. Research should focus on how to build a transit “culture” with Tren Urbano, buses, and públicos. In particular, it should identify ways to adapt successful marketing practices elsewhere to the Puerto Rican environment.

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Washington: [www.wmata.com](http://www.wmata.com)

## Appendix A: Case Studies

The following case studies of intermodal integration provide lessons for San Juan. They focus on the United States for two reasons. First, cities in the United States in general have developed differently from those in Latin America, Europe, Asia, Australia or Africa. Low density, high automobile ownership, and a severe decline of public transport have created unusual challenges for emerging rail systems that merit attention. Secondly, although the San Juan is arguably closer to Latin American cities in terms of language, culture and population characteristics, its travel patterns resemble many automobile-dependent United States cities. Indeed, American policies and capital have greatly influenced the transportation system and physical development of the San Juan metropolitan region.

While all North American cities with urban rail systems could provide lessons for San Juan, this research focuses on only a few: Los Angeles, Miami, San Francisco, Washington, and Portland. The chosen case studies have one or more of the following characteristics:

- (a) major restructuring of the surrounding bus network took place in response to a new rail line,
- (b) a new rail line altered the social or political landscape with respect to transportation,
- (c) multiple regional transit operators complicate route and schedule coordination,
- (d) demand responsive services meet some transportation needs

In addition, the case studies almost all involve rail systems that began during the 1970s or later. Like San Juan, these cities were mostly automobile-oriented but also had transit-dependent neighborhoods prior to the opening of their rail lines.

## **A.1 Los Angeles**

With the world's most extensive freeway network and a legendary affection for cars, Los Angeles is a well-known symbol of sprawl, smog, and traffic congestion. Although often overshadowed by the automobile, public transit still has played a noteworthy role in the city's overall transportation picture. Los Angeles once boasted an extensive electric streetcar and interurban railway network that rivaled systems in Chicago, Philadelphia, Boston, and New York. By the Second World War, Los Angeles was engaged in a transportation strategy that emphasized private mobility and massive highway construction over public transit investment. This policy allowed a once venerable rail empire to decline into a bus system patronized principally by transit-dependent minorities. Due to its sheer population size, however, Los Angeles nevertheless operates the nation's second largest bus system, now managed by the Los Angeles County Metropolitan Transit Authority (MTA).

Against this backdrop, Los Angeles embarked on an ambitious rail construction program in the 1980s. The Blue Line, a 22-mile light rail line linking Long Beach and Los Angeles, opened in 1990. Five years later, the Green Line added another 20 miles to the system. The city's first modern subway, the 11-mile Red Line, opened in 1993. It currently runs from downtown Los Angeles to Hollywood and will reach the San Fernando Valley by the year 2000. "Metro Rail" now transports around 135,000 passengers on weekdays (MTA website), more than well-publicized urban rail systems in San Diego, Portland, St. Louis, and Dallas.

While the physical integration between buses and trains has gone relatively smoothly, many people believe that Los Angeles has two separate and unequal systems: an expensive rail network that caters to middle-class white people and an underfunded bus system for low-income minorities. Rail critics suggest that the MTA has diverted resources from the bus system, used by over 90% of transit riders, to benefit comparatively few rail passengers. Some opponents also accuse the MTA of cutting bus service to force passengers onto trains (Rabin, 1999).

For many customers, bus overcrowding, ridership losses, and threatened fare increases came to symbolize how MTA's rail program was hurting the bus system. The widespread perception that the MTA favored trains over buses led to the formation of an

activist “Bus Riders’ Union”. In July 1994, under budgetary pressures, the MTA made itself more vulnerable to criticism by proposing to eliminate popular monthly passes and increase fares from \$1.10 to \$1.35 per ride. The “Bus Riders’ Union” and other bus advocates took the MTA to court and forced the agency to continue monthly passes, although the court allowed the base fare to increase (Klabin, 1996). In the summer of 1995, the MTA suffered another embarrassment: Red Line tunneling caused a sinkhole to form on Hollywood Boulevard. This unfortunate incident drew unwanted media attention to the beleaguered agency and spotlighted construction management problems (Davis, 1995).

In 1996, the MTA faced another lawsuit charging that the agency had discriminated against minorities and the poor by allowing the bus system to deteriorate. To avoid a trial, it negotiated a “Consent Decree” with the Bus Riders’ Union and its allies in which it agreed to increase bus service and address overcrowding issues. More specifically, the agreement restricted the number of bus standees during any 20-minute period to 15 or fewer (9 or fewer by the year 2002). In March 1999, the Bus Riders’ Union won another victory. A judge agreed with bus advocates that the MTA was not complying fully with the “Consent Decree” requirements and ordered the agency to purchase 532 new buses (Rabin, 1999). This ruling came even though the MTA was already complying with Consent Decree’s standees requirements more than 95% of the time and had added 100 peak-hour buses in the previous year (MTA Press Release, October 18, 1999). Meanwhile, political pressures and budget problems forced the agency to freeze rail projects to Pasadena, the Mid-City district west of downtown, and East Los Angeles. Ironically, these proposed rail corridors traverse communities with large transit-dependent and minority populations.

Even supporters of Los Angeles’ rail program acknowledge that the MTA made some tactical and political blunders. Still, they maintain that Metro Rail critics have not given the agency enough credit for building a heavily-patronized rail system from scratch. They suggest that opponents have been quick to polarize the discussion into a “bus v. rail” debate about technology, class and race, but slow to find workable alternatives to the automobile. One observer comments, “the [Bus Riders’ Union] labels

every light rail or subway system in Los Angeles County as ‘racist’, a statement that stretches credibility” (Rivera, 1999).

An analysis of the rail system reveals that some criticism of the MTA may have been unwarranted. Contrary to the perception that the rail system caters to white riders, it actually serves mostly low-income and minority neighborhoods. The Blue Line, for example, traverses African-American and Hispanic communities of South-Central Los Angeles, Watts, Compton, and North Long Beach. The Red Line serves the Hispanic and Asian-American enclaves of Westlake-MacArthur Park and Koreatown. In fact, minorities comprise 89% of the riders on the Blue Line, 86% on the Green Line and 75% on the Red Line. This hardly differs from MTA buses, where the figure is 88% (Stanger, 1999). From a level-of-service perspective, these riders have enjoyed faster and more reliable service as a result of Metro Rail. For example, an afternoon rush-hour trip from Downtown Los Angeles to Watts takes 20 minutes on the Blue Line compared to 57 minutes on the Line 55 bus. The Red Line shaves 25 minutes off a trip between downtown and the mid-Wilshire district (8 minutes on the subway versus 33 minutes on the Line 20 bus) (MTA website).

The transit controversy that has engulfed Los Angeles throughout the 1990s has made it easy to overlook other intermodal coordination efforts. Without fanfare, the urban rail lines have integrated with dozens of bus routes operated by both the MTA and municipal carriers. They have also facilitated regional travel. The Red Line now links some of the densest parts of Los Angeles County with Metrorail commuter trains to the suburbs. The Red and Green Lines also connect with the region’s two major bus priority facilities, the Harbor Transitway and the El Monte Busway (MTA System Map).

The rail lines have enabled the MTA to shift buses from rail corridors to underserved areas. Although this practice has been criticized in Los Angeles and in other cities, the MTA actually reconfigured only a few routes. It basically overlaid the rail lines upon an existing, comprehensive bus grid. In every case, it retained parallel local bus routes to serve short-distance travel needs and provide multiple transit alternatives. Rather than “force feeding” the rail lines to build ridership, the MTA mostly tried to give passengers choices.

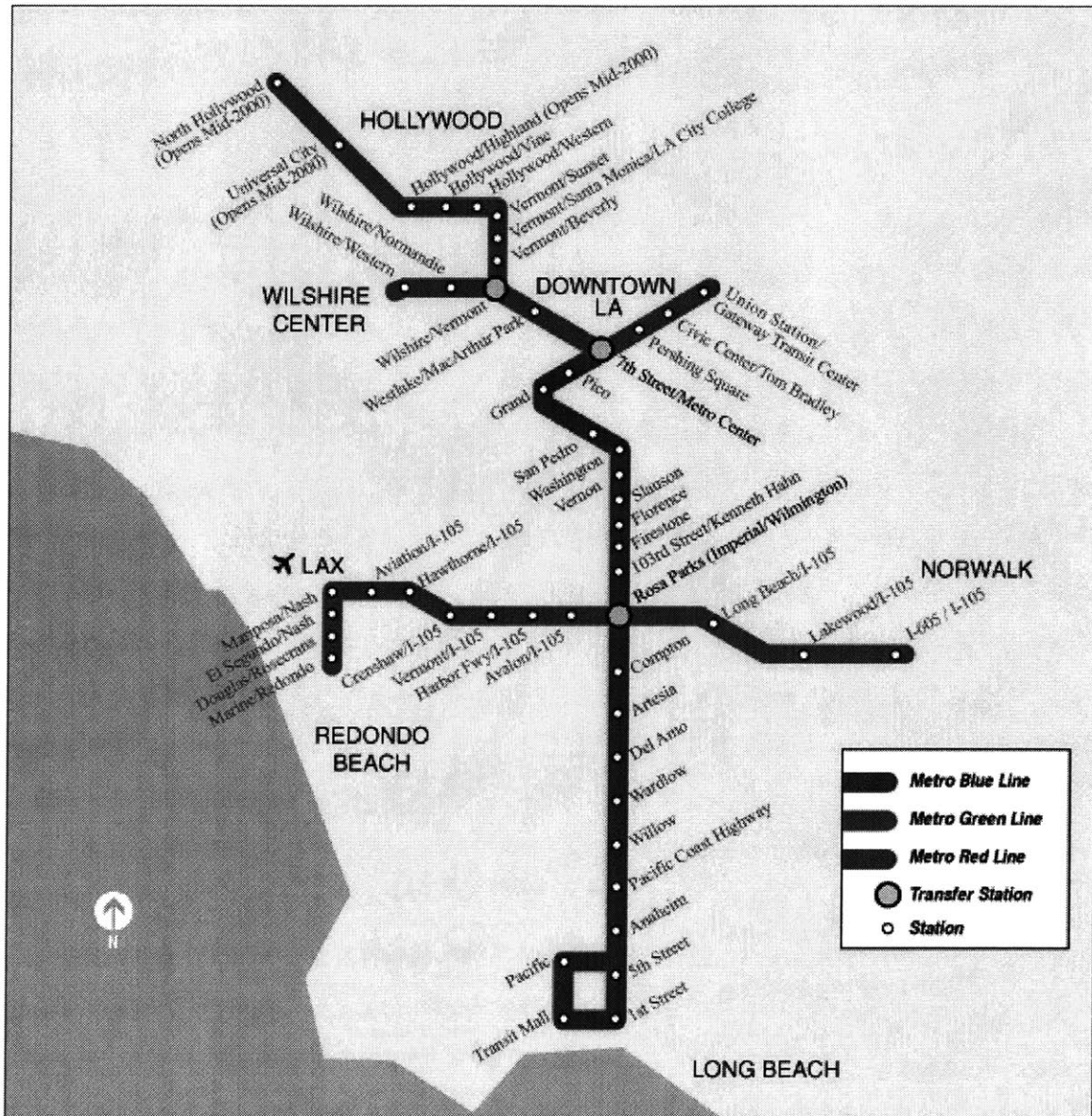
In some cases, however, the MTA discontinued parallel express or limited stop service where rail provided faster, more frequent, and more comprehensive service. For example, the agency eliminated Line 456, an express bus route that paralleled the Blue Line from Long Beach to Los Angeles. Unlike the train, this bus bypassed transit-dependent communities in Compton, Watts, and South-Central Los Angeles. Without intermediate traffic to support the route, Line 456 also had much lower demand than the Blue Line. Consequently, it also ran less frequently (every 15-30 minutes versus every 5-10 minutes during rush hours, and every 30-40 minutes versus every 12 minutes at other times) (RTD, 1990). Even though the bus ran non-stop once it reached the freeway, congestion still made it less reliable and slower than the train.

In other cases, opposition to transfers and a reduction in parallel bus service resulted in missed service integration opportunities and unrealized bus system improvements. Under pressure from the Bus Riders' Union, the MTA recently abandoned plans to eliminate bus service between Hollywood and Downtown Los Angeles that duplicates the Red Line. For the moment, express buses spend thirty extra minutes each way fighting freeway congestion and downtown traffic and continue to bypass major ridership generators (Richards, 1999). The three intermediate stops that these buses do make require passengers to "negotiat[e] long narrow stairways" and wait in an unpleasant freeway environment (MTA website). In contrast, redirecting these buses to the subway in Hollywood would have facilitated access to a major bus hub, Southern California's fourth largest employment center, and the nation's entertainment capital. The MTA also missed the chance to reallocate resources to shorten headways and ease overcrowding on other bus routes.

On a positive note, the MTA has begun to focus on the needs of bus customers and recently initiated many bus system improvements. However, the political damage has already been done. The Bus Riders' Union and sympathetic judges now seem to have the final say on service levels and bus procurement. The agency has also suspended rail projects that would provide high-quality alternatives to driving and, ironically, would serve minorities and the transit-dependent. Unfortunately, the Bus Riders' Union has conveyed the message that Los Angeles' transit system does not and should not serve "choice" riders. Noting the absurdity of the internecine conflict, a local transit expert

comments that the bus versus rail argument “is very damaging because it pits transit advocates one against the other. [Rail] and bus are both important. In fact, we should be arguing together for more transit spending in general and less spending on highways” (Rivera, 1999).

Figure A-1: Map of Los Angeles Metro Rail system



Source: MTA website



## A.2 Miami

### *Background*

Miami, Florida, resembles San Juan and many other cities that grew rapidly after the Second World War. While the city has a fairly extensive bus network, low densities and an automobile-scale development have contributed to heavy reliance on driving. Like San Juan, Miami is unusual among North American cities because private jitneys operate alongside the publicly funded transit system, Metro-Dade Transit. In both cities, Caribbean and Latin American influences also have helped shape the “jitney culture” and operations. Since the mid-1980s, the public sector has also undertaken efforts to develop high-quality rail services. In 1985, Metro-Dade Transit completed Metrorail, a 21-mile heavy rail line connecting downtown Miami with the northwest and southwest suburbs. Soon thereafter, it opened a connecting people mover system called Metromover that circulates around the central business district. In 1989, the Tri-Rail commuter rail line began operating between West Palm Beach and Miami Airport.

Traditionally, public buses and jitneys have formed the backbone of Miami’s transit system. A 1992 study by the Urban Mobility Corporation (UMC) reported that jitneys carried approximately 43,000 to 49,000 weekday passengers, compared to about 183,000 on Metro-Dade Transit buses (Lau, 1997). In the past, buses and jitneys have vied for similar territory, creating an adversarial relationship between transit employees and jitney operators. This contrasts with San Juan, where públicos and AMA bus system avoid direct competition in most corridors because they largely serve different geographical areas. Nevertheless, the fundamental issue in both Miami as in San Juan is the same: conventional transit operates both high-demand and low-demand routes as a public service, whereas jitneys operate only where and when drivers can make a profit.

In 1985, Dade County passed an ordinance stating that jitneys could only operate at least a quarter-mile away from “high-density” corridors where buses ran at least every 30 minutes. The regulation “allow[s] the County-operated bus system to maintain its ability to achieve the maximum possible operating efficiencies without jeopardizing existing service quality” (MDTA et al., 1987). Supporters of this policy contend that direct competition often results in jitneys skimming passengers from the transit authority by running slightly ahead of buses. Consequently, deregulating jitneys would cause

Metro-Dade Transit to lose passenger revenue that could help support low ridership routes. These routes do not attract enough traffic to support jitney operators but nevertheless are important because they may be the only public transit available in certain communities. Without adequate controls, the private sector would reap the benefits of the busiest corridors and leave the public to subsidize the most unproductive routes.

As in San Juan, Miami's jitney operators view themselves as business people more concerned with making a living than providing a social service. Jitney operators, of course, argue that they should have the right to operate anywhere and maintain that jitneys and buses serve separate markets. Estimates of costs and revenues suggest that jitney drivers earn roughly the minimum wage (Lau, 1997). From the jitney operator's perspective, the county ordinance limits their profitability. During the peak and weekday base periods, they have few opportunities to operate because "high-density" bus service covers most of the metropolitan area. The jitney owners have much more flexibility on weekends and evenings, but demand at these times is also lower. In the past, one jitney owner threatened to sue to deregulate the industry (MDTA et al., 1987). Jitney drivers have also defied the route regulations. In one case, Metro-Dade Transit responded to illegal jitneys by upgrading bus service. It "repackaged" route 77 as "Super 77", lowering fares from \$1.25 to \$0.75 and shortening headways to every 10 minutes. As a result, jitney business dropped 30% and bus ridership grew by 2,000 per day (Metro-Dade Transit website).

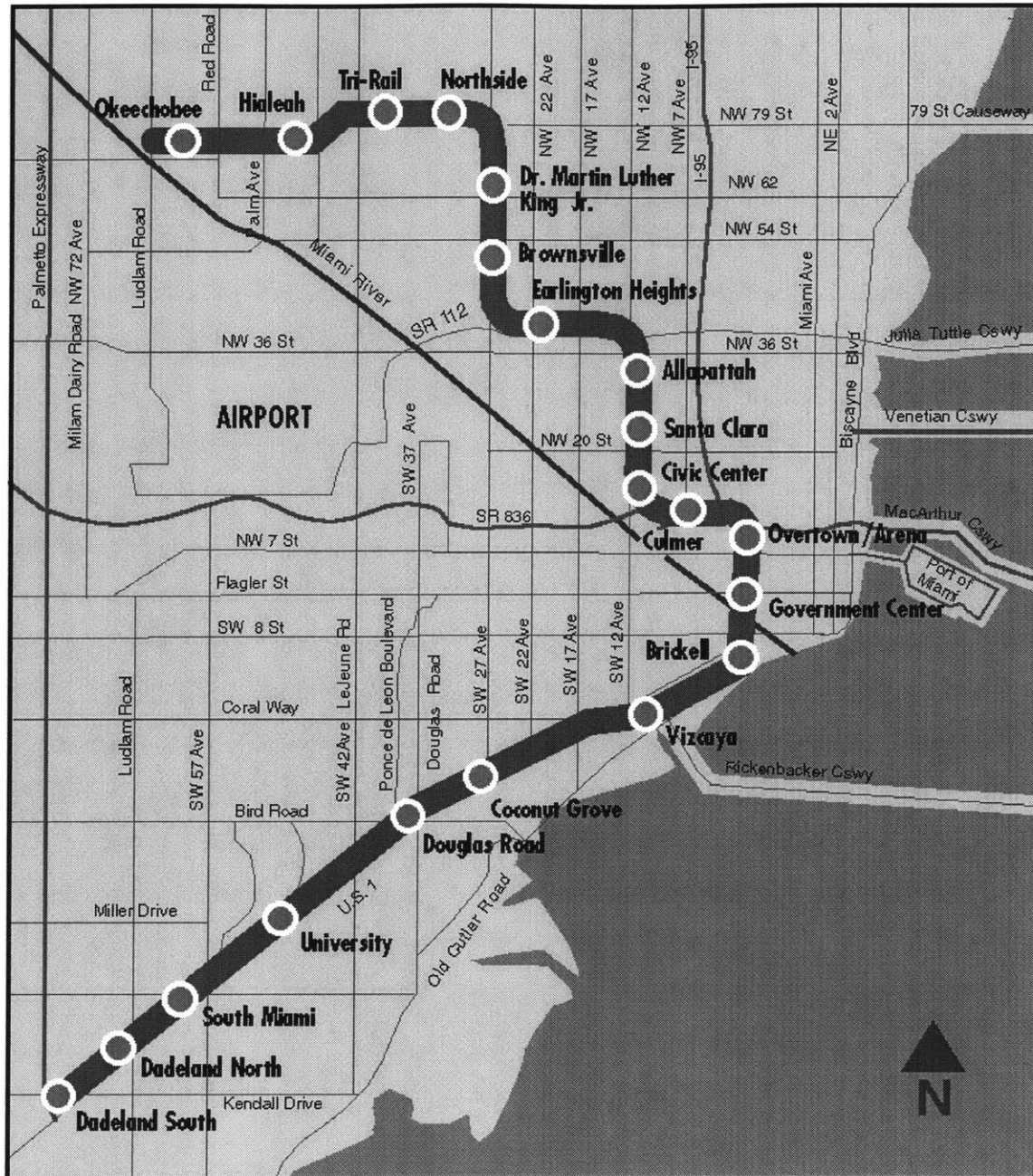


Figure A-2: Map of Miami's Metrorail system  
 Source: Metro-Dade Transit website

Planning for Metrorail in the mid-1980s posed many challenges for Metro-Dade Transit. Not only did it have to grapple with standard integration planning issues, such as how to handle parallel bus routes and transfers to the rail system, but it also faced budget limitations and pressures from jitneys. In the end, transit management saw Metrorail as an opportunity to reorganize the bus system, improve productivity, and provide the jitney

industry with new ridership opportunities. The integration plan established three primary goals:

- (1) to eliminate bus routes that paralleled or duplicated other routes or Metrorail
- (2) to shorten bus routes to improve operational performance
- (3) to emphasize a grid network rather than a radial one, with a focus on connecting buses with the Metrorail system
- (4) to modify service spans and headways on bus routes that did not meet service standards
- (5) to streamline bus service by allowing private sector jitneys to operate low-productivity routes without subsidy.

Metrorail opened in two segments, with the south line from downtown Miami to Dadeland beginning a year before the north line to Hialeah. The transit authority adopted a relatively low-key approach to integrating the south line with buses. On opening day, it simply realigned bus routes that operated near Metrorail to serve the stations. Three months later, it eliminated premium express routes that operated along the highway that parallels the rail line. Finally, it restructured some bus routes to become rail feeders and local circulators. The primary negative reaction came from passengers who formerly had a one-seat bus ride, but now had to switch modes and pay a \$0.25 transfer fee. In general, however, the public accepted the changes because Metrorail reduced travel time overall and stations provided pleasant transfer facilities.

Metro-Dade Transit pursued a much more aggressive integration strategy for the Metrorail's north segment because the rail line served an area with significantly higher bus ridership. Management was particularly concerned with how Metrorail would impact transit service in adjacent communities. As with the south line, some customers would lose one-seat bus rides and have to pay a \$0.25 transfer charge. This raised some equity concerns, since communities without rail service would continue to have direct bus service to downtown Miami. To demonstrate that it was serious about the needs of bus passengers, the transit authority decided to overhaul the system with the ostensible purpose of upgrading service, even in areas outside Metrorail's sphere of influence:

“[The plan] was presented to the public and to public officials as the best way to perform bus route planning. It offered more transit service with fewer miles and therefore the system would cost less because the service would be more efficient; it would be a response to critics who said that too much time and money were being spent on Metrorail and not on Metrobus, the primary transit mode in the County in terms of the number of passengers transported.” (Fialkoff, 1990).

The plan seems to have emphasized budget trimming over service enhancement. Metro-Dade Transit significantly reduced evening and weekend bus service, leaving riders in many communities with no transit service. A prime cost-cutting example was the attempt to shift low-productivity service to the private sector. Jitneys replaced buses on six poorly performing routes, some of which fed Metrorail stations. The public reacted strongly. First, people were disappointed at the lack of fare integration. The jitneys did not discount fares for senior citizens or people with disabilities and did not issue or accept transfers. Simply put, Metro-Dade Transit wanted to withdraw all financial support from these routes and jitney operators were unwilling to share revenues. Secondly, many people, especially the elderly, found the vehicles uncomfortable. As a result, “there was a public outcry for restoration of Metrobus service” (Fialkoff, 1990). This embarrassing episode, which included unfavorable media coverage and involved elected officials, soon forced the transit authority to reverse many of the service cuts (Fialkoff, 1990).

Although many changes involved routes outside the rail corridor, the system overhaul occurred in conjunction with Metrorail’s opening. Thus, an observer might have reasonably concluded that the rail line caused the bus system to decline. In retrospect, the integration plan created problems because it “was marketed as a service improvement where in reality it was a massive service cut” (Fialkoff, 1990). The political fallout included the removal of the agency director, several deputy directors, the planning director, and other transit professionals. Ultimately, Metro-Dade Transit restored most evening and weekend service and realigned many routes to their previous configuration (Fialkoff, 1990).

### *Subsequent Actions*

In 1987, shortly after Metrorail’s opening, a “jitney task force” revisited the jitney issue. This panel, composed of county staff, jitney industry members, and transit unions, could not agree on the specific role of Miami’s jitneys. While jitney owners continued to assert that they should be able to operate anywhere, county and union representatives maintained that such a policy would leave the public sector with only the poorly-performing routes.

Discussions also included the possibility of transfer discounts between the regular transit system and jitneys. For the network to appear seamless to the customer, jitney operators would have to agree on a specific transfer arrangement and reimbursement policy. Some of the jitney operators expressed interest in revenue sharing while others did not. The participants concluded that implementation would be difficult because the transit authority could not force independent jitney operators into a transfer agreement. Since jitney drivers pocketed fares directly, they would also be reluctant to accept Metro-Dade monthly passes. From the passenger's perspective, varying transfer fees and the inability to use monthly passes would make the system less convenient overall. Although the task force felt that a fare demonstration project would be useful, these obstacles so far have inhibited fare coordination between the jitneys and conventional transit systems (MDTA et al., 1987).

Despite these setbacks, Miami has since demonstrated that jitneys can complement the regular transit system. In September 1992, the Miami area became eligible for temporary federal financial assistance to help recover from Hurricane Andrew. Metro-Dade Transit began contracting with private van and minibus companies to link neighborhoods south of Miami with Metrorail. The transit authority agreed to pay four prime contractors \$28 per hour for vehicles, drivers, insurance, maintenance, and associated operations expenses; in turn, the contractors subcontracted services to private van and jitney operators for about \$21 per hour. By March 1993, the system had grown to twelve routes with five to ten minute headways and 20,500 daily riders (Lau, 1997).

One reason for this success is that government support allowed passengers to ride free. While the temporary financial assistance eventually ended, the experiment demonstrated that conventional transit and jitney operations could work together under certain conditions. First, the jitneys tapped a new market and met previously underserved travel demand, rather than saturating already well-served corridors and skimming passengers from buses. Secondly, outside funding provided a stable source of income for jitney drivers. This arrangement reduced the incentive to drive erratically, delay departures in order to fill vehicles, defer maintenance, or behave in other ways that degrade service quality and reliability.

The Miami experience shows that transit agencies should not view a new rail line as an opportunity to curtail bus service. In particular, disguising service cuts as “improvements” can ultimately embarrass the transit provider and result in political troubles. In addition, counting on the private sector to operate unproductive, low-revenue routes only works if operators receive financial assistance. Even then, fare and schedule coordination difficulties can arise because different operating paradigms often result in variable service and comfort levels.

### A.3 San Francisco

The San Francisco Bay Area boasts one of America's most comprehensive transit systems, in terms of mode diversity and service coverage. Rapid transit, commuter rail, light rail, buses, trolley buses, ferries, and even cable cars serve a population of about 5 ½ million spread over eight counties. Unfortunately, the sheer network size and numerous (over two dozen) service providers hamper service and fare coordination. Conflicts arise between the major regional rail carriers, primarily the Bay Area Rapid Transit (BART) and the CalTrain commuter rail line, and local transit agencies such as the San Francisco Municipal Railway (Muni), AC Transit, and SamTrans.

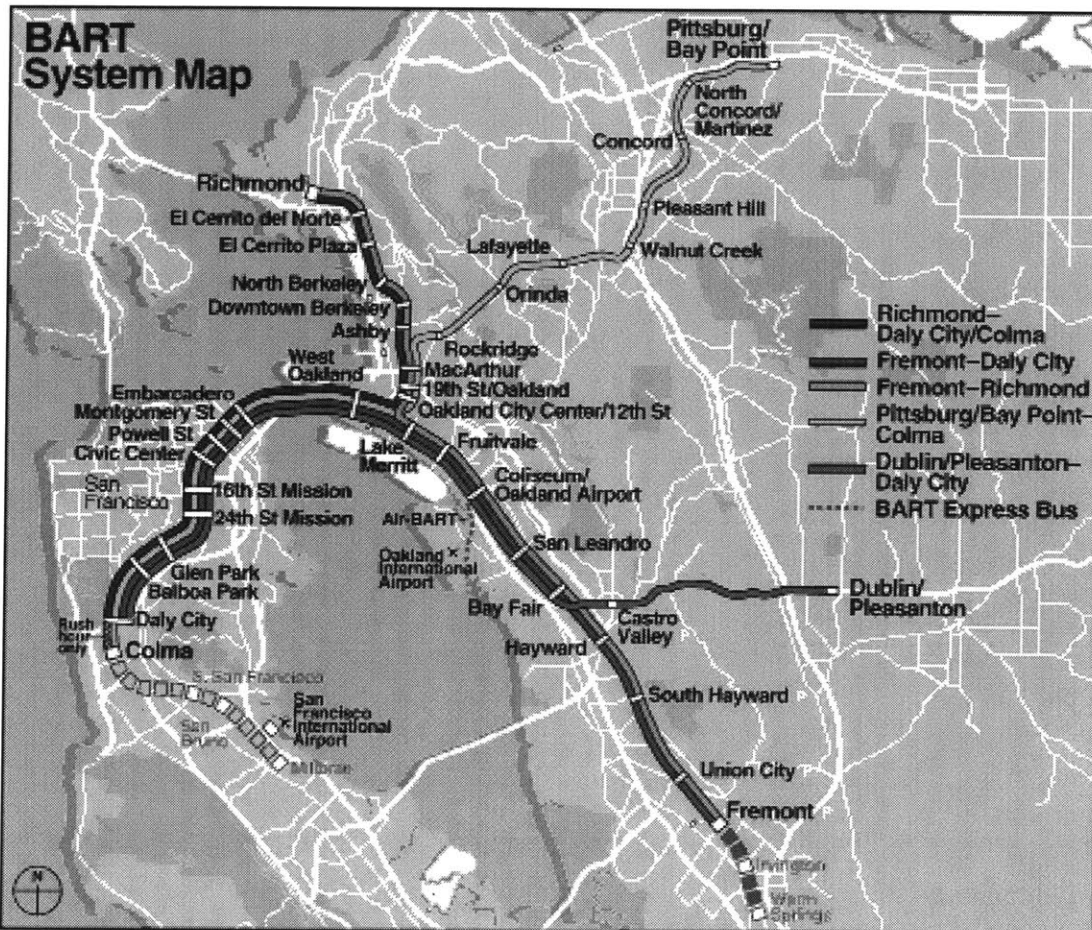


Figure A-3: Map of the BART system  
Source: BART website



### *The Transbay Corridor*

Although the Bay Area Rapid Transit (BART) heavy rail system serves some intra-urban trip patterns within San Francisco and Oakland, primarily it connects outlying suburban areas in the East Bay with downtown San Francisco. Figure A-3 illustrates that most trackage lies outside the San Francisco/Oakland urban core. Historically, BART represents the fourth generation of “transbay” public transit services across the San Francisco Bay. Before the San Francisco/Oakland Bay Bridge opened in the late 1930s, commuters rode the *Key System* interurban electric trains to West Oakland and transferred to ferries to reach San Francisco. Between 1939 and 1958, interurban trains ran along the lower deck of the bridge directly to the “Transbay Terminal” near downtown San Francisco. As a result of declining ridership and booming suburbs, the Key System converted entirely to buses in 1958 and was taken over by the publicly-owned AC Transit system in 1960. Since then, AC Transit has operated all transbay and local bus services in the East Bay (AC Transit, 1998).

When BART opened in 1974, some bus riders shifted to the “new” rail system. Transbay bus patronage fell from over 40,000 daily trips in 1971 to less than 10,000 in 1996. By comparison, by 1996 BART had grown to 121,000 daily transbay passengers, 90,000 of which came from the AC Transit service area. In 1996, BART and AC Transit captured a mode share of 40% and 5%, respectively, of afternoon-peak passenger trips in the corridor. Despite their relatively limited presence, however, the buses continue to provide a vital service for communities without BART. A week-long BART strike in 1997 also helped revive the transbay buses, then threatened by major service cuts. Since then, ridership increased 39% as former BART commuters have decided to stay with AC Transit (AC Transit, 1998).

In general, the rail and bus networks have evolved to serve different markets. Trains provide line-haul service between major suburbs and the Bay Area’s urban core; the bus offers one-seat rides to commuters who live far from train stations. Buoyed by its recent ridership turnaround, however, AC Transit has become more aggressive and begun to concentrate on BART corridors. Its November 1998 *Transbay Comprehensive Service Plan* states:

“In the short term, most of the District’s transbay lines will be oriented to areas not served by BART or ferry service, or where BART is operating with load factors above 1.0 during the peak commute periods, resulting in standees on BART trains. But as congestion in the Transbay corridor increases and BART lines extend out farther into Alameda and Contra Costa counties and begin to reach capacity in the outlying areas, the District may need to initiate peak-hour bus service even in areas well-served by BART.” (AC Transit, 1998)

BART’s *1999-2008 Short Range Transit Plan* sees the capacity issue differently. System improvements should allow the maximum peak headways to drop 20%, from 15 to 12 minutes, by 2002. The system’s busiest line (Pittsburg/Bay Point) mainly carries commuters from central Contra Costa County, which is outside the AC Transit service area. The three transbay lines that overlap primarily with AC Transit (Fremont, Richmond, and Dublin/Pleasanton) have room to grow. Within a decade, they are projected to require seven-car trains on average, far less than the ten-car capacity of station platforms (BART, 1999).

The focus on the radial market can also obscure the need to serve other travel patterns. Unlike the transbay buses (or its predecessors), BART not only serves the transbay corridor but also the East Bay intercity market. Stations in Berkeley, Oakland, Walnut Creek, Concord, Fremont, and other major activity centers outside San Francisco help to generate non-radial and reverse-commute ridership. BART trains also run frequently from early morning until past midnight everyday. AC Transit’s extensive local bus network and BART together provide general mobility throughout the East Bay.

Meanwhile, AC Transit’s transbay buses serve a much more limited set of customers, peak-hour commuters. Most transbay bus routes run locally for a few miles and then express once they reach the nearest highway. As individual routes are tailored to link a limited number of neighborhoods directly to San Francisco, few have the demand to operate during the off-peak. At the same time, they overlap with the local bus network. According to AC Transit’s *Transbay Comprehensive Service Plan*, “Transbay bus service should focus on transbay passengers, and not try to serve both transbay and local bus passengers.” It continues, “In some cases, transbay routes were redesigned over the years to combine them with a local route to increase overall ridership. Unfortunately, the effect in most cases was to slow down the transbay route to a point that it is no longer an attractive option to San Francisco bound passengers” (AC Transit, 1998).

Using buses to reach communities that rail does not serve conveniently can help attract customers to transit. However, saturating corridors with duplicative service can become problematic in an environment of limited funding. Although premium fares can offset higher costs, express service can be especially resource-intensive due to long cycle times and low passenger turnover. In AC Transit's case, improvements to attract choice transbay patrons – including BART customers - have occurred while transit-dependent riders have seen many off-peak services disappear. Local buses, which act both as a stand-alone system and a BART feeder, carry 94% of all AC Transit weekday bus trips (217,000 customers compared to 13,000 on the transbay system) (AC Transit, 1998). In 1996, budget troubles forced AC Transit to eliminate all owl service and, except for a few major arterial routes, cut most evening and weekend runs (Bowman, 1999). In October 1999, AC Transit finally restored about 40% of the service (Pimentel, 1999).

Unfortunately, in some ways BART's fare and parking pricing policies exacerbate the situation, reinforcing the perception that BART and AC Transit run two entirely separate systems. Built to connect low-density suburbs to the urban core, planners felt that BART's success depended more upon parking availability than bus accessibility. Today, BART offers about 42,000 free parking spaces at 28 suburban stations (BART, 1999). Customers who arrive on buses do not receive such generous benefits. Transfers between BART and AC Transit cost \$1.15, or 20 cents off the regular \$1.35 bus fare. Frequent riders fare only a little better. For approximately \$22 to \$26 extra per month, BART riders have unlimited access to several local transit systems. An intermodal trip from North Berkeley to San Francisco, for example, costs \$3.85 (\$2.70 for BART and \$1.15 for feeder bus). By comparison, AC Transit transbay buses cost \$2.50, or \$2.20 with a pre-purchased multi-ride ticket. From the passenger's perspective, this pricing policy makes the intermodal trip less attractive than either the transbay bus or driving to BART stations (Bay Area Transit Information website).

In essence, BART fares implicitly incorporate parking costs, regardless of whether or not a customer arrives by car. One might also argue that people who walk or ride transit to stations subsidize park-and-ride commuters. Spaces in parking garages cost \$6000 to \$9000 each; surface lots cost \$3000 to \$5000 plus maintenance costs. Free parking has attracted so many riders that many lots fill by 7 am in the morning. The

agency has also spent millions to construct parking structures, which also consume valuable land around stations that could instead foster transit-oriented development. Given the financial incentives to park and ride, it is not surprising that 42% of BART's customers drive to stations while only 22% take transit (Cabanatuan, 1998).

Modifying the fare and parking policy might improve coordination with AC Transit and encourage better resource utilization. For example, charging for parking but lowering rail fares accordingly may ease parking shortages and increase ridership on local buses that feed rail stations. This in turn would improve the local bus network overall, even for passengers not transferring to BART. At the same time, it would relieve pressure to operate parallel transbay express buses.

The San Francisco experience demonstrates that having multiple overlapping transit providers often impedes fare and service coordination, especially between different modes. Some customers may benefit from having more travel choices; however, others may lack basic service if too many resources are devoted to competitive routes. Separate agencies can also focus on satisfying their individual goals rather than looking for transportation solutions from a regional perspective, leading to conflicting organizational policies.

#### **A.4 Washington, DC**

Following BART in San Francisco, the Washington Metro was the forerunner of the modern generation of heavy rail systems in the United States. Opened in 1976, the 103-mile system serving the national capital and adjacent Maryland and Virginia suburbs is nearing completion. Over the past 25 years, the Metro has grown into the country's second largest heavy rail system, carrying about 600,000 passengers per weekday (APTA, 1998). The Metro has also influenced land development. The radial configuration has helped sustain the District of Columbia as the primary regional employment hub during a period of severe urban population decline. Meanwhile, it has also fostered relatively dense and transit-friendly suburban development surrounding stations, most notably in Silver Spring and Bethesda in Maryland and Rosslyn and Crystal City in Virginia.

From an intermodal systems perspective, Washington has also advanced from the pre-Metro era. After the disappearance of the last streetcars in the early 1960s, Washington's four uncoordinated, private bus firms limped along in an environment of rapid decentralization and declining ridership. The Washington Metropolitan Area Rapid Transit Authority (WMATA) was formed in 1967 to revitalize public transit in the capital region. The organization's primary mission, however, was to build a world class subway system, not to rescue buses from financial ruin. Recognizing the importance of both bus and rail modes, Congress forced WMATA to absorb the four private bus companies in 1973 (Feaver, 1999). Soon afterwards, WMATA overhauled the bus system. It streamlined routes, eliminated duplicative service, expanded into new territory, and instituted a zone-based fare structure. At the same time, some suburban jurisdictions also initiated independent contract bus operations, some of which overlapped with WMATA bus service (WMATA, 1993).

The Metro has brought significant changes to the bus network. When new rail segments have opened, WMATA has usually terminated bus routes at the nearest rail stations, particularly those that formerly ran express to Downtown Washington. It has generally retained some parallel local service to serve intermediate areas between rail stations, however. This policy reflects WMATA's desire to capitalize on the economic strengths of each mode. From a financial standpoint, the Metro's farebox recovery is

more than double that of buses, in part because the rail system has a higher ridership density, charges higher fares for premium service, and earns revenue from park-and-ride fees. Meanwhile, buses fill in the gaps between rail lines and penetrate neighborhoods where demand or geography does not justify rail infrastructure.

Table A-1: Service Integration at the Washington’s Pentagon and Anacostia Metro Stations

	Pentagon (Shirley Busway routes only)	Anacostia (excludes crosstown routes)
AM Peak Inbound Bus Trips	225	137
Weekday Inbound Bus Trips	350	430
Weekday Ridership (Sept. 98)	15,171	21,391
AM Peak Vehicles	79	39
Base Vehicles	8	16

Source: WMATA Metrobus Scheduled Time & Miles By Line Report, Jan. 6, 1999.  
WMATA Vehicles Scheduled Report, Jan. 24, 1999.

Two specific examples in the Washington region illustrate the effects on customer service and operating efficiency of WMATA’s service integration policy. At the Pentagon station in Virginia, WMATA demonstrates that a rail system can successfully interface with a bus transitway to offer customers the advantages of both modes. The station is located strategically between the Pentagon and the entrance ramps to the Shirley Busway, two reversible high-occupancy vehicle/bus lanes in the median of the Interstate 395. During the morning peak period, approximately 225 commuter bus trips originate from Virginia suburbs southwest of Washington, enter the busway and then travel non-stop in a separate right-of-way until they reach the Pentagon (see Table A-1) (WMATA Vehicles Scheduled Report, Jan. 24, 1999). From their passengers can connect to the Metro to reach employment centers in Virginia and the District of Columbia. In the afternoon, buses run in the reverse direction.

For about seven years prior to the opening of the Pentagon station in 1977, the Shirley Busway services had run directly into downtown Washington (WMATA, 1993). Truncating bus routes at the Pentagon and requiring a transfer to the Metro was undoubtedly a difficult transition for passengers initially. On the positive side, this policy expanded destination opportunities for customers, improved WMATA’s operating efficiency, and allowed the agency to redistribute resources to provide more local bus service. Busways by themselves tend to encourage point-to-point routes that avoid

transfers; however, they usually result in a “many-to-one” network that provides direct, but low connectivity and low frequency services often confined to the peak period. In the decentralized national capital region, a “many-to-one” route structure misses many potential ridership markets. Although Washington boasts a high concentration of government jobs, height restrictions have led to a sprawling “downtown” and the proliferation of satellite employment centers in adjacent Maryland and Virginia. By connecting to the Metro, the Shirley Busway services allow passengers in suburban neighborhoods to reach the Metro quickly. From there, the Metro acts as a circulator (in addition to providing radial service to the suburbs), facilitating access to key peripheral destinations such as the Pentagon, Rosslyn, National Airport, Crystal City as well as to downtown government offices.

If the Shirley Busway services were to continue directly into Washington, some 225 buses during each peak period would spend an additional half-hour circulating around downtown Washington.<sup>5</sup> The agency would need to divert resources from local services or enlarge its bus fleet in order to maintain existing headways, and most of these new vehicles would remain idle throughout the day. Even in its present configuration, the Shirley Busway services are overwhelmingly commuter-oriented: 79 vehicles operate during the morning rush hour, but only 8 vehicles provide base service (WMATA Vehicles Scheduled Report, Jan. 24, 1999). Despite the enormous financial undertaking that would be needed to ensure a one-seat bus ride for some passengers, many customers would still have to transfer to reach peripheral destinations.

Instead of duplicating rail services, WMATA has now begun to use buses to develop new markets. For example, it recently initiated a circumferential express bus route between Montgomery County, Maryland, and Tysons Corner, a major suburban employment and retail center in northern Virginia. As the Metro has expanded outward, suburban buses now spend more time in local communities than on highways into and out of Washington. Not only are local buses delivering suburbanites to rail stations, but they also are linking train stations to adjacent suburban employment centers to facilitate

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<sup>5</sup> Estimated time based on the travel time of an existing bus route that links the Pentagon with downtown Washington (WMATA website)

reverse-commuting. In fact, the reverse-commute is now WMATA's fastest growing market segment (Erion, 1998).

Transit service in southeast Washington also provides another example of WMATA's service integration policy. Following its standard operating practice, the agency truncated many routes at the Anacostia terminus when the Metro was extended to the area in 1991, except during early mornings when trains do not operate. As with the Pentagon/Shirley Busway services in Virginia, the reorganization of buses in southeast Washington was quite successful from a service and operational perspective. Some 137 morning rush-hour trips and 430 daily trips terminate at the Anacostia station instead of continuing to central Washington (WMATA Vehicles Scheduled Report, Jan. 24, 1999). Since buses do not have to navigate downtown traffic, they save at least 40 minutes in cycle time per round trip and have a better chance of adhering to schedules.

For southeast Washington residents, the Metro system improved access not only to employment opportunities downtown, but also in other parts of the city and the suburbs. The community has not wholeheartedly embraced the Metro, however. For both logistical and political reasons, the transition to an intermodal system has not gone as smoothly as elsewhere. Situated only a few miles from grand monuments and institutions, southeast Washington is largely poor and African-American. Some community leaders believe that outsiders "forget" that this section of the national capital exists, especially concerning transportation issues. For example, the Metro system arrived in southeast Washington years after it had been extended to distant, wealthy suburbs, even though the area has a large transit-dependent ridership base (Ripley, 1998).

Some residents felt that WMATA had reorganized bus routes to disguise service cuts and force passengers onto the train. Many bus riders also seemed concerned with the time and financial impacts of transferring at the Anacostia station. In particular, the lack of schedule coordination has tended to worsen the transfer waiting time problem, not just at Anacostia but throughout the system. Specifically, transferring from rail to bus can become inconvenient during off-peak hours when vehicles arrive less frequently. On Saturdays, for example, trains run relatively frequently (every 12 minutes) but do not consistently meet with buses that operate 20, 30, or 40-minute headways. In this situation, tight connections arise periodically. Passengers can increase their waiting



times deliberately by taking an earlier train to ensure a connection, or “risk it” and hope that the train is not delayed. WMATA is looking to improve transfer reliability with experimental signal lights that warn bus drivers of delayed trains, but so far has not addressed the schedule coordination issue (Erion, 1998).

Customers from southeast Washington also complained about the lack of fare integration. Riders can purchase rail-to-bus transfers for a nominal 25-cent fee; however, there are no discounts for bus-to-rail transfers. Thus, round trips using both bus and rail services cost an additional \$1.35 (the \$1.10 base bus fare to the Metro plus \$0.25 in the opposite direction). For low-income southeast Washington residents, this charge seemed particularly burdensome compared to the pre-Metro days without transfers. WMATA management, however, did attempt to soften the impact by reducing fares on selected Anacostia routes to \$0.60, which in effect reduced the round trip bus fare to \$0.85 with a rail-to-bus transfer (Erion, 1998).

Indeed, poor or non-existent fare coordination historically has hampered intermodal integration throughout the region, despite the fact that a single agency controls core bus and rail services. The proliferation of independent suburban transit agencies has also contributed to fare (and service) fragmentation. The rail system has a complex, but “equitable” pricing structure based on distance traveled and time of day. Fares range from \$1.10 for short trips at all times to \$3.25 for long rush-hour trips. Park-and-ride lots also cost \$1.75 to \$2.25 for parking on weekdays, but are free on weekends (WMATA website).

Prior to July 1999, Metrobus also charged by distance, time of day, and sometimes direction. The metropolitan area consisted of eight fare zones: one for the District of Columbia, two for Maryland, and five for Virginia. Public timetables listed a total of 24 zonal fare categories, each of which had a peak fare, an off-peak fare, a rail-to-bus peak transfer fare, and a rail-to-bus off-peak transfer fare. Express routes also had varying surcharges. Bus-to-bus transfers cost 10 cents for each use; there were no discounts for bus-to-rail transfers. In total, there were at least a hundred different fares. In some cases, the pricing policy made little sense. For example, passengers boarding a Maryland-bound bus within Washington city limits paid \$0.90 with a rail-to-bus transfer, but paid the full \$1.10 fare if they boarded the same bus with a transfer in Maryland.

In July 1999, WMATA launched “A Simple Fare to Anywhere,” a complete overhaul of its fare structure. Rail fares continued to vary by distance and time-of-day, but the system shortened the peak surcharge period by an hour. On local buses, the agency set the base fare at \$1.10 regardless of jurisdiction, direction, or time of day. It also dropped the bus-to-bus transfer fee and charged \$0.25 for all rail-to-bus transfers, although it continued not to issue bus-to-rail transfers. Express fares became \$2.00 (WMATA website). Base fares and transfer fees remained constant on many routes; on others, the overhaul also resulted in a real fare decrease. “A Simple Fare to Anywhere” boosted ridership immediately. By August 1999, two months after the new fare policy began, average Metrobus weekday boardings grew 12.6% over the previous year (473,000 v 420,000 trips). Saturday and Sunday ridership increased by 12.5% and 16%, respectively (WMATA Press Release, Oct. 20, 1999).

Overall, Washington’s intermodal experience has been generally positive. Although WMATA has had to reduce service levels in the past due to budget constraints, the transit system has improved dramatically since the pre-Metro era. Management seems to understand the need to design an efficient route structure that serves multiple travel patterns while avoiding service duplication. Nevertheless, more attention to schedule coordination and other details could result in more effective integrated services. With its recent fare overhaul, WMATA seems to be headed in a positive direction.



# System Map

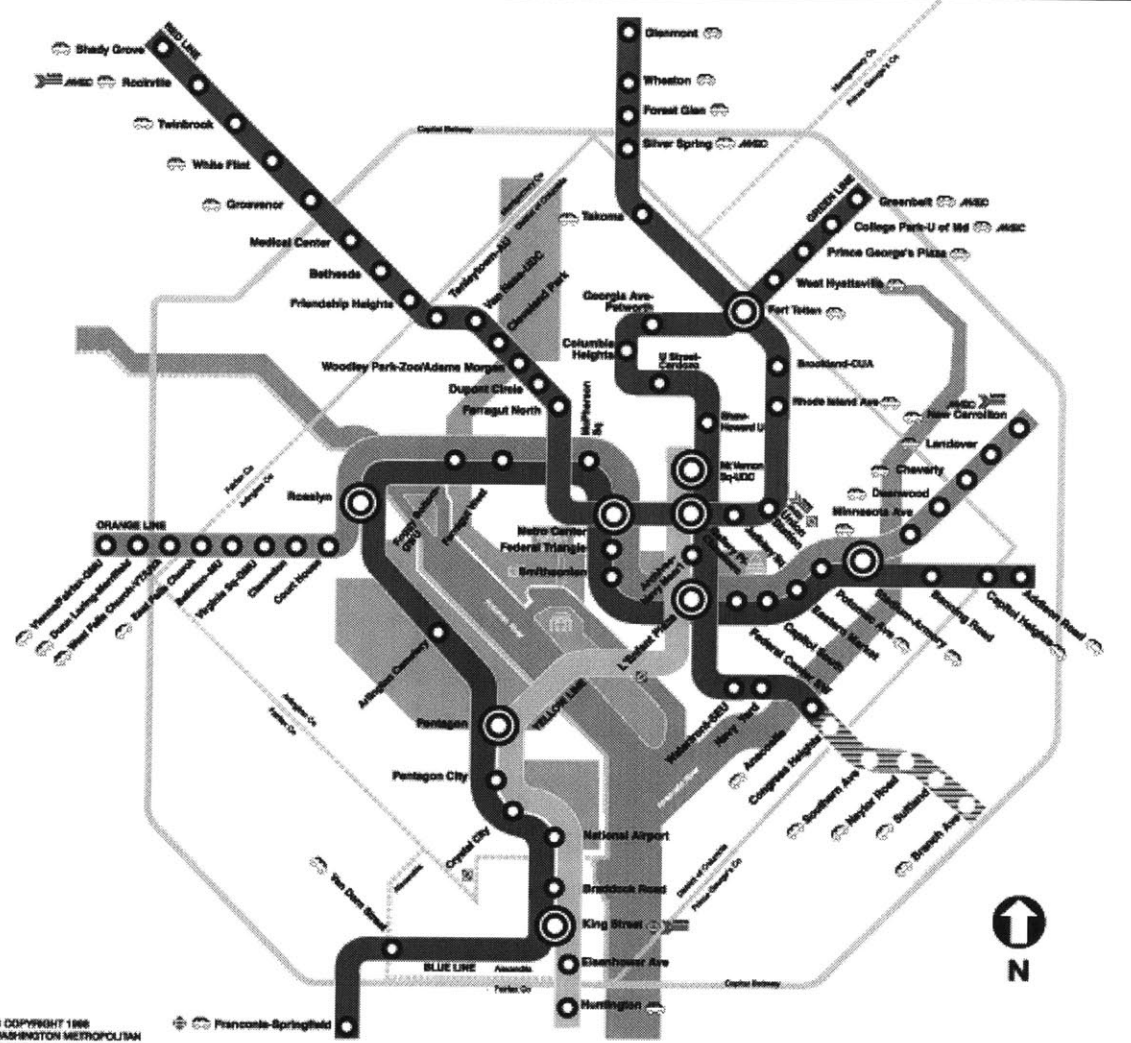
## Legend

- Red Line • Glenmont/Shady Grove
- Orange Line • New Carrollton/Vienna/Fairfax-GMU
- Blue Line • Addison Road/Franconia-Springfield
- Green Line • Branch Avenue/Greenbelt
- Yellow Line • Huntington/ML Vernon Sq-UDC

## Commuter Rail

- AMSC
- YVRG
- YRGP
- YRSP
- Station In Service

- Transfer Station
- Parking
- Future Station



- No Smoking
- No Food or Drinks
- No Animals (except guide dogs)
- No Audio or Video Devices (without earphones)
- No Litter or Spitting
- No Dangerous or Flammable Materials

Figure A-4: Map of Washington's Metro System  
 Source: WMATA website

## A.5 Portland

Within the planning community, Portland is perhaps best known for its policies on metropolitan development. In the 1970s, Portland established an urban growth boundary designed to curb sprawl and focus resources on existing neighborhoods and downtown. Recognizing the importance of coordinating land use and transportation, Portland has also become one of the country's most progressive transit-oriented cities. City leaders replaced a riverfront highway with a park and cancelled a freeway that would have plowed through southeast Portland. Tri-Met, the regional transit operator, then used highway funds to build the "MAX" light rail line out to the eastern suburbs in the 1980s. Due to these efforts, Portland's urban core and transit system are healthier than most cities of similar size.

In September 1998, Tri-Met opened "Westside MAX", an 18-mile light rail extension that parallels the heavily-congested Sunset Highway out to the western suburbs in Washington County. Combined with the initial eastern line, light rail now runs across the entire metropolitan area. While Tri-Met has worked hard to promote MAX, the agency has also paid close attention to redesigning bus services to complement the new rail line and to serve new markets. In formulating an integration plan for Westside MAX, Tri-Met planners were particularly concerned with how urban and suburban growth would affect transit. By the year 2010, population and employment in downtown Portland and Washington County are projected to increase 25% to 40% over 1995 levels (Tri-Met, 1998).

Cognizant of these trends, Tri-Met had established a progressive route structure for the Westside area many years prior to light rail. The network consisted of radial local and express lines linking the area with Portland and a few supplemental feeder routes. Transit centers provided key interface points for timed transfers between buses. However, limited financial resources and equipment forced Tri-Met to concentrate service on a few radial routes with high ridership (more than 70% of the service hours). Tri-Met also developed an extensive peak-hour express network with direct service in the peak direction to downtown Portland to build ridership for the future light rail extension. Meanwhile, local routes provided some limited mobility for suburb-to-suburb trips. Nevertheless, there were clear service gaps and unmet travel needs. Large areas of the

service district had no bus service at all. In most neighborhoods with direct peak-hour express routes to Portland, buses did not operate during the off-peak. These express lines also ran into traffic along the Sunset Highway, which lowered reliability and on-time performance. There was hardly any service to the burgeoning “Silicon Forest” suburban employment corridor (Tri-Met, 1998).

The MAX light rail extension provided an opportunity for change. With explosive Westside residential and job growth, Tri-Met wanted its bus system to be more responsive and relevant to the travel needs of people living and working within its service area. The agency’s “Westside Bus-Rail Integration Plan” notes that:

“Westside residents expressed interest in local bus service that would connect to MAX, but would also allow for intra-Westside and non-downtown Portland trips. Interest has also been high among Westside employers regarding how they could be connected to Westside MAX” (Tri-Met, 1998).

In the end, Tri-Met ended most bus services that paralleled the light rail line, but retained four radial routes that served intermediate areas and neighborhoods distant from the train.

With the resources saved from eliminating duplicative service, the agency expanded service coverage and boosted frequency throughout the Washington County. Approximately 20,000 more residents and 12,000 employees now were within walking distance of a transit route. Some 70,000 residents and 79,000 employees gained more frequent service. For commuters, Tri-Met initiated six rush-hour shuttle routes between MAX stations and job centers. Four of these routes circulate around suburban office parks, while the other two serve large Portland employers. The agency also shortened headways on three key suburban trunk lines, introduced daily service to areas that previously had only limited peak-hour or weekday-only express buses, and initiated a demand response taxi shuttle linking a low-density area with light rail (Tri-Met, 1998).

Along with the service coverage and frequency improvements, Tri-Met also redesigned the bus network to support multiple travel patterns both during the peak and off-peak. The new configuration emphasizes route connectivity rather than direct, but infrequent express routes. To facilitate both bus-to-bus and bus-to-rail transfers, it established three new transit centers at key rail stations with timed connections during off-peak hours. An integrated, three-zone fare structure with free transfers also helped make the system equitable for passengers who had to transfer to complete their trips.

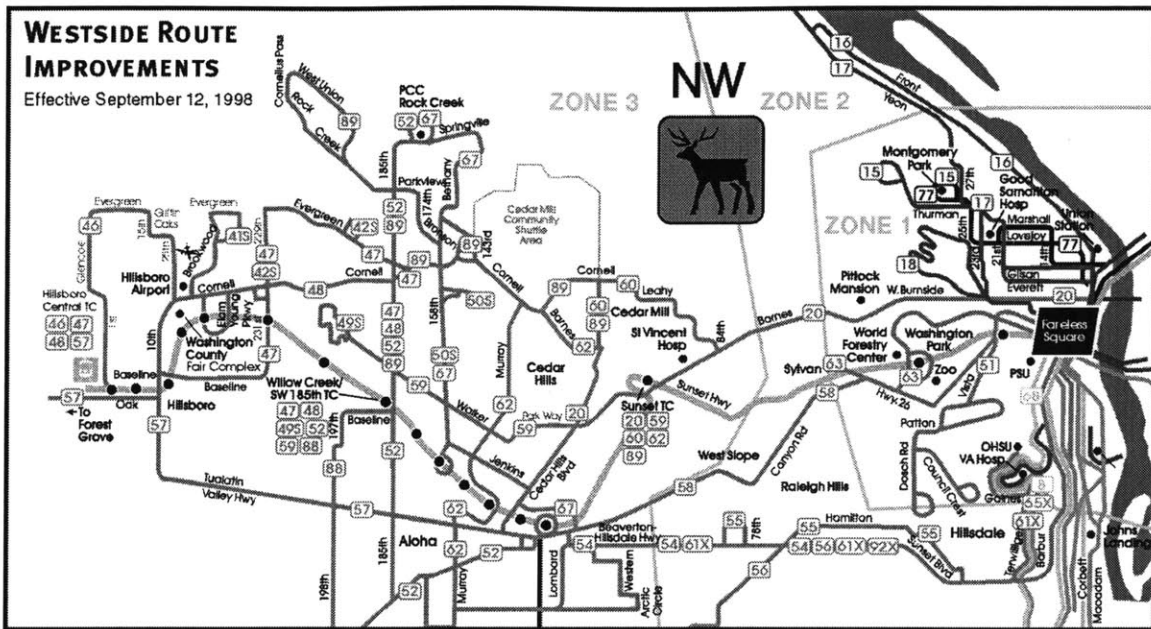


Figure A-5: Map of integrated Westside light rail and bus services  
 Source: Tri-Met website

Table A-2: Restructuring Effects on the Westside Bus System

	Before	After	Change
Weekday Rev. Hrs.	837.3	873.6	5.1%
Saturday Rev. Hrs.	400.1	506.5	26.6%
Sunday Rev. Hrs.	225.8	339.6	50.4%
Weekly Rev. Hrs.	4812.4	5213.9	9.0%
Peak Vehicles (estimated)	113	102	-8.9%
Base Vehicles (estimated)	56	62	10.7%
Ridership	30,915	31,255	1.5%
Riders/Rev. Hour	36.9	35.8	-3.2%
Wkdy Deadhead Hrs.	125.9	83.4	-32.1%
Portland CBD Trips	613	309	-49.6%
Portland Transit Mall Trips	460	156	-66.1%
Pop. Within ¼ mile of route	125,461	146,596	14.4%
Employment within ¼ mile of route	123,586	135,756	9.0%
Radial percentage of Rev. Hrs	70.50%	26.20%	
Local percentage of Rev. Hrs	28.8%	66.9%	
Shuttle percentage of Rev. Hrs	0.7%	6.9%	

Sources: Tri-Met FY 98 Route Performance, Tri-Met Route Performance Report (Sept. 12, 1998-Nov 29, 1998), Tri-Met Operations Planning and Analysis: Recapitulation and Analysis of Schedules (June 4, 1998 and Dec. 7, 1998)

Ignoring light rail for the moment, the restructuring effort resulted in some significant performance and operational changes for Tri-Met's buses. Table A-2 shows that despite the major frequency and coverage increases, weekday revenue hours did not increase significantly because buses were reallocated from radial to local routes. Weekend revenue hours grew substantially, in contrast, reflecting Tri-Met's emphasis on

expanding weekend service coverage. In terms of fleet requirements, discontinuing express lines also freed a disproportionately large number of buses for redistribution during the peak and decreased the substantial deadheading associated with these lines. The peak vehicle requirement actually decreased, while the base vehicle requirement increased. This relieved pressure on the bus system during the busiest periods, utilizes the fleet better throughout the day, and potentially reduces driver spread penalties.

Other operational effects included a precipitous drop in bus traffic in downtown Portland, by over 300 trips per weekday (see Table A-2). This helped improve traffic flow for other Tri-Met buses using the Portland Transit Mall, a pair of dedicated bus lanes on two downtown streets. Train traffic increased only slightly, since the Westside MAX was an extension of an existing light rail line that already ran through downtown. Bus system productivity slightly decreased in terms of rides per revenue hour. Replacing busy peak-hour express buses with large amounts of less-patronized off-peak local service probably contributed to the modest productivity decline.

Tri-Met's integration strategy also produced significant ridership gains. For the past six years, Tri-Met and the Oregon Department of Transportation have monitored flow along the Sunset Highway corridor between Portland and Washington County. During this time, a 9% growth in population and a 26% jump in employment have led to sharp increases in travel demand in Washington County. Their joint "Westside Corridor Travel Study," released in October 1999, reveals that the combination of light rail and enhanced bus services has boosted transit usage in the corridor. From May 1993 to May 1999, transit's mode share of afternoon peak-direction trips rose from 13% to 20% along the corridor, even though the Sunset Highway was widened during the same period. Tri-Met has also succeeded in penetrating new markets. Between October 1997 and May 1999, afternoon reverse-commute transit usage more than tripled from 4% to 14%. The study explains,

"The growth in Washington County employment has resulted in substantially more reverse commute travel ... than occurred in 1993. The combination of Westside MAX and restructured westside bus service allows Tri-Met to serve the reverse commute more efficiently than the bus service available before September 1998 [when light rail opened]" (Tri-Met and ODOT, 1999).

In the relatively short time since the light rail extension, Portland's system integration effort appears to be producing favorable results. Of course, some bus riders who lost one-seat rides were undoubtedly inconvenienced by Tri-Met's service changes. However, the present system continues to handle the traditional radial commute well but is also much more responsive to off-peak, suburb-to-suburb, and reverse-commuting travel needs. In the Sunset Highway corridor, the increasing transit mode share indicates that Westside MAX has not merely shifts transit customers from buses to trains; rather, it has allowed Tri-Met to attract choice riders with a more efficient intermodal network.



## **Appendix B: Quantitative Analysis of Bus Routes that Parallel Rail**

In many cities developing rail system, the typical questions that arise are whether to convert a radial bus line into a feeder to a nearby rail station and whether to discontinue or reduce parallel service. Before examining specific situations in detail, we will first examine the impacts of such decisions on both the operator and the riding public.

Any service modification may have major cost implications for the operator. In the transit industry, a common principle guiding bus-rail network restructuring is to reallocate resources from parallel radial bus lines (express or local) to expand local service. This local service feeds rail stations, enhances overall mobility outside the CBD especially during the off-peak, and provides shuttle service to outlying employment areas. Of course, the size of a transit system's operating budget will determine the extent of bus restructuring. Given that radial routes generally attract disproportionately more riders than these other route types, this restructuring strategy will likely lower productivity (measured in rides per vehicle hour, for example) for the bus system. (Overall system productivity, however, may not decrease if the rail line can carry passengers much more efficiently.)

Nevertheless, restructuring may still improve the bus system's operating efficiency. For example, radial express routes with long cycle times and limited service hours require a disproportionately high number of vehicles and deadhead hours per trip operated. Depending on the transit agency work rules and the availability of part-time workers, these peak-hour runs may also incur expensive driver spread penalties. Thus, a transit agency can lower maximum equipment requirements and reduce expenses for the bus fleet by converting an equivalent number of peak service hours to off-peak service hours. The train's larger capacity can partially offset the labor expense of providing replacement service for former CBD-bound bus riders.

To arrive at an estimate of the financial costs, we will first calculate the change in vehicle requirements necessitated by a bus route truncation. Dividing a route's cycle time by its headway  $h$  gives the number of vehicles required to operate the route. Cycle time consists of: (1) the mean round trip running time, (2) the maximum of the layover time and the recovery time needed to start the next run on schedule due to run-time

variations. The following formula gives the number of vehicles required to operate a route:

$$\text{Vehicles required on route } i = (\text{cycle time})(\text{frequency}) = (\mu + \max\{z_\alpha\sigma, l\})f \quad (1)$$

$\mu$  = mean round-trip running time

$\sigma$  = round-trip running time standard deviation

$z_\alpha = \alpha$  run-time standard deviations desired for recovery time

$l$  = layover time

$h$  = headway

$f$  = frequency

Suppose a new rail line opens. Common route modifications include discontinuing or reducing service on parallel bus routes, or converting radial services into rail feeders. The following equation estimates the impacts on bus requirements due to these modifications:

$\Delta$  buses required for route  $i$  = buses required before change - buses required after change

$$\Delta \text{ buses required for route } i = (\mu_0 + \max\{z_{\alpha_0}\sigma_0, l_0\})f_0 - (\mu + \max\{z_\alpha\sigma, l\})f \quad (2)$$

Note that the frequency of bus service may change (from  $f_0$  to  $f$ ). A reduction in service may occur should ridership densities drop due to line truncation or the introduction of an additional transfer, for example. On the other hand, ridership densities could increase if the shorter line allows reliability to improve or service to increase (shorter headways or a longer span of service). A more detailed discussion of elasticity of ridership with respect to route structure or service level changes will follow.

A transit agency may choose to alter headways based upon a systemwide maximum passenger load standard. To provide reasonable service quality, however, transit agencies should also consider passenger utility in addition to their own costs when setting frequencies, particularly for low frequency routes commonly found along the suburban alignments of new rail extensions. Setting uniform load factors across all routes regardless of ridership would tend to provide extremely poor service quality for sparsely-patronized routes. Presumably, the low frequency route is providing more of a “lifeline” base level of service. Further, the consequences of denying passengers

boarding a full bus that comes once an hour are much more severe than on high-frequency routes due to the higher waiting time penalty.

Perhaps the best-known theory for setting frequencies on a bus route that incorporates passenger utility is the square-root rule. This method attempts to minimize the sum of total passenger wait-time costs and total operator costs. It states that service frequency for a given route should be proportional to the square root of the ridership per unit distance or time on that route. Unfortunately, it does not consider capacity constraints as a lower bound for frequency or the elasticity of demand with respect to headways.

An alternative strategy considers the benefits versus costs of each route. All transit routes display diminishing marginal benefit in relation to costs beyond a certain frequency level. Shortened headways may not necessarily attract the ridership (and therefore revenue) necessary to offset the costs associated with service improvements. Wait time benefits as well as ridership suffer from diminishing marginal returns. At the optimum “solution”, the marginal benefit-to-cost ratios are similar across all routes although individual subsidies may differ. Total benefit cannot increase by reallocating resources at this point (Furth and Wilson, 1981).

In addition to modifying the bus network, train service will also have to increase above base levels to accommodate passengers who now transfer from the bus or switch entirely to rail. Assuming that the train has sufficient capacity so that additional passengers will have negligible effects on dwell times, the number of trains needed above base levels equals the train’s cycle time divided by the change in headways needed to accommodate the extra passengers.

$$\begin{aligned} & \text{trains to accommodate bus passengers for route } i \text{ (over base levels)} \\ &= (\text{cycle time}_{\text{train}})(\Delta f_{\text{train}}) \\ &= (\mu_{\text{train}} + \max\{z, \alpha\sigma, l\})(\Delta f_{\text{train}}) \end{aligned}$$

If the transit agency wants to provide just enough capacity to handle the extra bus passengers, then frequency at a minimum changes enough to accommodate demand.

$$\Delta f_{train} = \frac{\text{passengers per hour}_{bus \rightarrow rail}}{\text{train capacity}}$$

$$= \frac{(\% \text{passengers}_{bus \rightarrow rail})(\text{load}_{bus})(f_{bus})}{\text{capacity}_{train}}$$

As in the bus case, a transit agency should also incorporate “passenger utility” when establishing rail levels of service. An appropriate desired load factor can again reflect this preference:

$$\Delta f_{train} = \frac{(\% \text{passengers}_{bus \rightarrow rail})(\text{load factor}_{bus})(\text{capacity}_{bus})(f_{bus})}{(\text{load factor}_{train})(\text{capacity}_{train})}$$

Thus, the number of additional trains needed to accommodate bus passengers from route i (over base levels) is given by:

$$(\text{cycle time}_{train})(\Delta f_{train})$$

$$= (\mu_{train} + \max\{z_{\alpha,train}\sigma_{train}, l_{train}\}) \left( \frac{(\% \text{passengers}_{bus \rightarrow rail})(\text{load factor}_{bus})(\text{capacity}_{bus})(f_{bus})}{(\text{load factor}_{train})(\text{capacity}_{train})} \right)$$

Comparing the net financial effects of an integration strategy can give some idea of the impact of introducing a rail line into an existing bus network. Ideally, a transit agency will want a high marginal savings-to-expenditure ratio, defined by:

Marginal savings-to-expenditure ratio

$$= \frac{(\text{Cost}_{bus} / \text{hr})(\Delta bus)}{(\text{Cost}_{train} / \text{hr})(\Delta train)}$$

$$= \frac{(\text{Cost}_{bus} / \text{hr})[(\mu_0 + \max\{z_{\alpha 0}\sigma_0, l_0\})f_0 - (\mu + \max\{z_{\alpha}\sigma, l\})f]}{(\text{Cost}_{train} / \text{hr})(\mu_{train} + \max\{z_{\alpha,train}\sigma_{train}, l_{train}\}) \left( \frac{(\% \text{passengers}_{bus \rightarrow rail})(\text{load factor}_{bus})(\text{capacity}_{bus})(f_{bus})}{(\text{load factor}_{train})(\text{capacity}_{train})} \right)}$$

$$= \left( \frac{\text{Cost}_{bus} / \text{hr}}{\text{Cost}_{train} / \text{hr}} \right) \left( \frac{(\mu_0 + \max\{z_{\alpha 0}\sigma_0, l_0\})f_0 - (\mu + \max\{z_{\alpha}\sigma, l\})f}{(\mu_{train} + \max\{z_{\alpha,train}\sigma_{train}, l_{train}\})} \right) \left( \frac{(\text{load factor}_{train})(\text{capacity}_{train})}{(\% \text{passengers}_{bus \rightarrow rail})(\text{load factor}_{bus})(\text{capacity}_{bus})(f_{bus})} \right)$$

*Important Observations*

From a cost perspective, this equation suggests that it may make sense to truncate or reduce service on a route that parallels the rail line in whole or in part when one or more of the following occurs:

- Load factor and capacity for the train is much higher than on the bus
- The difference in cycle times for the pre- and post- rail bus route is large, especially relative to the cycle time for the train. Longer-distance buses also tend to have poorer reliability, especially compared to the train. Clearly, bus routes that duplicate rail services for a long distance are better candidates for truncation than those that do not. This assumes a demand profile for the train where most people are travelling to the central business district; an agency could short-turn trains to better match the profile.
- A small number of people would have to transfer from bus to rail.
- The cost to run a train is relatively low, and the cost to run a bus is relatively high.

This equation also illustrates the tradeoff between bus frequency and cycle time. Budget constraints mean that more direct service, which requires longer cycle times, limits the level-of-service that an agency can provide on each route.

The model presented above has its limitations. For example, it does not model the larger network impacts of route design policy or the distinction between commuter-oriented and regular buses. It also does not handle some of the political subtleties that surround these decisions; for instance, the low marginal costs of operating rail service relative to its high infrastructure costs may encourage agencies to maximize rail usage and level-of-service. In contrast, the presence of separate bus and rail operators can result in duplicative bus service even when it is slower, less efficient, or less reliable.

## Appendix C: Analysis of AMA & Metrobús Service Modification Proposals

This section analyzes specific proposals for modified AMA bus routes in conjunction with the opening of Tren Urbano in San Juan, Puerto Rico. It utilizes two major data components: existing ride check data and forecast Tren Urbano usage predicted by demand models. To understand current travel patterns better, ride check data were collected on a sample of trips on key bus routes (Multisystems, 1999 [4]). This information helps predict how bus route restructuring for Tren Urbano might affect existing riders. Specifically, it provides passenger origin and destination data at the stop level. This would be useful, for example, in quantifying passenger inconvenience caused by splitting a bus route and requiring a transfer. The ride checks also help determine basic route load profiles, which may highlight existing or potential vehicle overloading or underutilization problems. For San Juan, such information would help determine how reducing rail-competitive bus service might impact loads on remaining bus routes.

Rail ridership forecasts come from the Tren Urbano Environmental Impact Statement, which applies the commonly-used four-step demand model. This model predicts the number of home-based work (HBW), home-based non-work (HBNW), and non-home based (NHB) trips that are expected to use Tren Urbano in the year 2010. When generating the numbers, the model recognizes that an entire “Tren Urbano trip” may require other modes such as automobiles, buses, or walking to reach the stations. The model then generates origin-destination matrix data by estimating the number of Tren Urbano trips between each pair of TAZs in the San Juan metropolitan area.

Predicting the origins and destinations of Tren Urbano trips can help in the design of a route structure that meets the anticipated bus access demand. To determine the bus access needs of individual areas within the San Juan metropolitan area, the model data were used to map the density of Tren Urbano trip origins and destinations by zone. Since this method assigns each *end* of all trips to a zone, the map actually represents twice the number of expected one-way Tren Urbano boardings.

Of course, these data have some significant limitations. The ride check sampling techniques capture only a tiny subset of trips, and thus inherently are subject to error. The Tren Urbano Demand Model makes many assumptions regarding, for example,

economic growth, highway congestion, and the quality of bus and público feeders. Therefore, one should exercise caution when analyzing proposals due to potential data integrity problems and uncertainty.

### **C.1 Proposal: Modify A9's northern terminal**

Route A9 serves Viejo San Juan, the Isleta, Santurce, Barrio Obrero, Avenida Barbosa, UPR, and Río Piedras. The route currently ranks as San Juan's second most heavily patronized bus route (after Metrobús). Dense transit-dependent neighborhoods and major San Juan destinations help to generate substantial traffic and support 10-minute weekday headways. Indeed, the level of passenger crowding has become a major concern, with rush-hour vehicles approaching capacity on average between Santurce and Río Piedras. Like other high-frequency lines without tight operations control, buses on Route A9 have a greater tendency to "bunch". This suggests that vehicles may arrive at irregular intervals. On average buses may be comfortably full, but some may have severe overcrowding while others have few passengers on board.

When Tren Urbano opens first to Sagrado Corazón and then to Minillas, it will likely carry many passengers who will need to transfer to buses destined for Miramar, the Isleta, and Viejo San Juan. Since the route's heaviest loads typically occur from Minillas to just south of Sagrado Corazón, with the peak load point around Sagrado Corazón, Tren Urbano's transferring passengers may overwhelm the route.

To reduce the likelihood of overcrowding, one possibility includes terminating the northern end of Route A9 at the Isla Grande Naval Base (the future site of a large convention center) or even sooner at Parada 18. Under this proposal, passengers travelling from south of Santurce to the Isleta and Viejo San Juan could no longer take route A9 directly. Forcing these customers to switch to other bus routes would reduce passenger volumes on route A9 at the peak load point. Additionally, average loads drop as buses leave Santurce and enter the Isleta and Viejo San Juan. Discontinuing a major route to Viejo San Juan could potentially lead to better resource utilization and reduce vehicle requirements, but also introduce a bus-to-bus transfer.

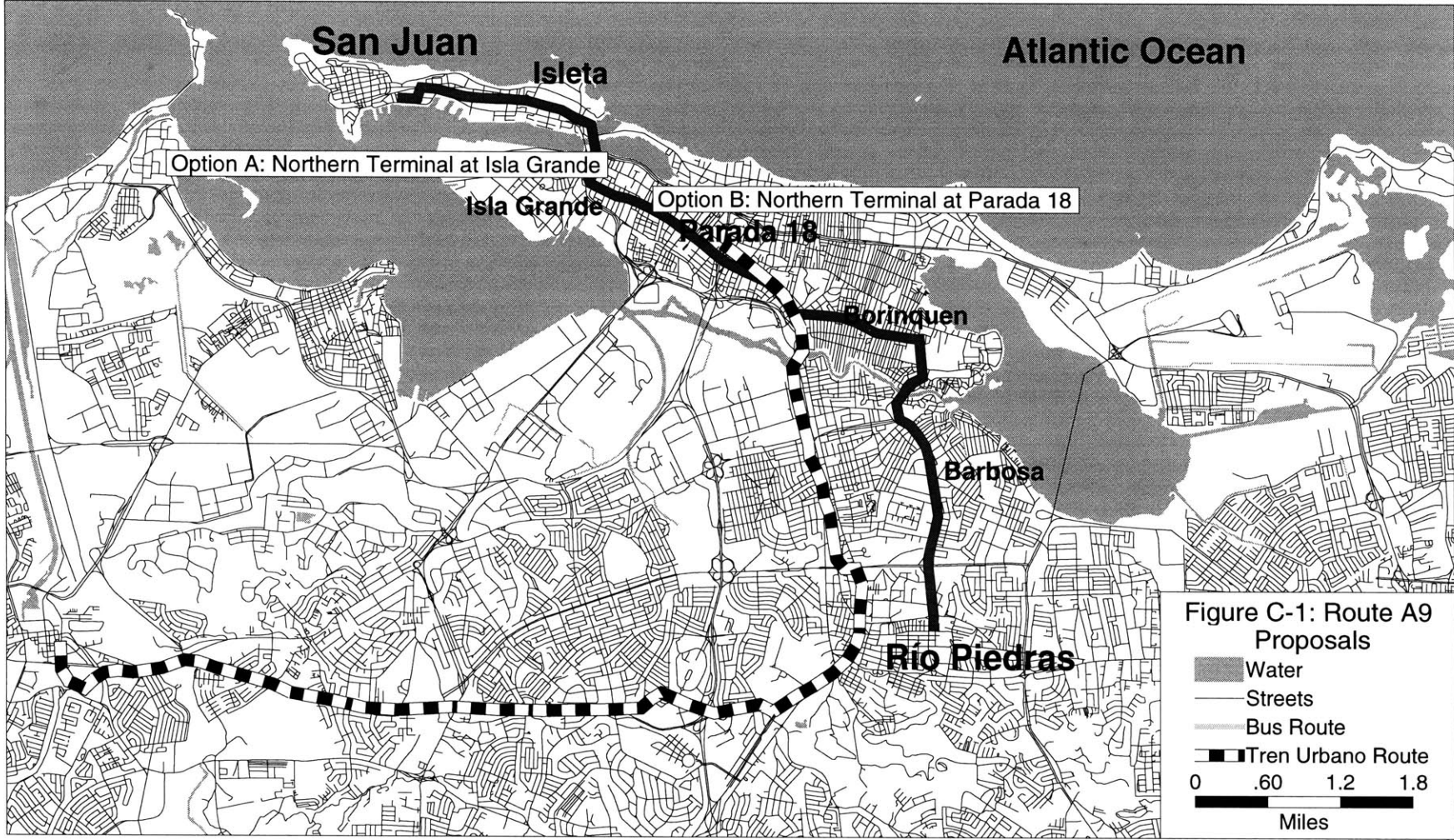
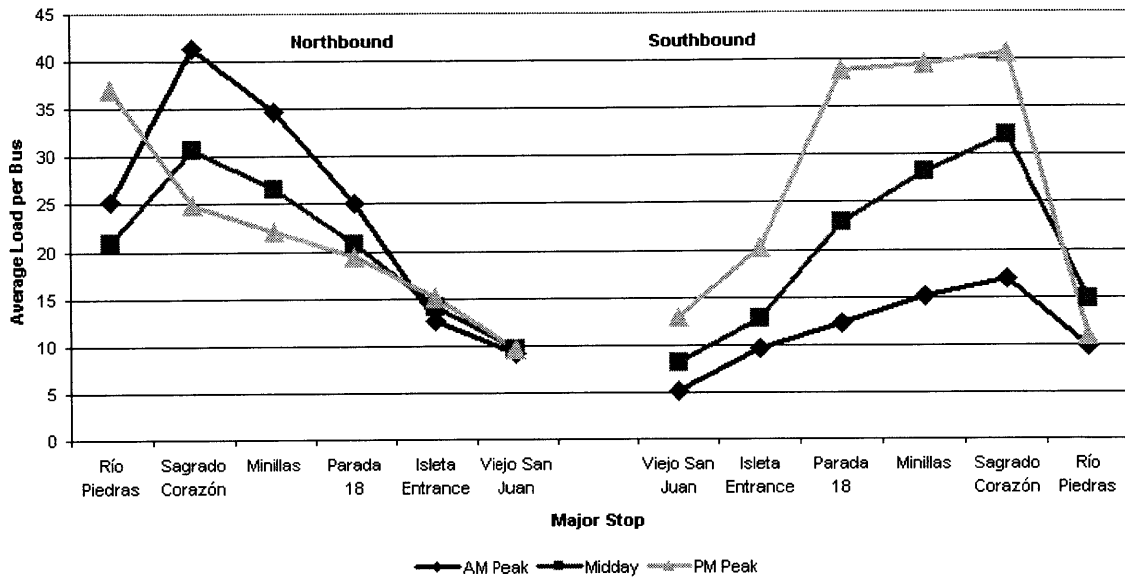




Figure C-2: Route A9 Average Loads



*Option A: Terminate Route A9 at Isla Grande*

Diverting route 9 to Isla Grande instead of continuing onto Viejo San Juan would not likely produce significant run time savings. While traversing the Isleta takes perhaps 6 or 7 minutes, looping through Isla Grande would also require extra time. With a small cycle time difference, this proposal would likely result in few, if any, resource savings. In contrast, the change would impact ridership greatly. Some 1,511 trips from Río Piedras to the Isleta would lose direct bus service on two routes (A9 and Metrobús I), although the quicker ride on Tren Urbano could offset the transfer time, inconvenience, and additional fare. Over two-thousand daily trips from south Barbosa/Borinquen area to the Isleta would require a bus-to-bus transfer. Depending on fare policy, passenger may also have to pay again to board the second vehicle. The bus-to-bus transfers would not accomplish the objective of boosting Tren Urbano ridership, and passengers could fault for Tren Urbano for the inconvenience. As the Isla Grande site develops and demand for transit services grows, options such as a shuttle connecting the convention center with Condado hotels and a link to Tren Urbano should be explored.

Table C-1: Impacts of terminating A9 at Isla Grande

Travelling Between	Impacts	Number of Riders
Santurce-Borinquen/Barbosa seg. to Isleta-Viejo San Juan seg.	Bus-to-bus transfer introduced; additional transfer charge	2,043
Río Piedras to Isleta-Viejo San Juan seg.	Bus-to-bus transfer introduced; additional transfer charge, but perhaps a faster ride	1,511

*Option B: Terminate Route A9 at Parada 18*

Terminating Route A9 even sooner at Parada 18 would result in even greater impacts. The difference in scheduled cycle times for this shortened route 9 is approximately 27 minutes (14 minutes in the westbound direction and 13 minutes in the eastbound direction). With daytime headways of about 8 minutes, truncating the route could produce savings of 3 to 4 buses. However, the heavy demand along this segment would require additional service on other routes, which would probably offset most of these savings. Over two thousand trips from Río Piedras to Miramar and the Isleta would lose direct bus service on two routes (A9 and Metrobús I), but could still benefit from Tren Urbano’s higher level-of-service. More significantly, approximately 3,590 trips from south of the Barbosa/Borinquen area to Miramar and the Isleta would require a bus-to-bus transfer and an additional fare. As in the previous case, these changes would inconvenience riders, but not result in higher rail ridership.

Table C-2: Impacts of terminating A9 at Parada 18

Travelling Between	Impacts	Number of Riders
Santurce-Borinquen/Barbosa seg. to Santurce-Viejo San Juan seg.	Bus-to-bus transfer introduced; additional transfer charge	3,590
Río Piedras to Santurce-Viejo San Juan seg.	Bus-to-bus transfer introduced; additional transfer charge, but perhaps a faster ride	2,069

Unfortunately, these proposals cause significant impacts on existing riders: two to three thousand daily trips would require an additional bus-to-bus transfer. While they may help alleviate overcrowding along certain segments of the route, they would not accomplish the objective of encouraging Tren Urbano usage. The affected customers may perceive that Tren Urbano has affected their bus service negatively, and would not even have the opportunity to ride the train. Further, these changes would not likely

produce significant resource savings. Other options might better address the crowding problem.

### **C.2 Proposal: Truncate Metrobús I**

Several bus routes currently parallel the Tren Urbano alignment from Río Piedras to Minillas. The A3 enters from the west at Hato Rey, and continues south along the corridor to Río Piedras. Metrobús II also enters from the west at Hato Rey, but continues north along the corridor to Minillas and Parada 18. Metrobús I parallels the entire alignment north of Río Piedras. Metrobús Expreso, which bypasses Santurce, is a faster version of Metrobús I.

Serving the region's major commercial spine, Metrobús I offers very frequent service and is the most heavily patronized public bus route in San Juan. Metrobús I parallels Tren Urbano from Minillas to Río Piedras. Once train operations begin, the corridor may become saturated with competing services. To lessen redundancy and facilitate the reallocation of resources to other areas of San Juan, one possibility is to eliminate Metrobús I south of Santurce. The A3 and Metrobús II routes would still continue to provide local service along the entire alignment. Thus, current short-distance bus customers (between Hato Rey and Minillas, or between Hato Rey and Río Piedras) could choose between the bus and Tren Urbano while long-distance customers travelling through Hato Rey would need to take Tren Urbano. This plan would also require some passengers continuing to the northern end of Santurce or Viejo San Juan to transfer between Tren Urbano and another bus.

Current Metrobús I operations require up to 25 buses (17 for regular service and 8 for express service), more than 10% of the entire Metrobús and AMA peak fleet combined. Curtailing bus service that directly competes with the train would free bus resources for service expansion elsewhere. In particular, these resources could be used to shorten headways on the remaining portion of Metrobús I, from Santurce to Viejo San Juan. Tren Urbano should generate significant new transit ridership along the entire Viejo San Juan-to-Río Piedras corridor, and many people destined for Viejo San Juan will need to transfer to buses in Santurce. Reducing duplication would also fulfill the objective of encouraging existing bus riders to take Tren Urbano. Before making such a



change, one must consider impacts on current ridership (such as accessibility, transfers, and fares) as well as on system operations.

### *Accessibility Impacts*

Tren Urbano stations are generally located about every half-mile along the Río Piedras corridor. Bus stops, which are usually spaced every three blocks or so, provide slightly better area coverage than the train. Thus, discontinuing Metrobús may require some customers to walk further to reach Tren Urbano. To determine accessibility impacts, this analysis compares the physical location of bus stops compared to train stations, ridership levels at impacted and non-impacted stops, and the impacts on various rider groups categorized by their origins and destinations.

Table C-3: Metrobús Stop Locations between Minillas and Río Piedras

	Northbound	Southbound	Total
Bus stops within 1 block of TU station entrance	12	9	21 (48%)
Bus stops within 2-4 blocks of TU station entrance	7	8	15 (34%)
Bus stops in the Río Piedras area	4	4	8 (18%)

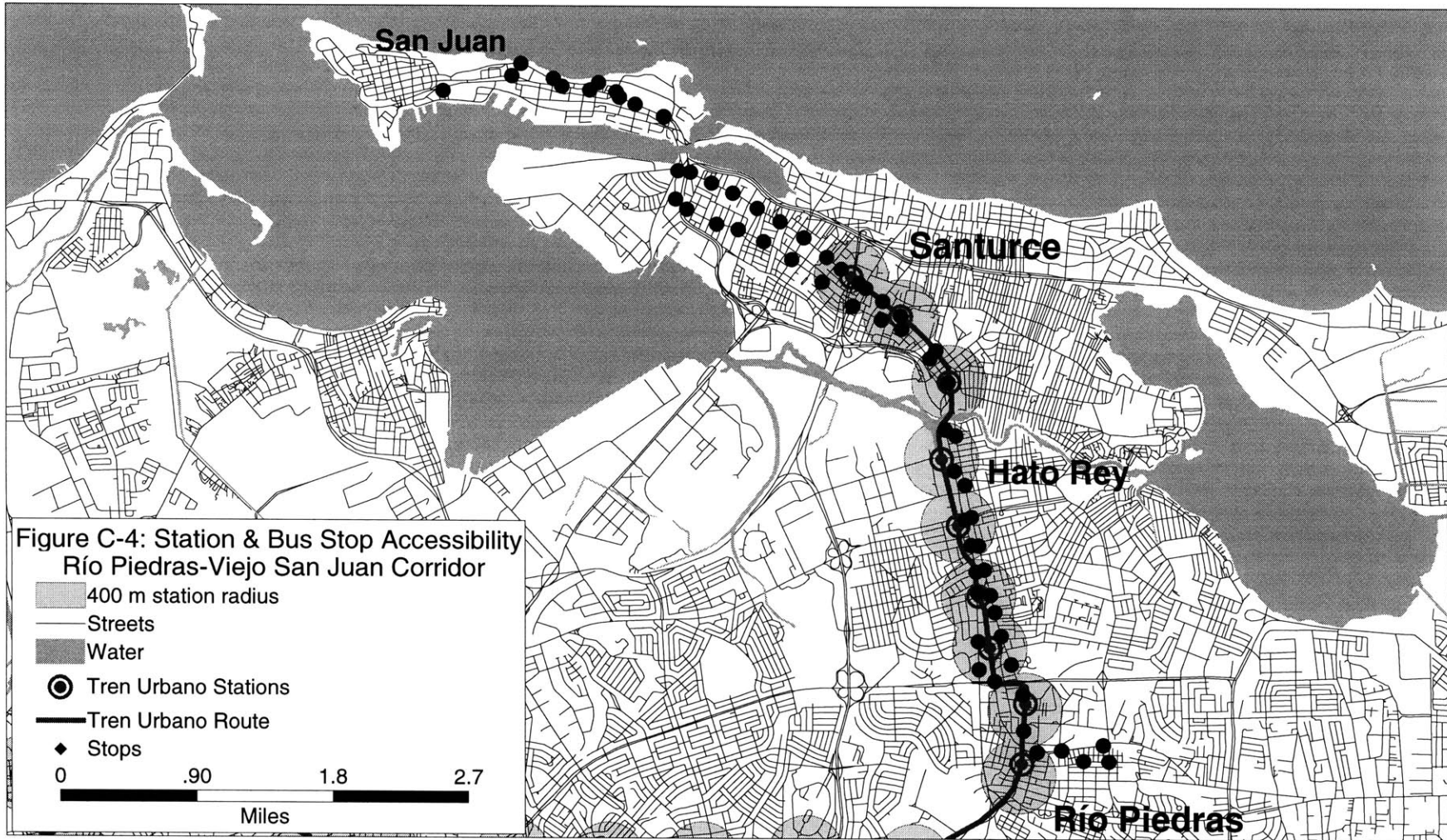
Table C-4: Metrobús Stop Activity between Minillas and Río Piedras

	Boardings	Alightings	Total
Bus stops within 1 block of TU station entrance	9,863	7,987	17,850 (42%)
Bus stops within 2-4 blocks of TU station entrance	4,201	5,738	9,939 (23%)
Bus stops in the Río Piedras area	8,165	6,718	14,883 (35%)

Due to the short spacing between Tren Urbano stations, the majority of existing bus stops are located within one block of planned station entrances. As well, the majority of boardings and alightings are at stops adjacent to future stations. In the Río Piedras area, the effects of stop location are unclear. Buses currently skirt the commercial district along peripheral arterials to avoid the narrow and congested streets. The large Capetillo transit center is located on the eastern edge of the neighborhood. It is likely that most Río Piedras passengers are now walking several blocks anyway to reach their destinations. Tren Urbano's centrally located Río Piedras station may well provide superior access compared to existing bus routes.

Customers fall into four categories, based on their walking distance to Tren Urbano:

- (1) those who have the option of taking a direct bus (A3 or Metrobús II) or Tren Urbano
- (2) those who must take Tren Urbano with no additional walk at either end



- (3) those who must take Tren Urbano with an additional walk at one end
- (4) those who must take Tren Urbano with an additional walk at both ends

Of the four categories, the last two require additional walking. In the third category, customers may have to walk a little further (up to about four blocks or ¼ mile), but the inconvenience could be offset by the more comfortable station waiting environment. The last category has the most negative impact since a person may have to walk roughly eight more blocks or an additional ½ mile.

Accessibility impacts were evaluated for bus riders currently travelling entirely within the Río Piedras to Minillas corridor. (Separate transfer issues affect passengers destined for points north of Minillas, such as Viejo San Juan. Changes in accessibility are relatively less significant; at most, they will affect one end of their trip.)

Table C-5: Summary of Impacts based on Origin-Destination Data, Río Piedras to Minillas only

	Weekday Riders	% of Total
Option of taking Tren Urbano or Bus (A3 or Metrobús II)	6,569	60.1%
Tren Urbano only, but no extra walk	643	5.9%
Tren Urbano only, but extra walk at one end	746	6.8%
Tren Urbano only, but extra walk at both ends	164	1.5%
Tren Urbano only, Río Piedras trips	2,808	25.7%
TOTAL	10,931	100.0%

Of the passengers travelling within the Río Piedras-San Juan corridor, the majority will continue to enjoy direct bus service and have the option of taking Tren Urbano. The rest will lose direct bus service, but Tren Urbano stops will be near both their origins and destinations. About 6% of trips will require minimal additional walking, while another 7% will have to walk up to four additional blocks at one end. Eliminating Metrobús I will “seriously” impact just 164 passengers (or 1.5%), who will need to walk further at both ends. Río Piedras trips were classified separately since the effects the neighborhood station would have on transit access distance was unclear.

*Transfer and Fare Impacts*

If Metrobús were curtailed, “long-distance” riders that travel through Hato Rey will not have the option of taking the remaining Metrobús II or A3 buses. Tren Urbano

would directly serve some 4,360 trips with origins and destinations between Santurce and Río Piedras. These riders would pay higher fares (\$1 according to latest plans versus \$0.50 for Metrobús). The other 4,090 trips originate south of Sagrado Corazón and continue beyond Santurce to Miramar and Viejo San Juan. These passengers would pay a higher train fare and transfer to buses to complete their trip. (If kept in its present form, Route A9 could handle all local trips between Sagrado Corazón and Viejo San Juan.)

While these fare and transfer impacts may seem dramatic, Tren Urbano's higher level-of-service (speed, reliability, frequency, service hours, more comfortable waiting areas, etc.) may help offset the inconvenience. As well, the frequent bus service planned for the Minillas-Viejo San Juan corridor should reduce wait times for passengers transferring from Tren Urbano. Reliability along this segment should also improve because Metrobús will no longer have to travel through heavily congested Hato Rey and Río Piedras. Finally, a coordinated fare policy which provides discounted or free transfers could also mitigate the monetary effects of transferring.

#### *Service Impacts on Remaining Routes*

While Tren Urbano will likely attract many former bus customers, buses will continue to serve some trips more conveniently. For instance, current A3 and Metrobús II riders who travel between the Minillas/Viejo San Juan corridor and points west of Hato Rey are unlikely to ride Tren Urbano since the train does not serve one end of their trip. Once Tren Urbano opens, discontinuing Metrobús I may add pressure to the remaining A3 and Metrobús II routes. Some local travelers may prefer the bus if it offers lower fares and better accessibility.

This demand could tax the remaining bus service. To estimate this effect, existing bus riders with at least one trip end within the Minillas/Hato Rey or Hato Rey/Río Piedras segments are classified according to the likelihood that they would remain on the bus versus switching to Tren Urbano. To focus on service planning issues, this initial level of analysis ignores fare impacts on mode choice. The "unlikely" bus rider group consists of people whose trips begin and end within one block of future station sites. For Metrobús II, "unlikely" bus riders also included people who traveled from Bayamón to

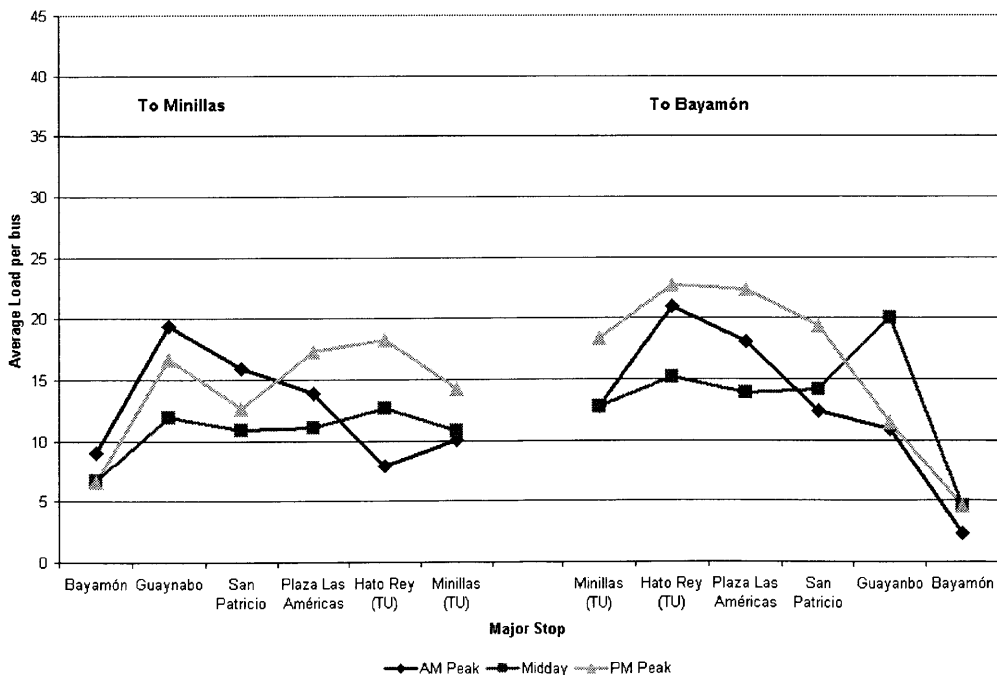


Hato Rey or Minillas. Tren Urbano will take about half the time as the bus does now between these points; thus, it was assumed that these people would prefer the train even at a higher fare. “Possible” bus passengers have one trip end next to a Tren Urbano station, and the other end several blocks away from a station entrance. “Likely” bus customers either must walk several blocks to reach a station at both trip ends, or travel between the rail corridor and somewhere else (such as San Patricio or Cataño).

Using origin-destination data from ride checks, the load impacts of removing Metrobús I on the remaining A3 and Metrobús II routes were simulated. A conservative model was employed that assumes that only “unlikely” bus riders switch to Tren Urbano while “likely” and “possible” ones remain on the bus. The results, illustrated in the two tables below, indicate:

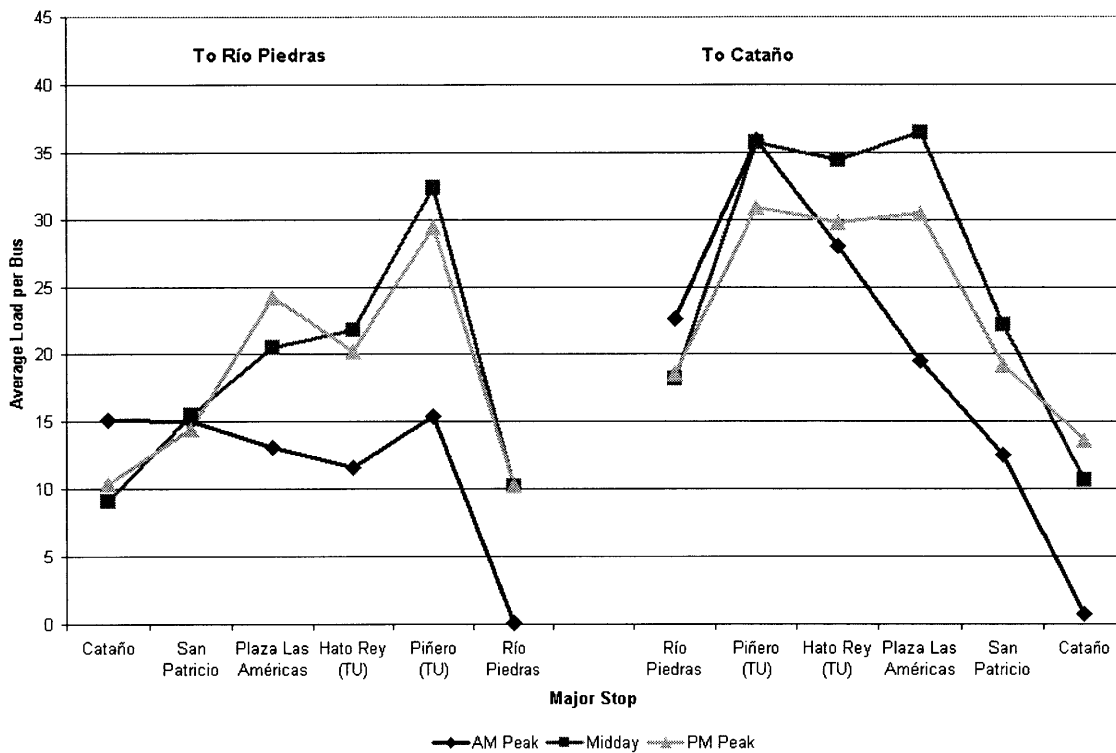
- At present ridership levels, overcrowding on Metrobús II and Route A3 should not be a serious issue.
- Metrobús II has fairly consistent, but relatively low-to-moderate loads along the entire route. Discontinuing Metrobús I should increase loads on the overlapped section between Hato Rey and Minillas, although some local riders may also elect to switch to Tren Urbano. Enough capacity to absorb them exists because many current end-to-end Metrobús II riders can take Tren Urbano instead. The model suggests that the current 10-minute headway may lead to low productivity.

Figure C-5: Projected Metrobús II Average Loads (with Tren Urbano)



- Compared to Metrobús II, Route A3 has higher loads and a more uneven load profile. With future ridership growth, it is possible that the segment between Plaza las Américas and Río Piedras might warrant additional service. A shuttle between ferrying customers from Tren Urbano and Plaza las Américas could relieve some pressure and improve regional access to the shopping mall.

Figure C-6: Projected Route A3 Average Loads (with Tren Urbano)



Discontinuing the Metrobús I segment that parallels Tren Urbano could well be the most controversial piece of any bus-rail integration effort. In summary, the above analysis suggests that if the route were discontinued:

- The vast majority of existing customers would not have to walk very much further to reach Tren Urbano. Tren Urbano riders may have to pay a higher fare but would also receive better service.
- “Local” customers could still use Metrobús II or A3 services. In their present form, these routes could accommodate the traffic.

- People travelling on to Miramar, the Isleta, and Viejo San Juan would have to transfer. Frequent connecting bus services should reduce the transfer wait time. However, friendly transfer policies would need to be enacted to avoid large de facto fare increases.

These observations suggest that discontinuing Metrobús I is feasible from a service delivery standpoint *as long as a favorable fare coordination policy with Tren Urbano exists*. Nevertheless, when Tren Urbano opens, current Metrobús I customers might react strongly to the loss of bus service and may be reluctant to switch to the train immediately. To avoid negative publicity during the transition period, it may make sense to simply reduce bus service levels on opening day, but defer route discontinuation until several months later.

### **C.3 Proposal: Revamp services on the Santurce –Viejo San Juan corridor**

In the future, Tren Urbano may expand beyond the planned Phase 1A terminal at Minillas to the Isleta and Viejo San Juan. At present, the Isleta and Viejo San Juan attract significant ridership – approximately 12,000 daily trips - from throughout the San Juan metropolitan area. Well-developed bus service runs in this corridor, including two major AMA routes (A9 and A5) and Metrobús I. Another bus route connects the area with Condado.

According to the Tren Urbano Demand Model, trips to Viejo San Juan from the rail corridor should nearly double over current levels. Ridership on existing routes could also jump given current growth trends and favorable economic development. In short, greater demand could necessitate service increases.

One possible option is the development of an express bus linking Tren Urbano with Viejo San Juan. This service, a shortened version of the existing Metrobús I express, would bypasses the Miramar area of north Santurce and local stops on the Isleta. This would help relieve traffic from local routes and shorten trip times for Viejo San Juan passengers. Another possibility is to implement high-quality “Bus Rapid Transit” as an interim step to a possible long-term Tren Urbano extension. “Bus Rapid Transit” would take advantage of existing exclusive bus lanes along the corridor. These service concepts would require further research.

Table C-6: Estimated weekday trips travelling to Viejo San Juan/Isleta

	Current	Future
Local travel between Viejo San Juan and the Isleta	1,026	1,200***
Viejo San Juan/Isleta segment to Tren Urbano corridor	2,968	5,474*
Viejo San Juan/Isleta segment to Santurce	2,620	3,065***
Viejo San Juan/Isleta segment to east of Minillas (current A5)	1,825	2,135***
Viejo San Juan/Isleta segment to south of Sagrado Corazón (current A9)	2,043	2,390***
Viejo San Juan/Isleta segment to Río Piedras (current A9 or Metrobús I)	1,511	**
<b>Total</b>	<b>11,993</b>	<b>14,265</b>

\*Source: Tren Urbano Demand Model

\*\*Included under Tren Urbano numbers

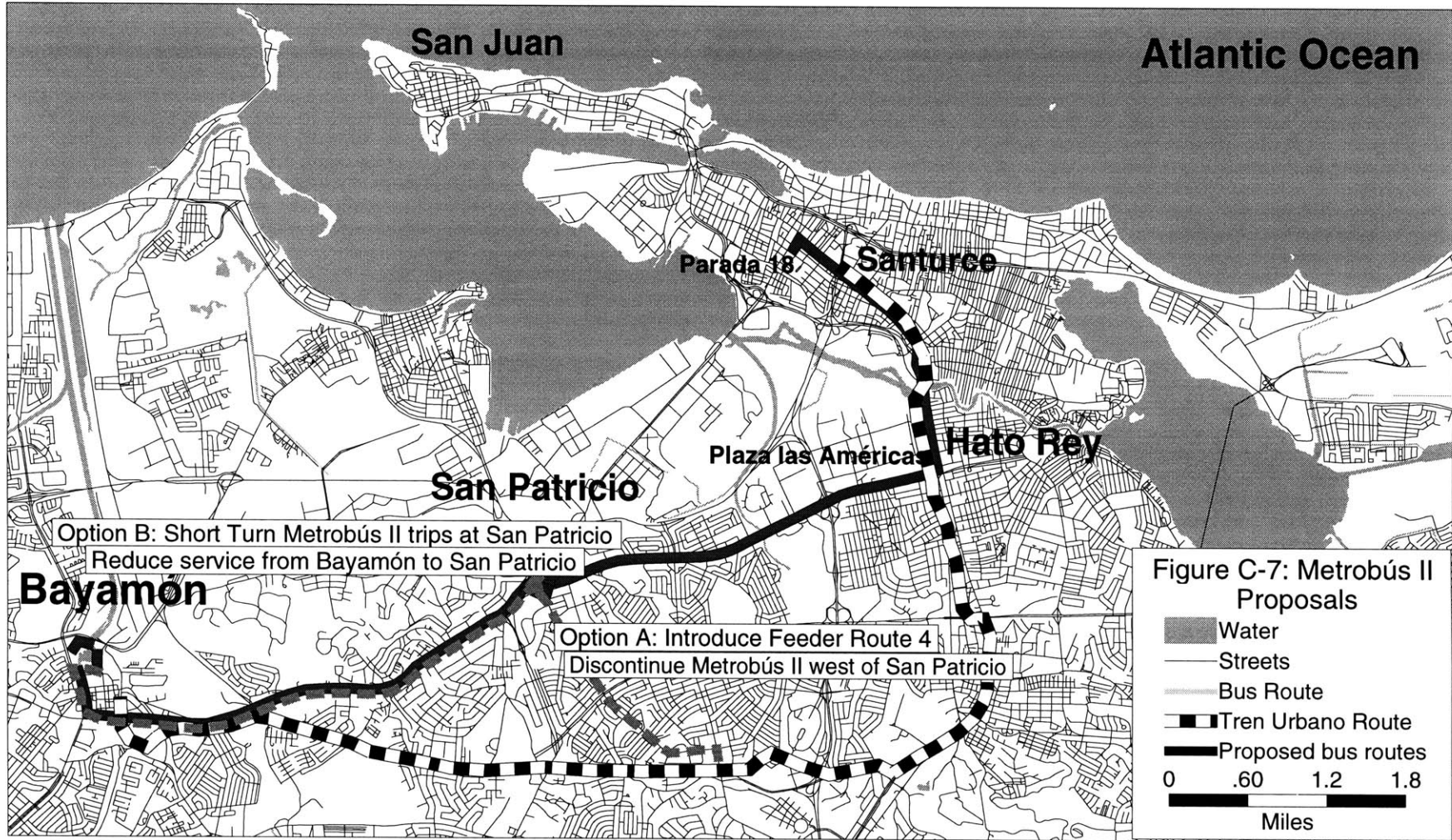
\*\*\* 17% assumed growth in current ridership

#### **C.4 Proposal: Split Metrobús II at San Patricio**

As noted earlier, Metrobús II presently runs from Santurce to Bayamón, serving the future Tren Urbano terminals at Bayamón Centro and Minillas (as well as the interim terminal at Sagrado Corazón). Although Metrobús II charges \$0.50 instead of the regular \$0.25 fare, it is extremely popular given that it runs along major east-west arterials (PR 2 and Avenida F.D. Roosevelt) and stops by Hato Rey, Plaza Las Américas, San Patricio, and other major destinations. The ridership helps support frequent service (every 10 minutes on weekdays, every 15 minutes on Saturdays, and every 20 minutes on Sundays), which in turn makes the route attractive. As of 1998, it registered approximately 9,000 daily boardings.

Metrobús II presently connects the endpoints of Tren Urbano. It also parallels the rail alignment from Bayamón to Guaynabo, and from Hato Rey to Minillas. However, Metrobús II is much slower and serves more local traffic. With heavy traffic, the bus takes about 50 minutes to travel from Bayamón to Hato Rey and over an hour from Bayamón to Santurce. By contrast, these trips on Tren Urbano will take slightly over half that time, even though the train takes a more roundabout path. Approximately 2,100 Metrobús II riders travel between the areas served by both Metrobús II and Tren Urbano. About 1,900 of these riders access Metrobús II at points within a reasonable walking distance of future Tren Urbano stations at Torrimar, Jardines, Deportivo, and Bayamón.

Earlier analysis suggests some Metrobús II patrons would switch to Tren Urbano. Average loads would drop but would become relatively balanced along the route. The



route would also continue to serve local travel patterns. Even so, options were explored to eliminate any competition between bus and rail. If Metrobús II remained in its present form, some Bayamón-to-Hato Rey/Minillas riders may elect to stay on the bus because of a lower fare and more direct routing.

*Option A: Convert the western half of Metrobús II into a feeder route and discontinue through service*

This proposal calls for the breakup of the route at San Patricio, approximately midway between Hato Rey and Bayamón. A reconfigured Route 4 would absorb the western half, connecting with Tren Urbano at both San Francisco and Bayamón. Metrobús II would continue to cover the eastern half between Santurce and Minillas. On weekdays, Metrobús II would maintain its current headway of 10 minutes; however, Route 4 would run only every 20 minutes. Reducing frequency between San Patricio and Bayamón would save resources. The affected segment's cycle time is about 54 minutes (29 minutes eastbound and 25 minutes westbound). On weekdays, this translates into eliminating three buses with a change from 10-minute to 20-minute headways.

People now travelling between the Hato Rey-Minillas corridor and the areas of northern Guaynabo beyond walking distance to Tren Urbano could potentially benefit from this change. According to origin-destination survey data, approximately 260 daily trips on Metrobús II fit this category. They would receive direct service to Tren Urbano's San Francisco station via Route 4. Unless their ultimate destinations were Río Piedras or Centro Médico, however, the route would take them on a very roundabout and time-consuming path. The trip to the area around the future San Francisco station takes about as long as Metrobús now takes to reach Hato Rey (about 20 minutes from San Patricio). Then these passengers would have to ride Tren Urbano to reach their final destination.

Unfortunately, this proposal would negatively impact the approximately 5,500 daily riders customers who use Metrobús II between Bayamón and San Patricio. Slightly less than 2,000 of them (those travelling Minillas/Hato Rey corridor) would have the option of taking Tren Urbano. More than sixty percent, however, now take trips that do not involve travel to points that Tren Urbano serves. People with origins and destinations entirely within the Bayamón-San Patricio segment (about 2,255 daily trips) would avoid

transferring, but could wait twice as long for a bus. Customers with one trip end along the Bayamón-San Patricio segment and the other along Avenida Roosevelt (about 1,209 daily trips) would experience both a bus-to-bus transfer and longer waiting times. Given Metrobús II's present riding patterns, halving service on the San Patricio-Bayamón segment may result in overcrowding. It may also drive away customers as there exists some elasticity of ridership with respect to headways.

Table C-7: Impacts of Splitting Metrobús II at San Patricio

Travelling Between	Impacts	Number of Riders
Bayamón-San Patricio segment & San Patricio-Plaza las Américas seg. (through San Patricio)	Bus-to-bus transfer introduced; frequency reduced from 10 to 20 minutes along western segment	1,209
Bayamón/San Patricio to Hato Rey/Minillas	Feeder bus to Tren Urbano with bus-to-rail transfer, but long diversion OR bus-to-bus transfer to MII; many of these people could walk to Tren Urbano directly, however	2,164
Bayamón & San Patricio	Frequency reduced from 10 to 20 minutes	2,255
San Patricio & Santurce local	No impacts	4,223
Potential Beneficiary: segment just west of San Patricio to Tren Urbano (outside walking distance of station)	Direct feeder bus (but long ride) to TU; frequency reduced from 10 to 20 min	263

*Option B: Short-turn some Metrobús II buses at San Patricio, reducing service along the western half*

Table C-8: Impacts of Short-Turning Metrobús II trips at San Patricio

Travelling Between	Impacts	Number of Riders
Bayamón-San Patricio segment & San Patricio-Plaza las Américas seg. (through San Patricio)	Frequency reduced from 10 to 20 minutes along western segment	1,209
Bayamón/San Patricio to Hato Rey/Minillas	Frequency reduced from 10 to 20 minutes along western segment	2,164
Bayamón & San Patricio	Frequency reduced from 10 to 20 minutes	2,255
San Patricio & Santurce local	No impacts	4,223

Short-turning certain Metrobús II trips at San Patricio (instead of continuing onto Bayamón) also reduces service along the line's outer portion, but avoids introducing a bus-to-bus transfer. It can also present operational problems, however, particularly on high-frequency routes such as Metrobús II. Passengers travelling entirely within the heavier segment will tend to board the first vehicle, while those headed for the lighter

segment may have to wait for a specific vehicle going to their destination. Assuming random passenger arrivals, short-turn patterns may distribute traffic unevenly with more people on full-route vehicles than on short-turn ones. Non-uniform loading may increase bus bunching and average waiting times in the absence of tight operations control.<sup>6</sup>

Unfortunately, both of these proposals would have significant side impacts on existing customers. These may include significantly longer headways, operations control problems, or additional transfers. At the same time, they would not accomplish goals of diverting significant numbers of additional riders to Tren Urbano. Even with no route structure changes, many people would still switch to rail for the time savings. In a scenario with both Metrobús II and Tren Urbano, the two would serve different markets and therefore would not truly “compete” with each other. Adjusting headways over the entire route may be the most appropriate way to handle Tren Urbano-induced demand changes.

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<sup>6</sup> Furth, Day, and Attanucci. “Operating Strategies for Major Radial Bus Routes,” Moltiplications, Inc., May 1984.



## **Appendix D: Americans with Disabilities Act Implications**

The Americans with Disabilities Act of 1990 specifies the accessibility requirements for public transportation providers. Different regulations apply based on service type (fixed route or demand responsive) and service provider (public entity - including contracted operations to a private party - and private entity).

Regarding service type, the públicos would probably be classified as “fixed route” operations. Although they do not adhere to schedules presently, they follow specific routes and passengers do not have to make advance reservations for the service. The U.S. Department of Transportation interprets the ADA to mean the following:

“With fixed route service, no action by the individual is needed to initiate public transportation. If an individual is at a bus stop at the time the bus is scheduled to appear, then that individual will be able to access the transportation system. With demand-responsive service, an additional step must be taken by the individual before he or she can ride the bus, i.e., the individual must make a telephone call.(S. Rept. 101-116 at 54).

“Other factors, such as the presence or absence of published schedules, or the variation of vehicle intervals in anticipation of differences in usage, are less important in making the distinction between the two types of service. If a service is provided along a given route, and a vehicle will arrive at certain times regardless of whether a passenger actively requests the vehicle, the service in most cases should be regarded as fixed route rather than demand responsive.”<sup>7</sup>

Currently, the públicos are considered private carriers since they receive no direct financial assistance from the government. (Public funding has supported the construction of público terminals and vehicle loans, however.) Some future options include:

- (1) making no substantive changes,
- (2) contracting out service completely during all hours of operation, or
- (3) contracting out base service during some or all hours of operation, supplemented by licensed, for-profit “Tren Urbano Públicos”. Tren Urbano would subsidize the públicos indirectly by reimbursing operators for transferring passengers.

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<sup>7</sup>Construction and Interpretation of Provisions of 49 CFR part 37, US Department of Transportation (<http://www.fta.dot.gov/library/legal/ada/appendix.html>)

According to the ADA, the accessibility requirements for public agencies also apply “under a contractual or other arrangement or relationship with a public entity.”<sup>8</sup> With the last two options, both the contracted *and* licensed feeder services probably would have to meet “public entity” requirements. In the latter case, the government would form, in spirit, a service contract by agreeing to reimburse transfer revenue to the licensed operators.

Table A.1 summarizes the requirements according to system classification. Given the considerations discussed above, any significant government intervention to assist the públicos would likely trigger the ADA requirements for fixed route services operated by public entities. Specifically, the public agency must ensure that all new vehicles have wheelchair lifts and must initialize paratransit for the corresponding service area. The agency could avoid paratransit if it demonstrates that such operations would create an “undue financial burden,” or if it successfully argued that Tren Urbano feeder services were equivalent to “commuter bus” operations.

Even if the public transport agency could show that the licensed públicos were completely separate private operations, all new vehicles would still require full accessibility. In essence, the government would merely pass the ADA responsibility to potential licensed público owners. The added expense, approximately \$10,000 per van, would discourage owners from joining the program. (Theoretically, the público owners could exploit a “loophole” by always purchasing used vans.) The public agency would also need to address the paratransit requirement (through compliance or exemption) since it would operate contracted base service in any case.

However, licensed públicos would *not* need to be accessible if they fell into the “demand responsive” category. Specifically, if they were permitted to deviate upon customer request, one could arguably consider them “demand responsive”. In this case, the ADA waives the accessibility requirement as long as the system, “when viewed in its entirety, provides a level of service to such individuals equivalent to the level of service provided to the general public.” One could interpret this to mean that this arrangement would not violate the ADA as long as the contracted base service provided alternative accessible vehicles.

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<sup>8</sup> Americans with Disabilities Act, Section 221

Table D-1: Accessibility Requirements

	Public Entities (including contract operations)	Private Entities (primarily engaged in the business of transporting people)
Fixed Route Services	Required for all new vehicles. Exception: Used vehicles, as long as the entity made “good faith” efforts to acquire accessible used vehicles (Sect. 222)	Required for all new vehicles. Exception: an automobile or van with a seating capacity of less than 8 people as long as alternative accessible service is available (Sect. 304)
Demand Response Services	Not required as long as the system, “when viewed in its entirety, provides a level of service to such individuals equivalent to the level of service provided to the general public” (i.e. alternative accessible services are available) (Sect. 224)	Not required as long as the system, “when viewed in its entirety, provides a level of service to such individuals equivalent to the level of service provided to the general public” (i.e. alternative accessible services are available) (Sect. 304)
Complementary paratransit required?	Required if the public entity operates a fixed route system Exception: If the public entity can demonstrate that paratransit would impose an “undue financial burden” or it operates “commuter bus” services. (Sect. 223)	Not specifically addressed in ADA legislation and assumed to be not required.

Source: Americans with Disabilities Act

## **Appendix E: Relevant Americans with Disabilities Act Passages**

### **SEC. 221. DEFINITIONS. 42 USC 12141.**

As used in this part:

- (1) Demand responsive system. The term demand responsive system means any system of providing designated public transportation which is not a fixed route system.
- (2) Designated public transportation. The term designated public transportation means transportation (other than public school transportation) by bus, rail, or any other conveyance ... that provides the general public with general or special service (including charter service) on a regular and continuing basis.
- (3) Fixed route system. The term fixed route system means a system of providing designated public transportation on which a vehicle is operated along a prescribed route according to a fixed schedule.
- (4) Operates. The term operates, as used with respect to a fixed route system or demand responsive system, includes operation of such system by a person under a contractual or other arrangement or relationship with a public entity.

### **SEC. 222. PUBLIC ENTITIES OPERATING FIXED ROUTE SYSTEMS. 42 USC 12142.**

(a) Purchase and Lease of New Vehicles. It shall be considered discrimination for purposes of section 202 of this Act and section 504 of the Rehabilitation Act of 1973 (29 U.S.C. 794) for a public entity which operates a fixed route system to purchase or lease a new bus, a new rapid rail vehicle, a new light rail vehicle, or any other new vehicle to be used on such system, if the solicitation for such purchase or lease is made after the 30th day following the effective date of this subsection and if such bus, rail vehicle, or other vehicle is not readily accessible to and usable by individuals with disabilities, including individuals who use wheelchairs.

(b) Purchase and Lease of Used Vehicles. Subject to subsection (c)(1), it shall be considered discrimination for purposes of section 202 of this Act and section 504 of the Rehabilitation Act of 1973 (29 U.S.C. 794) for a public entity which operates a fixed route system to purchase or lease, after the 30th day following the effective date of this subsection, a used vehicle for use on such system unless such entity makes demonstrated good faith efforts to purchase or lease a used vehicle for use on such system that is readily accessible to and usable by individuals with disabilities, including individuals who use wheelchairs.

(c) Remanufactured Vehicles.

(1) General rule. Except as provided in paragraph (2), it shall be considered discrimination for purposes of section 202 of this Act and section 504 of the Rehabilitation Act of 1973 (29 U.S.C. 794) for a public entity which operates a fixed route system

(A) to remanufacture a vehicle for use on such system so as to extend its usable life for 5 years or more, which remanufacture begins (or for which the solicitation is made) after the 30th day following the effective date of this subsection; or

(B) to purchase or lease for use on such system a remanufactured vehicle which has been remanufactured so as to extend its usable life for 5 years or more, which purchase or lease occurs after such 30th day and during the period in which the usable life is extended; unless, after remanufacture, the vehicle is, to the maximum extent feasible, readily accessible to and usable by individuals with disabilities, including individuals who use wheelchairs.

**SEC. 223. PARATRANSIT AS A COMPLEMENT TO FIXED ROUTE SERVICE. 42 USC 12143.**

(a) General Rule. It shall be considered discrimination for purposes of section 202 of this Act and section 504 of the Rehabilitation Act of 1973 (29 U.S.C. 794) for a public entity which operates a fixed route system (other than a system which provides solely commuter bus service) to fail to provide with respect to the operations of its fixed route system, in accordance with this section, paratransit and other special transportation services to individuals with disabilities, including individuals who use wheelchairs, that are sufficient to provide to such individuals a level of service (1) which is comparable to the level of designated public transportation services provided to individuals without disabilities using such system; or (2) in the case of response time, which is comparable, to the extent practicable, to the level of designated public transportation services provided to individuals without disabilities using such system.

...

(c) Required Contents of Regulations.

...

(4) Undue financial burden limitation. The regulations issued under this section shall provide that, if the public entity is able to demonstrate to the satisfaction of the Secretary that the provision of paratransit and other special transportation services otherwise required under this section would impose an undue financial burden on the public entity, the public entity, notwithstanding any other provision of this section (other than paragraph (5)), shall only be required to provide such services to the extent that providing such services would not impose such a burden.

**SEC. 224. PUBLIC ENTITY OPERATING A DEMAND RESPONSIVE SYSTEM.**

If a public entity operates a demand responsive system, it shall be considered discrimination, for purposes of section 202 of this Act and section 504 of the Rehabilitation Act of 1973 (29 U.S.C. 794), for such entity to purchase or lease a new vehicle for use on such system, for which a solicitation is made after the 30th day following the effective date of this section, that is not readily accessible to and usable by individuals with disabilities, including individuals who use wheelchairs, unless such

system, when viewed in its entirety, provides a level of service to such individuals equivalent to the level of service such system provides to individuals without disabilities.

SEC. 304. PROHIBITION OF DISCRIMINATION IN SPECIFIED PUBLIC TRANSPORTATION SERVICES PROVIDED BY PRIVATE ENTITIES. 42 USC 12184.

(a) General Rule. No individual shall be discriminated against on the basis of disability in the full and equal enjoyment of specified public transportation services provided by a private entity that is primarily engaged in the business of transporting people and whose operations affect commerce.

(b) Construction. For purposes of subsection (a), discrimination includes

...

(3) the purchase or lease by such entity of a new vehicle (other than an automobile, a van with a seating capacity of less than 8 passengers, including the driver, or an over-the-road bus) which is to be used to provide specified public transportation and for which a solicitation is made after the 30th day following the effective date of this section, that is not readily accessible to and usable by individuals with disabilities, including individuals who use wheelchairs; except that the new vehicle need not be readily accessible to and usable by such individuals if the new vehicle is to be used solely in a demand responsive system and if the entity can demonstrate that such system, when viewed in its entirety, provides a level of service to such individuals equivalent to the level of service provided to the general public;

...

(5) the purchase or lease by such entity of a new van with a seating capacity of less than 8 passengers, including the driver, which is to be used to provide specified public transportation and for which a solicitation is made after the 30th day following the effective date of this section that is not readily accessible to or usable by individuals with disabilities, including individuals who use wheelchairs; except that the new van need not be readily accessible to and usable by such individuals if the entity can demonstrate that the system for which the van is being purchased or leased, when viewed in its entirety, provides a level of service to such individuals equivalent to the level of service provided to the general public;