Strategic Transit Service Planning In The Santurce / Old San Juan corridor

by

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Abstract

Whenever a rail system begins to be constructed, the interface between the new rail system and the pre-existing bus system is complex. As the new rail system begins operations, additional capacity is suddenly introduced, well beyond what will be immediately needed. At the same time, the bus system will appear to be providing redundant capacity, yet also serving as a feeder and distributor for the new high capacity rail segments. Short-term pressures for efficiency could lead to service cuts which will lead to a reduction in the quality of transit the rail system was built to provide. The resolution of the tension between the needs of the existing riders and those of future riders, and between short-term efficiency and long-term effectiveness, is the objective of this thesis. The strategic approach developed considers socio-economic factors, infrastructure and service structure from three points of view: riders, transportation providers, and the general community. This approach is then applied to the specific case of San Juan, Puerto Rico.

The San Juan Metropolitan Area (SJMA) is the latest region in the United States to implement a heavy rail system, referred to as Tren Urbano. Tren Urbano is Puerto Rico's first modern rail line and will provide high quality service that will substantially change the face of the public transportation system in San Juan. Expected to be completed several years after the first phase, Phase IA will extend Tren Urbano into the Minillas activity center. However, the introduction of Tren Urbano into the existing bus system will pose service quality, capacity, and coordination issues that will need to be addressed. In order for Tren Urbano to be successful in serving San Juan's residents, service strategies designed to seamlessly integrate the bus and rail systems at the Sagrado Corazón, Minillas, and future Tren Urbano termini must be planned and implemented.

This thesis will be focused on the corridor between Old San Juan and Sagrado Corazón– the Santurce / Old San Juan corridor. Transit service in the Old San Juan corridor is abundant and will improve with the new Tren Urbano terminus at Sagrado Corazón and at Minillas in the future. Hence, bus service strategies must be designed to integrate effectively with Tren Urbano and its future extensions in order to improve levels of service, establish high quality transfers, retain existing riders in the short-term, and in the long-term, attract new riders and ensure the success of Tren Urbano.

Based on an analysis of the levels of service, service capacity at the station and along the route, travel times, and the impacts of transfers, a set of recommendations for bus service are made. Before Tren Urbano opens, the existing bus service hours should be extended to increase transit usage in the off-peak periods and ensure that when Tren Urbano debuts, it will attract riders during all periods of the day. Once Tren Urbano opens, analyses show that the current bus service will not be able to adequately handle the forecast passenger transfer volumes at the Sagrado Corazón station. Metrobús service would need to be truncated at the station in order to provide the extra capacity needed. The Sagrado Corazón station is designed to facilitate transfers, and having empty buses waiting at the station will further improve the transfer experience for the passengers. As for Phase IA, it was found that bus-rail transfers could not be accommodated effectively at the Minillas station, so the Sagrado Corazón and/or San Mateo stations would serve as the major transfer points. Since there will be a need for a major transfer point closer to Old San Juan, the extension of Tren Urbano to the RH Todd station at Parada 18 should be pursued aggressively.

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Chapter 1. Introduction

In high demand urban transportation corridors, public transportation has maintained its status as a viable alternative to the automobile. While operating along these corridors, public transportation is often able to provide a competitive means of travel. Buses are generally the first form of transit to operate in such high demand transportation corridors, with their ability to operate on city streets along with other vehicular traffic. However, over time increasing traffic in these corridors results in increasing congestion levels, thereby decreasing the effectiveness of public transportation, and creating a need for a more effective public transportation solution.

Many cities have constructed new rail lines along high demand corridors as a means of providing high-quality alternatives to on-street travel. However, rail systems can never be more than the skeleton of the public transportation system. Effective feeder buses are required to provide more extensive access to AMA from the metropolitan area. In addition, public transportation operators are pressured to show positive returns on the investments in the rail system, and as a result may implement short-term strategies designed to boost rail ridership, such as a major restructuring of the existing bus system to directly feed the rail system. Yet, given the constraints imposed by the existing transportation system and operating environment, such modifications may not be the most effective way to improve transit service. In addition, without carefully selecting the strategies that integrate bus and rail services with minimal service disruptions, implementing major changes potentially risks numerous negative repercussions; the modifications may not necessarily yield immediate ridership increases, and can also result in the permanent loss of riders, ineffective services, and increased public and political opposition.

The tension that exists between different objectives for the transit system is one that must be managed carefully. The operator must carefully weigh each objective and select the appropriate service strategies that will ultimately achieve the goal of developing a

successful public transportation system. The short-term and long-term implications of implementing service changes play a very important role in the process of selecting appropriate service strategies. This research will aid transit planners in the analysis and selection of appropriate service strategies by developing and applying a decision-making framework that identifies and helps resolve the tensions related to the strategic planning of transit services.

1.1 Motivation

The bus plays a large role in the success of any public transportation system. In most cities across the United States, bus service is the foundation of the transit system. According to the 1997 National Transit Database, a total of 364 agencies directly operated bus fleets compared to twenty agencies with light rail, and fourteen with heavy rail systems. Bus services are common because they are easy to implement; they operate on existing road networks, without a need for separate rights-of-way. This flexibility allows bus services to operate in a wide range of environments and service areas. As a result, they are a very important aspect of the services provided by a transit agency, and the success of the bus services is critical to the success of the transit agency.

Establishing a successful bus service is dependent on a number of factors, the most important being the ability to maintain high levels of service. However, the environment within which the bus service operates is dynamic; developments are constantly taking place. These developments alter customer travel patterns and behavior, as well as the face of public transportation. Transit agencies must be able to anticipate these future developments and strategically plan bus services in order to maintain service levels and avoid service disruptions.

Bus-oriented strategic planning is different from the strategic planning of rail systems. Since the implementation of rail systems has significant time, resource, and infrastructure requirements, strategic rail planning processes focuses on long-term decisions and

developments. Hence, without the ability to adjust quickly to short-term developments, the planning process for rail systems is quite inflexible. There is often a tendency for transit agencies to focus on short-term needs and developments when planning transit services, while the long-term implications are not taken into account. Bus services, with their flexibility and adaptability, can be restructured quickly and effectively to accommodate short-term developments, introducing a high level of flexibility into the strategic planning process. Yet, ridership patterns adjust slowly, so it is also important to maintain service continuity.

A particular problem must be addressed occurs when opening a new rail transit line. Since ridership will take time to increase, there will be an increase in capacity which will exceed demand in the short-term. Transit agencies may be pressured by external forces to show immediate returns, such as high ridership and utilization, on any investment made in the public transportation system. As a result, fearing that the presence of excess capacity will reflect poorly on the system, transit agencies are likely to implement short-term strategies to meet expectations without fully recognizing the long-term impacts of the changes on the passengers and communities.

Hence, the implementation of a strategic rail/bus service planning process can be very beneficial, as it will guide the service development strategies that consider the long-term implications of short-term strategies. By factoring in anticipated long-term developments when developing and selecting appropriate short-term service strategies, strategic rail/bus planning avoids the implementation of unnecessary and costly service changes that may damage the system's ability to build ridership.

In order to successfully carry out the strategic planning of bus services, decisions on which service strategies to implement need to be made. The outcomes of these decisions need to ensure that the strategies will provide both short and long-term benefits for the transportation system while minimizing disruptions to service to existing riders. In selecting a service strategy, the decision-making process must account for and balance a number of different elements, including the availability of infrastructure, the timing of the

implementation, the necessity and impacts of transfers on service strategies, the availability and requirements of resources, and the potential impact on both existing and potential customers, institutions, and public transportation operators. This thesis develops a decision-making framework to assist transit planners in the analysis and selection of rail/bus service strategies that will satisfy both the short-term and long-term needs and objectives of the public transportation system.

1.2 San Juan Context

A specific motivation for this thesis is the need to develop an effective strategy for public transportation in San Juan, Puerto Rico. The San Juan Metropolitan Area (SJMA) is the latest region in the United States to implement a heavy rail system, referred to as Tren Urbano. Expected to be completed in mid-2002, Tren Urbano is Puerto Rico's first modern rail line, with the first phase consisting of seventeen kilometers of track and sixteen stations (Figure 1-1). The Tren Urbano Phase I alignment links Sagrado Corazón, at the southern edge of Santurce, with the western suburb of Bayamón and serves high demand areas including the Hato Rey financial district, several universities at Río Piedras, and the major medical center. Tren Urbano will provide high quality service that will substantially change the perception of transit in San Juan. It will begin revenue service daily at 5:00am and continue until 1:00am, providing frequent service throughout the day. Table 1-1 lists the planned Tren Urbano Phase I operating hours and headways.

Table 1-1. Tren Urbano Phase I Operating Plan

	Weekdays		Weekend	
	Hours of Operation	**Headways**	**Hours of Operation**	**Headways**
AM Peak	6:30 am-8:30 am	4 minutes		
PM Peak	4:00 pm-6:30 pm	4 minutes		
Base	8:30 am-10:00 am 3:00 pm-4:00 pm 6:30 pm -7:30 pm	8 minutes		
Off-Peak	5:00 am-6:30 am 10:00 am-3:00 pm 7:30 pm-1:00 am	12 minutes	5:00 am-1:00 am	12 minutes

Source: FEIS, Tren Urbano (1995)

Figure 1-1. Tren Urbano Phase I-IA Alignment

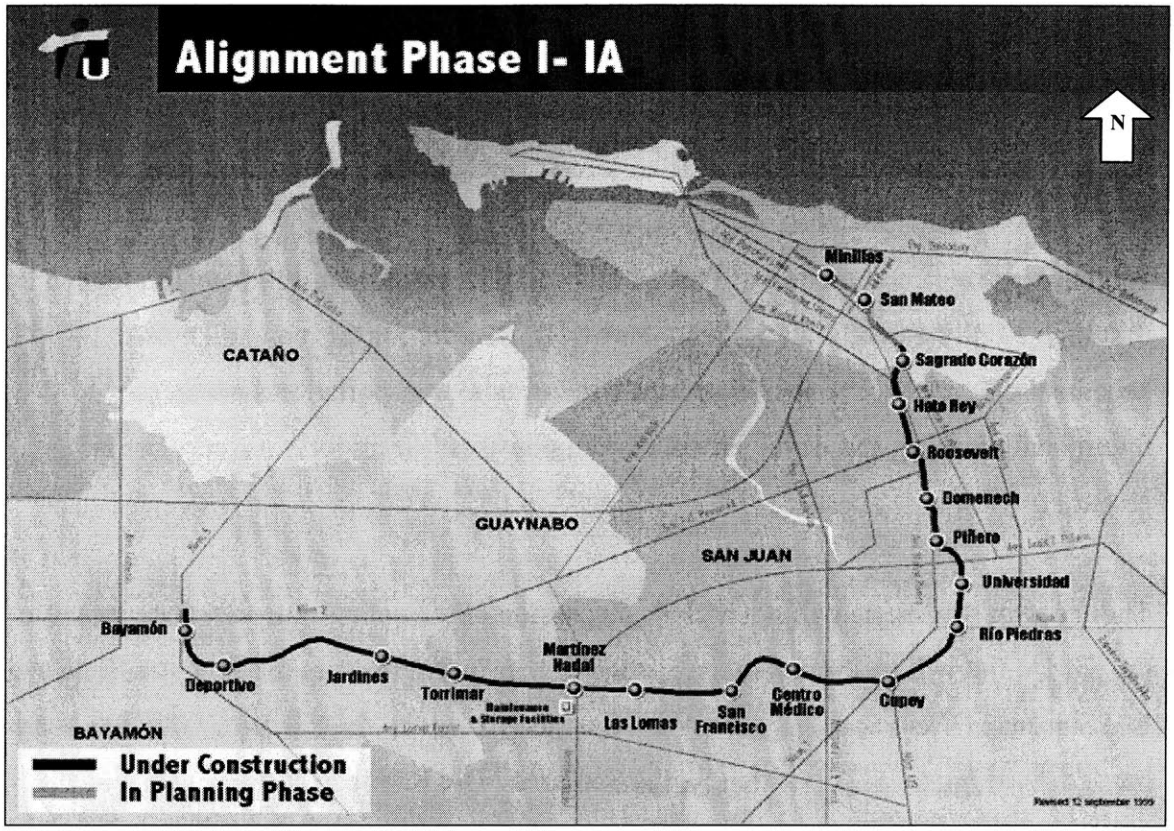
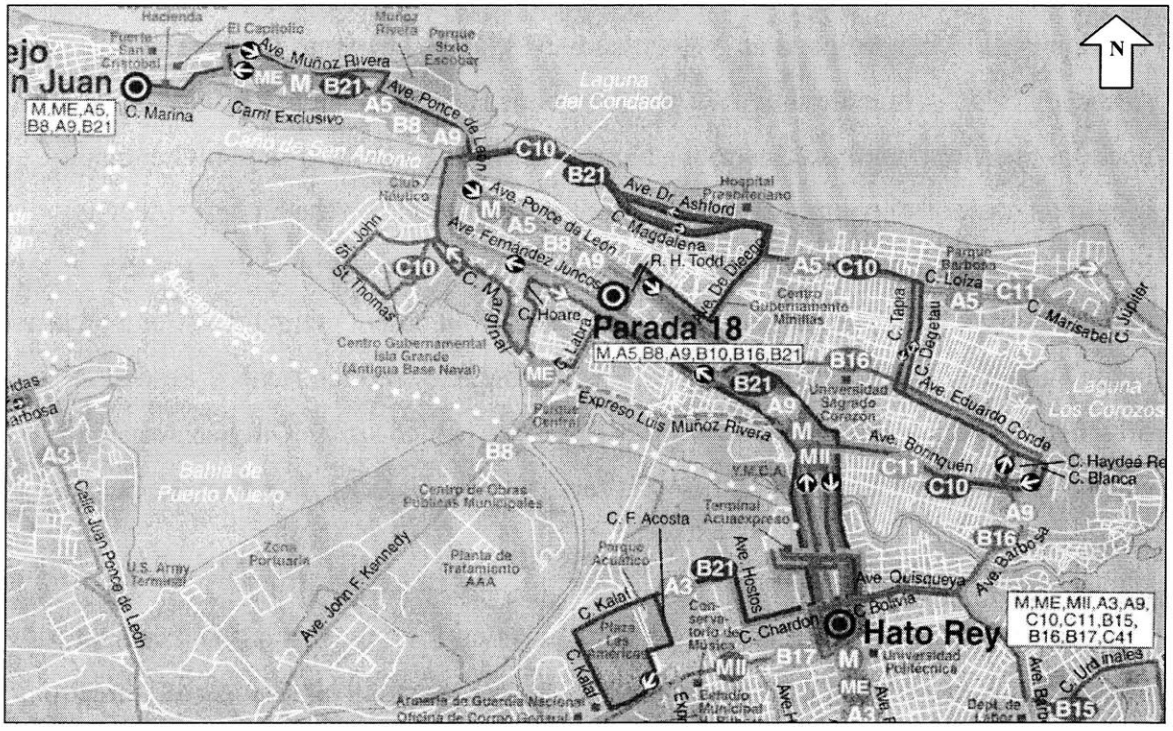


Figure 1-2. AMA/Metrobús Routes in the Old San Juan Corridor



The first Tren Urbano extension, Phase IA (Figure 1-1), is expected to be completed several years after Phase I is completed (Phase IA FSEIS, 1999). Currently in the advanced planning stage, Phase IA will extend Tren Urbano approximately one mile northwest from Sagrado Corazón to the employment center of Minillas. This extension will provide two additional stations (San Mateo and Minillas) within Santurce.

With the expected completion of Phase I in mid-2002, the SJMA will have introduced its first high quality modern rail system. However, in order for this new rail system to become the future backbone of San Juan's intermodal transportation system, proper intermodal planning and development of complementary transportation services is essential.

The scope of this thesis will not include discussion of the entire transportation system in the SJMA, but will be limited to the portion of the system that lies between the Isleta and Old San Juan (Viejo San Juan) areas and Sagrado Corazón– the Santurce / Old San Juan corridor (see Figure 1-2). Currently, the Santurce / Old San Juan corridor is one of the transportation corridors in the SJMA that is well served by a number of public transportation services. Two main bus services make up the bus system in the SJMA. The Autoridad Metropolitana de Autobuses (AMA), also known as the Metropolitan Bus Authority (MBA), operate the AMA and Metrobús II services while a private contractor operates the Metrobús I and Metrobús Express services. The AMA and higher quality Metrobús routes that operate in this corridor currently maintain the highest ridership levels of all bus routes in the SJMA. Públicos (privately owned jitneys) are also a popular mode of public transportation in the SJMA, but do not maintain a strong presence in the Santurce / Old San Juan corridor. Finally, the ferry service Acuaexpreso also has a presence in Old San Juan. However, only one route, which serves Old San Juan and Cataño is currently in operation; the other route serving Hato Rey has been suspended indefinitely.

The Santurce / Old San Juan corridor is quite different from the rest of the San Juan Metropolitan Area. The Old San Juan and Isleta area maintain high levels of recreational

and commercial activity that results in travel patterns that are unlike those of a typical central business district (CBD). A number of government and commercial institutions are located along the Isleta and in Old San Juan, making it an important destination for commuters. On the other hand, Old San Juan also hosts numerous restaurants, shops, and recreational activities that are popular with tourists and locals alike, making the area particularly active in the evenings and on weekends. With its strong recreational and commercial activity centers, the Old San Juan area is a major trip attractor during the peak *and* off-peak periods, so the residents' demand for transportation service to the area remains high during all periods of the day. The daily traffic to the Isleta and Old San Juan is expected to increase by 46 percent by the year 2005 and 113 percent by 2015 (Steer, Davies & Gleave, 1996). Additionally, since the Isleta is an island, access is hindered and limited capacity exists on its roadways, resulting in vehicular congestion that will get worse as traffic levels increase. Moreover, the off-peak activity that occurs in the Santurce / Old San Juan corridor is not located near the Phase I Tren Urbano alignment, which may discourage residents from taking transit, resulting in increased automobile usage. As a result, it is imperative that effective bus service along the Santurce / Old San Juan corridor be retained and improved so that the transit system will be able to effectively serve the peak and off-peak trips to attract a number of these trips onto transit that would otherwise be auto-based.

The effectiveness of the bus service in serving the Santurce / Old San Juan corridor will be especially important once Phase I of Tren Urbano is completed. Tren Urbano must serve as the backbone of a high quality intermodal public transportation system. The opening of Tren Urbano, as well as any future extensions, will present significant changes that will impact many of the bus routes traveling in the Santurce / Old San Juan corridor. Furthermore, in the face of a dynamic environment, the success of transit service is dependent on both Tren Urbano and the bus services that will complement it. Especially important is the intermodal connection at the Sagrado Corazón station, which will become the major bus-to-rail and bus-to-bus transfer point in the Santurce / Old San Juan corridor. The strongest bus route in the SJMA, Metrobús I, serves this corridor and needs to interface effectively with Tren Urbano at the Sagrado Corazón station while also

avoiding major disruptions to service. Hence, bus service strategies must be built around Tren Urbano including future extensions in order to ensure high levels of service, improve the accessibility of Tren Urbano throughout the Santurce / Old San Juan corridor, maximize the use of Tren Urbano, and increase the role of public transportation in the Santurce / Old San Juan corridor.

1.3 Research Objectives and Approach

The primary goal of this thesis is to formulate a decision-making framework that aids transportation planners and service providers in the implementation of integrated bus and rail services that will maintain and improve high levels of service and ridership growth as the rail system is opened and expanded. In addition, the application of this framework to the San Juan Metropolitan area, and specifically the Santurce / Old San Juan corridor, will ensure that as developments occur over time, Tren Urbano will remain successful in providing high levels of service and attracting additional ridership.

There are several objectives associated with this research:

- Assess the Santurce / Old San Juan corridor to identify the socio-economic, infrastructure, and transportation service characteristics of key service markets.
- Identify and evaluate the critical developments that will have a major impact on the transportation system and the critical issues facing the integration of bus service with the phased implementation of Tren Urbano.
- Develop an analysis framework to evaluate and recommend integrated bus and rail service strategies for a city with a new rail system, based on three points of view: the rider, the public transportation provider, and the general community.
- Present the factors critical to effective strategic planning and implementation of integrated bus/rail service strategies.
- Apply the framework to the Santurce / Old San Juan corridor.
- Evaluate the effectiveness of the Sagrado Corazón station in facilitating future intermodal transfers.

- Present alternative strategies for bus service modifications in the Santurce / Old San Juan corridor.
- Recommend which strategies to implement to ensure continued improvement in public transportation services in the area.

Once the operating environment has been evaluated and the key issues facing the transportation system within the Santurce / Old San Juan corridor have been identified, the analysis and selection of bus service strategies can be conducted. A framework developed for the analysis and evaluation of integrated bus and rail service strategies and their impacts on the transportation system in the Santurce / Old San Juan corridor will be applied. Using this framework, bus service alternatives will be selected to form a strategic plan that guides the implementation of service strategies. In the formation of this strategic plan, there will be specific recommendations on the bus service strategies for the more immediate time periods. However, a framework for decision-making will be established for the longer-run decisions which cannot and should not be made now. The implementation of the strategic plan will help assure both short-term and long-term success of the integrated transportation system in the Santurce / Old San Juan corridor.

1.4 Thesis Organization

The remainder of this thesis is organized into five chapters:

Chapter Two provides a review of literature on strategic planning. A description of the strategic planning process is provided. A specific focus of the review will be on the elements important to the strategic planning of bus services in relation to new rail systems.

Chapter Three presents a service strategy analysis framework that guides the analysis and selection of bus service strategies to integrate the Santurce / Old San Juan corridor with the Tren Urbano system.

Chapter Four presents a timeline chronicling the major developments in the operating environment. Their impacts on the short-term and long-term public transportation system will also be assessed. Finally, the critical issues facing the bus and rail system as a result of these developments will be identified.

Chapter Five focuses on the application of the analysis framework to bus service strategies in the Santurce / Old San Juan corridor. Recommendations will be made on which bus service strategies are appropriate in resolving the critical issues identified for the Santurce / Old San Juan corridor and ensuring the long-term success of the public transportation system.

Chapter Six summarizes the findings and recommendations presented in this thesis and suggests areas for further research.

Chapter 2. Strategic Transit Service Planning

This chapter provides an overview of strategic planning and the strategic planning process as they relate to the planning of integrated rail/bus services. Strategic planning processes are commonly utilized to manage not only organizational decisions, but also operational decisions within an agency. Though general strategic planning concepts are valid in any context, the context of strategic planning introduces a number of different characteristics. A review of previous research is conducted to identify the concepts that are important to the successful planning of an integrated bus-rail system. Additionally, given that transfers are inherently an issue of great importance, and will be so at Sagrado Corazón, a review of the impacts of transfers on passengers is provided.

2.1 Strategic Planning

"Strategic planning is the process of deciding on objectives ... or changes in these objectives, on the resources used to attain these objectives, and the policies that are to govern the acquisition, use, and disposition of these resources," (Anthony, 1965). Anthony's statement outlines the principles of strategic planning– determining what goals need to be achieved and what strategies need to be implemented to achieve them. Strategic planning provides guidance for current decision-making through consideration of the future implications of decisions, as well as the desired future outcome. Strategic planning identifies issues and trends in the current environment, the desired results in the future, and the means of attaining those long-term results. In her thesis, Shaw (1995) noted that "strategic planning is a concern for the whole, a consideration of the future goals for the company (the strategy), and evaluation of different methods by which to achieve those goals (the planning)."

There are two main elements of strategic planning: the strategic analysis, and the strategic plan. First, the development of a strategic analysis involves the determination of a set of

long-term or short-term objectives that the organization needs or desires to achieve. Secondly, the formation of a strategic plan provides an outline of the possible methods of attaining these objectives, a means of evaluating the outcomes and choosing one, and an implementation approach.

With continual evaluation and assessment of the current and future environment, strategic planning is inherently a very dynamic process. Long-term strategic plans look at a number of elements over a ten or twenty year planning horizon. This outlook may also be used with large-scale projects with lengthy implementation times. However, long-term plans also include short-term strategic plans. Typical short-range strategic plans focus on the attainment of objectives in the two to five year planning horizon, with frequent reevaluation and revision of the plans and goals. Short-range and long-range service planning are quite similar, but the former has a shorter time horizon in which the focus is primarily on a comprehensive operational analysis (Hemily, 1986).

Within strategic planning, there are three tiers of decision-making. The first tier, operational planning, encompasses very short-term decision-making. Short-term decision-making takes place weekly, daily, or even in real-time. The second tier consists of short-term plans or tactical planning, and focuses on decisions and plans for the near-term (two to five years). Re-evaluation of tactical plans occurs at least every year, and can be as frequent as once every several months. Long-term strategic planning makes up the third tier and entails a 5 to 20 year time frame and less frequent revision, and requires more substantial advanced preparation.

Strategic planning is often used as a method of reacting to changes in the external environment. Through the evaluation and revision process, service strategies can respond to unforeseen events that may take place. As events arise that influence the provision of service, strategic planning provides the ability to evaluate the impacts of these events and restructure the service strategies to accommodate any necessary changes.

On the other hand, strategic planning can also help to shape the external environment. With strategic planning, changes can be implemented in the short-term to ensure that long-range objectives are achieved. For example, with a large capital investment in a heavy rail system, the ability to react to changes in the external environment is restricted. Hence, strategic planning provides the ability to utilize the large capital investment made in the system to shape the external environment so as to ensure the success of the rail system

Many large corporations that practice strategic planning with a long-term focus also incorporate short-term planning. Trends in the economy, employment, regulation, and other areas are constantly changing with potentially huge impacts on the firm's success, so the firm must be able to react quickly to these developments and make appropriate adjustments to their organization. Therefore, many implementations of strategic planning processes are focused specifically on the short-term in order to handle any uncertainties that may arise. However, the short-term focus must also be incorporated into long-term plans to ensure consistency with the long-range objectives of the firm.

When applied in the context of a transit service provider, strategic planning guides the assessment of the operating environment and the service provided. In the evaluation of the operating environment, specific opportunities and goals that the operator may define over the course of time are identified. Service strategies must then be selected based on their ability to utilize the opportunities available to attain the future goals. The consequences of the strategies that are implemented by the service provider are also assessed to determine the impacts on the environment and future events.

2.2 Strategic Transit Service Planning

Strategic planning in transit agencies occurs at two levels. The first level of strategic planning focuses on the organizational structure and how the transit agency manages change internally. However, in the context of this thesis, the second level of strategic

planning, which focuses on the operational aspect of transportation services, will be emphasized.

There has been a sizeable amount of work done on the planning of transportation services which can be separated into strategic, tactical, and operational levels. Current literature on transit planning reflects this, through topics ranging from the long-term strategic planning of transport systems to the detailed analysis and optimization of network structures and scheduling of individual routes.

When transit services are planned, there is often a focus on addressing the immediate problems facing the agency. Although implementation of rail systems requires lengthy planning and design phases, due to the large infrastructure and resource requirements, the majority of transit systems use buses that travel on existing city streets, and as a result do not have long planning and design cycles. Typical planning horizons for bus service usually range between one and three years, with a maximum of about five to seven years. With shorter planning horizons, transit agencies are better able to predict and accommodate developments in the operating environment.

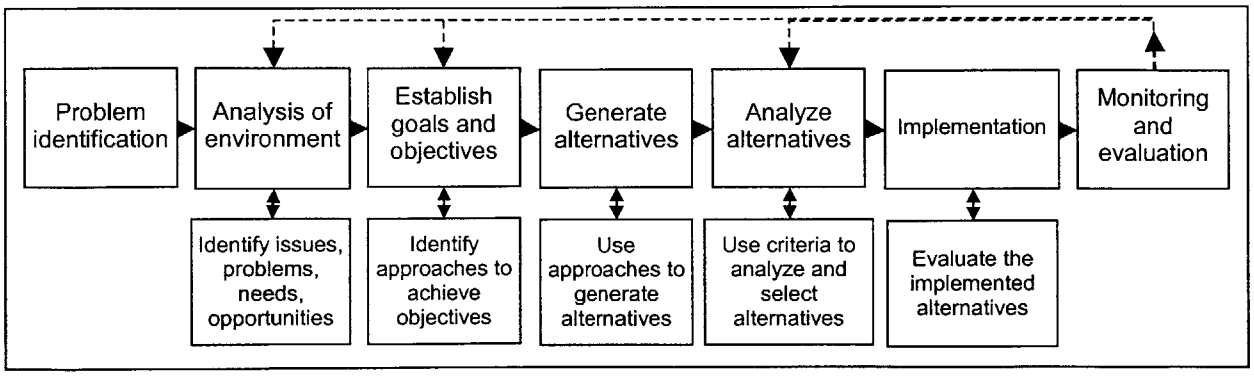
Each of the three tiers of public transportation planning has a different focus and time horizon. Strategic planning is concerned with long-term development of the system including fixed investments such as subway and light rail facilities and major modifications to the bus route network. Strategic planning deals with changes in transit services in light of changes in land use, demographics, employment, travel patterns, traffic conditions, and budgets. Yet, since it is difficult for the public to adapt to major revisions in the bus network, most changes at this level require extensive reviews and must stay in place for some time to achieve their full potential. Tactical planning involves minor route revisions, the structuring of routes in high ridership corridors and the assignment of service frequencies to routes. Tactical planning cycles often occur annually, to provide the opportunity for continual review and modifications to services. Operational planning encompasses all scheduling-related activity, including the production of timetables, the scheduling of vehicles, the generation of daily duties for

drivers, and the construction of rosters. In the context of this thesis, the strategic level will be emphasized, since service changes at this level have the greatest impacts on the transportation system.

In this research, the process used to identify and select bus service strategies for the current and future operating environments, is based on the classic strategic planning process. This process starts with an assessment of the strengths and weaknesses of the agency in light of the threats and opportunities presented by the changing external environment to determine what actions need to be taken to be successful. The scope of the strategic planning process includes the monitoring and evaluation of existing services, the modification of routes, the design of individual services, the development of transit priority measures, the estimation of demand, and coordination with public and political institutions. The purpose of the planning process is to provide information that is most important to decision-makers. Information on how much growth, where, and when it occurs is provided by the planning process and is critical in understanding the issues to be addressed when planning transit services. Moreover, the impacts of planning decisions should be pursued through the evaluation of performance, impact, and implementation aspects of transportation system alternatives (Shaw, 1981).

Many strategic planning texts describe the traditional strategic planning process as consisting of formulation of alternatives followed by comprehensive analyses and evaluation. The planning process can be broken down into seven primary steps, which are diagrammed in Figure 2-1 and summarized below.

Figure 2-1. Traditional Strategic Planning Process



1. *Problem identification and definition*

   This step identifies what broad issues and problems need to be addressed, and why. This step provides direction in the planning process, as the remaining steps will be tailored toward solving the identified problems. Hence, the critical issue here is the way in which the problem is perceived and defined. If the problem is poorly defined, the rest of the process may generate ineffective or irrelevant solutions.

2. *Analysis of overall environment*

   The analysis of the overall environment seeks to identify major trends, issues, problems, needs, and opportunities that affect the agency. The external forces that impact the transit services need to be identified and assessed. Since the operating environment is dynamic, any developments that arise can create problems for the agency. Shaw (1995) stresses the importance of external assessments in the strategic planning process. Through proper assessments, the agency is able to identify the influence of various trends and developments on the service it provides, and how the services can be modified to ensure better service to its customers.

   In addition, with a strategic approach toward service planning, both the current and future state of the operating environment must be taken into account in the evaluation process. An accurate assessment of the current environment is needed to ensure that the transit service addresses all the issues it currently faces. Yet, developments occurring in the future have an impact on which services and options available in the present should be implemented. Any service changes occurring in the present have long-term implications that can only be accurately predicted through a thorough assessment of the future environment.

3. *Establish goals and objectives*

   The formulation of a strategy occurs in this step. Based on the results from the analysis of the overall environment conducted in the second step, a set of desired service objectives are identified. Furthermore, a set of evaluation criteria can then be defined to provide measurable indicators of the progress toward the objective. Priorities must also be established, based on the overall environmental analysis, to identify and address the objectives that are critical to the provision of transportation services. Finally, an action plan is created that pulls together all of the above aspects and outlines the processes and changes necessary to accomplish each goal.

4. *Generation of alternatives*

   The generation of alternatives is one of the most critical aspects of strategic planning and is one area of concern for many agencies implementing strategic planning. In this step, alternative service strategies are generated based on the goals, objectives, and expected state of the current and future operating environments (Step 2). By taking into account the future operating environment, the long-term success of the service strategies can be ensured.

5. *Analysis of alternatives*

   The analysis of the alternatives generated in the previous step is another critical component of the strategic planning process. In this step, alternatives are evaluated using a number of different criteria to ensure that the short-term and long-term impacts of their implementation will help maintain and improve the success of the transportation system. Hence, the results from this analysis will be a set of recommended strategies that are designed to support the agency's short-term and long-term objectives.

6. *Implementation*

Implementation is the next step in successful strategic planning. This stage is operational in nature, as it focuses on tailoring existing services and operations around the selected alternative. The implementation process is also strategic, as extensive coordination, planning, and management is required. A detailed plan of when developments in the operating environment are expected to occur is useful in identifying when service strategies should be implemented. Approaching this process strategically will ensure that the implementation of service strategies will not be disruptive and will be successful in improving existing services.

7. *Monitoring and Evaluation*

It is in this step where the evaluation and monitoring of the implemented alternatives is conducted. With the implementation completed, the impacts of the chosen alternatives on the organization and on the environment can be fully reviewed. However, this stage is another critical area of concern for many agencies implementing strategic planning since it must be conducted with due diligence (Hemily, 1986).

When evaluating alternatives, there are a number of underlying assumptions and uncertainties that must be taken into account. Shaw (1981) identified several factors that need to be accounted for in the evaluation process.

- Population changes
- Land use changes
- Travel demand / ridership
- Resource demand/supply
- Technological innovation
- Institutional regulations and controls
- Socio-economic changes

By considering the factors above, a better understanding of the current and future environment can be formed, resulting in a more accurate identification of each

factors' influence on the selected alternatives. Furthermore, the short-term and long-term impacts of implementing the selected alternatives will also be better understood. This information can then be used to refine existing service strategies to reflect any new developments or to plan and evaluate future service strategies.

Uncertainty

An important motivation for the use of the strategic planning process is to help reduce the amount of uncertainty associated with planning service strategies designed to accommodate both short-term and long-term needs of the transit agency and operating environment. Uncertainty is one major factor that transit service providers have to face when making short and long-term service planning decisions. The presence of uncertainty is acknowledged by many, but the planning process, specifically the design and evaluation of alternatives, often does not consider it explicitly. Transit agencies must address uncertainty and make this a focal point while they formulate their strategic plans. This is especially true when working with short-range plans and when the operating environment experiences periods of constant change. Manheim (1974) identified three areas of change that are relevant to transportation systems: change in demand, change in technology, and change in values. Though these three areas are broadly defined in this context, Manheim supports the point that uncertainty has a major influence on the success of a transportation system, and these changes must be addressed correctly. Shaw (1973) also points out that uncertainty "needs to be strongly addressed and considered in the public transportation decision-making process so that the region knows there is great future uncertainty, that we can highlight some of that *uncertainty*, that every *decision* we make *now closes* a *future option* to some extent, and therefore, our responsiveness."

Mierzejewski (1998) writes about the application of a strategic approach to transportation planning, and how uncertainty can be managed. His paper focuses on the premise that traditional transportation planning processes can be improved to account for biases, errors, and uncertainties that occur in the future. He evaluated the transportation planning process and identified two main sources of error and uncertainty: models are

unable to replicate current and future conditions, and data are unable to be interpreted correctly due to bias. To correct them, he suggests several changes to the transportation planning process:

- Define a strategic vision
- Highlight uncertainties through strategic planning
- Promote flexibility
- plan for incremental implementation

Mahmassani (1983) presents a detailed discussion on uncertainty in the evaluation of transportation systems. He notes that evaluating decision-making under uncertainty cannot be performed merely by applying specific quantitative procedures, but rather by applying a methodology that recognizes the realities that exist in the environment.

The first step in understanding uncertainty in transportation is the identification of the types and sources of uncertainty impacting the decision-making process. Mahmassani identified five different types of uncertainties that affect the evaluation of alternative transportation options:

1. The unknown – consists of new and unforeseen situations
2. Occurrence of exogenous events or states – events independent of the decisions made by the agency, but affecting the operating environment.
3. Randomness in the values of measured or predicted impacts – result of modeling activities
4. Vagueness in the definition of evaluation criteria – quantitative analyses will be inaccurate due to poor results from fuzzy evaluations
5. Uncertainties relating to the normative basis of the evaluation – uncertainties affect the structure or value system against which the transportation options are evaluated.

The impacts of the above uncertainties vary depending on the transportation system and operating environment. Due to this variance, it is difficult to pinpoint and handle the

source and impacts of these uncertainties. However, Mahmassani (1983) suggested four approaches to deal with uncertainty:

1. Reducing uncertainty – acquire more information through continued measurement and experimentation
2. Structuring the decision process (over time) – use of a sequential decision process takes advantage of the opportunity to learn about the transportation system as it evolves
3. Evaluation and design criteria and guidelines – redefine the criteria and guidelines used to define the objectives and goals in the planning process to be more specific to the environment
4. Explicit evaluation techniques – utilize quantitative evaluation tools to account for the presence of uncertainty

Mahmassani presents a good foundation for how further study on the impacts of uncertainty on transportation systems can be conducted. He provides a basic methodology that can be used to break down the various types of uncertainties into components that can be assessed using quantitative procedures. The framework and approaches that Mahmassani identifies in this paper is very representative of the process that should be taken when planning bus service strategically. Mahmassani's approaches are very useful when analyzing and evaluating the potential success of a service strategy and will provide detailed information that will help select the service strategies that are better positioned to effectively accommodate the introduction of a new rail system and ensure a high quality bus-rail interface is provided.

2.3 Strategic Bus Service Planning in the Context of the Phased Introduction of a Rail System

A key problem in the introduction of a new rail system or any subsequent extensions into an existing transit system is the maintenance of high quality service at the bus-rail interface. At the bus-rail transfer point, high levels of intermodal coordination and

integration are necessary in order to ensure that the new rail system will retain and attract riders. The introduction of a new rail system into an existing bus system causes significant impacts that need be anticipated and addressed with properly planned bus service strategies. The introduction of rail systems can introduce large amounts of excess capacity in the short-term that need to be managed effectively to avoid negative perceptions that the new system is not well utilized. With strategic planning, the potential excess capacity and inefficiency issues can be anticipated, and service strategies guiding tactical level adjustments to the bus system that aim to improve the utilization of the excess capacity, ability to adjust to increases in demand, and the effectiveness of the transit system can be designed and implemented.

The new rail system will also have significant impacts on existing riders, as they will not have a high quality alternative to the bus and automobile. However, since rail systems are inherently inflexible and cannot serve all areas, in order for riders to take advantage of the system, a bus-rail transfer is required. This transfer can have profound impacts on the attractiveness of the system not only to existing passengers but also to potential passengers. Hence, in order for the new rail system, and the transit system as a whole, to retain existing ridership as well as generate additional ridership, the service at the bus-rail interchange needs to be planned effectively. Strategic planning of bus service helps the operator to anticipate the potential impacts of the transfer on passengers and design and implement strategies that are focused on minimizing the negative impacts of the transfer.

Planning strategically helps to design bus service strategies that are flexible enough to accommodate both short-term and long-term changes in the operating environment. Short-term changes can be accommodated easily, since information is readily available. While long-term changes are subject to uncertainty, this uncertainty can be reduced with the constant reevaluation of the operating environment and the long-term focus that planning strategically provides. As a result, the reevaluation process is able to provide updated information on the status of the current and future operating environment that will help refine the service strategies to accommodate any long-term changes that may occur. The flexibility of bus service strategies also makes it easy to implement revisions

and refinements. Hence, strategic bus planning combines the flexibility of bus services with the constant reevaluation of the operating environment to provide the ability to effectively integrate the bus system with the new rail phases to ensure the long-term success of the transportation system.

However, no matter how effectively the bus system integrates with the rail system, the residents will still be slow to adjust their travel patterns. As a result, when the rail system becomes operational, there will be an initial period when excess capacity will exist. Though this problem may only be temporary, political pressures may arise to reduce this excess capacity to make the system more efficient in the short-run. Though this short-term strategy may be feasible, it does not provide a good long-term solution to the problem. Eliminating excess capacity immediately is likely to hurt the quality of service provided, and can result in negative long-term implications, such as the inability to sustain and generate ridership. Strategic planning provides the means to account for potential implications of short-term strategies in the development of a long-term strategy. A well-planned long-term strategy will make it easier to argue against counterproductive short-term pressures on the transit system.

Another important component of the planning of bus service around new rail systems is the intermodal transfer. Planning strategically will provide insight into the impacts of transfers on the passengers and the transportation system. Hence, short-term service strategies which anticipate the potential impacts of transfers can result in service changes to effectively prepare the passengers, as well as the transit services, for the increased need to transfer. Implementing service changes early will allow time for both the passenger and the service providers to adjust to the new services; this will help to ensure that service levels remain high, and that a smooth transition between the two systems occurs. As a result, disruptions to service and passenger inconvenience can be reduced, improving the passengers' perceptions and willingness to take transit, which can result in the increase of transit ridership over time.

Strategic bus service planning must also recognize that there are several different perspectives to consider in developing a successful strategy:

- Passenger perspective – Many studies on the planning of bus services focus on operational issues, such as resource scheduling and availability, but may neglect to consider the potential impacts on the passengers' experience. A positive passenger experience is central to ensuring the long-term success of the transit system. Moreover, there are many subsets of passengers that must be served, and service strategies may be altered slightly to accommodate all of them. The different sets of passengers that must be accommodated are the existing set of passengers, potential riders that can be attracted with high quality service, and the set of new riders that are generated with the introduction of the new rail system.

- Operator perspective – Service planning must focus on providing high quality transit services to retain existing passengers and attract additional riders. However, service planning should also utilize new bus technologies and incorporate technological advances when possible. Service strategies should also address the technical aspects behind developments that occur in the operating environment, such as changes in the road network. In addition, the availability of resources, such as operating funding and budget, and vehicles and drivers, influence the planning of successful service strategies.

- Community perspective – Any changes in bus service must be coordinated with other transportation systems and benefit the communities impacted by the changes. The service strategies should improve the accessibility of the community, as well as the mobility of the residents. Any negative environmental impacts due to the new rail system or the modification of bus services should be minimized. Accounting for the communities' needs can help to improve the likelihood that any changes in service will be promoted effectively and encourage passengers to use the new integrated system, and eventually lead to more transit oriented land use patterns.

Service Capacity

In the planning of bus service around the phased rail implementation, it is important that high levels of service are established at the bus-rail interchange. Approaches to providing high levels of service can vary; the operator can provide an adequate amount of bus service capacity at the station to provide seats for all passengers, increase service frequencies of the connecting buses to match those of the rail system, or provide waiting buses with empty seats at the transfer point to accommodate transferring passengers. In addition to service at the transfer point, high levels of service also need to be maintained along the bus routes to ensure that existing ridership levels are not adversely affected. Hence, a critical aspect of bus-rail service planning is to ensure that enough service capacity is provided at the transfer point and along the route to accommodate existing and new bus riders, as well as new riders generated by the rail system. However, the operator is also constrained by the availability of resources to implement these strategies. Strategic planning will help reduce this constraint by identifying the requirements of each strategy so that the operator can adjust its long-range resource plans accordingly.

Service Coordination

One critical aspect of the integration of bus service with a new rail system is the intermodal coordination between the two systems, as it is crucial to the success of the service provided by public transportation system. Coordination between two systems is possible when they "function as if they were ... two parts of one large comprehensive system, with fully integrated route structures, with identical fares for the same distance traveled, with no fare penalty for transferring, and without designed redundancy except where justified for reasons of capacity," (Higgins, 1981). Pratt (1971) approached the issue of coordination at a strategic level. He conducted a study of the impacts of rail transit on bus operations, and found that the diversion of riders from existing bus operations to new rail systems is extensive. In order to handle the impacts, preplanning bus and rail coordination is vital. The extent to which bus service is coordinated with rail

service has a large influence on rail ridership. Pratt also identifies some benefits obtainable through pre-planned coordination between rail and bus systems:

1. Transit service is maximized for all rider groups.
2. Rail line ridership can be improved.
3. Continuity is maintained for essential transit service.
4. Damage to or negative impacts on pre-existing bus operators are avoided.

Without coordinated bus service, Pratt reiterates, "new rail systems cannot provide the overall high level of transit service that the metropolitan area residents are entitled." If bus service remains unchanged, the probability of coordination with new rail systems will be quite low.

Hickey (1992) addressed the coordination of intermodal transfers at LRT stations. He identified that the benefits and effectiveness of a new LRT line can be improved with proper coordination of bus and rail services at a station. Hickey (1992) also noted that "the degree of coordination between connecting services at a transfer site can significantly influence passengers' perceptions of discomfort... An uncoordinated transfer en-route can have the most pronounced effect on ridership." In addition, he presents a list of objectives for intermodal coordination that can be useful in the planning of service strategies around future rail extensions:

- Provide transit routes and services that are responsive to identified passenger travel patterns
- Minimize overall travel time for the most passengers
- Simplify the overall route structure
- Avoid unnecessary disruptions of present routes and services without clearly demonstrated benefits
- Improve the overall operating efficiency of the transit system

Chowdhury and Chien (2000) conducted a tactical level analysis on the design of a coordinated intermodal transit system consisting of rail and feeder bus service. In their analysis, an analytical approach to optimizing headways and slack times of coordinated

routes was developed. Their results showed that the scheduling of vehicles with special attention to the reduction of transfer time is central to increasing service quality. Not only does it allow the operator to provide high quality service, but it also improves the passengers' experience on the transit system. Hence, by designing service strategies that are coordinated with the rail system to reduce the transfer time, high service quality can be ensured, which will make the transit system more attractive to the passengers.

The research conducted by Chowdhury and Chien addresses intermodal coordination issues at the tactical level, but lacked discussion on the impacts of coordination at the strategic level. Pratt, on the other hand, explored the issues affecting effective coordination at the strategic level. However, all recognize that the planning of bus services to ensure coordination with other services is fundamental to establishing a successful transit system. Moreover, with strategic planning, future developments can be accounted for in the planning and implementation of service strategies, resulting in improved coordination and minimal service disruption when the developments do occur.

Lee (2000) addressed a number of strategic-level issues that planners must deal with when coordinating and integrating new rail lines with existing transit systems. In his thesis, Lee (2000) develops a framework to assess the implications of the integration of bus and jitney services with new rail systems. His framework addresses various aspects of intermodal integration, including network design, fare policy, and institutional issues. The application of the framework to the San Juan Metropolitan Area focuses on the evaluation of several service modification proposals and the implications of these proposals on the successful integration of existing bus and público services with Tren Urbano. He finds that fare coordination, transfers, and the incremental implementation of major changes are key factors that must be considered. However, Lee does not fully address the impacts of transfers on the selection of bus service strategies and the discontinuity between the short-term political pressures facing the transit system and the longer-term needs facing the planning of bus services in the San Juan Metropolitan Area. Though the work performed by Lee is similar to the research that is conducted in this thesis, this thesis focuses on the problem that occurs when the opening of a new rail

service dramatically expands capacity and introduces transfers, causing tensions between short-range issues of efficient use of bus services and possible disruption of the existing passengers, with long-range goals of building new ridership. Lee provides a good framework for evaluating intermodal integration issues, but this thesis will build upon his framework by emphasizing the development and selection of service strategies that can be implemented over time to ensure the success of the transit system.

Transfers

Another component critical to the success of an integrated bus and rail system is the impact of transfers on the transit riders. Appendix A provides a detailed review of existing studies on the transfer penalty on users.

The impact of transfers has a direct relationship with the network structure; Newell (1979) identified that the optimal structure of a transit network (e.g. radial vs. grid) depends upon the size of the transfer penalty, as does the assessment of impacts of route changes. The impact of route changes and transfers on users is generally expressed through user disutility. It has been shown that there are two components of transfers that affect the disutility of bus transit trips: the act of changing vehicles and the time it takes to transfer (Horowitz, 1981). This finding has also been supported by Liu (1997), who notes that the impedance of a transfer is comprised of transfer time and a penalty beyond the time cost of transferring. Though both components negatively impact user utility, the act of transferring has been shown to impose a rather large disutility, or penalty.

Transfers, however, are often unavoidable. Vuchic and Musso (1992) state that "transit networks with many transfer opportunities offer passengers much greater selection of travel paths than networks with disconnected lines which involve no transferring." The use of transfers within a given network structure requires that a number of issues be addressed. First, the design of bus routes must be functional and tailored to easily accommodate transfer points. Secondly, the schedules must be coordinated to decrease the negative impacts of transfers. Finally, transfer stations must be laid out such that

transfer time and walking distance, major elements of resistance to transferring, are minimized (Vuchic and Musso, 1992).

Liu, et. al. also concludes that if transfer points were to be used, then the intermodal transfer facilities need to be planned very carefully. The introduction of transfer points has a negative impact on transit ridership, and must be positioned strategically within the transit network to maximize the network coverage while minimizing ridership loss. This view also parallels Vuchic and Musso's view of the importance of transfers in improving service, and the importance of station design and layout in minimizing transfer impacts.

Horowitz and Zlosel (1981) studied how transit riders perceived transfers. The results of their surveys support three conclusions. First, any transfer, regardless of the length of time, greatly reduces satisfaction with bus transit. Secondly, long transfer times are also associated with low satisfaction with bus transit. Third, the penalty associated with a time independent transfer penalty is large relative to the penalties associated with transfer time. Essentially, riders perceive bus transit trips to be worse when the trip requires a transfer, even if the transfer time is negligible.

The studies reviewed above and in Appendix A indicate that a transfer penalty does exists for transit riders, and that this penalty can have a substantial impact on their attitudes toward, and willingness to use, transit. Bus service modifications need to anticipate the potential negative impacts of the transfer and implement service at the bus-rail interchange points that are designed to minimize the three components of the transfer penalty. The first is a constant and is related to the inconvenience of the act of transferring. Much of this component can be improved with a comfortable and convenient transfer environment. The second component is related to the time spent during the transfer. Long wait-times for connecting vehicles increase the total passenger travel time, which increases the inconvenience of the trip and makes the transfer less desirable. Finally, the third component is related to the monetary cost of transferring. Most of the studies reviewed do not explicitly consider the impacts of transit fare on the

passengers' willingness to transfer, but it is clear that free transfers or a discounted transfer fare are incentives that can decrease the inconvenience of the transfer.

In Appendix A, the numerous studies suggest different levels of the transfer penalty. These varying assessments of the penalty show the transfer penalty is highly dependent on the transfer and operating environment, and that a transfer penalty determined for one transit system is not necessarily applicable to a similar system elsewhere. In order to accurately and reliably assess the transfer penalty and its influence on passenger utility, detailed passenger data specific to the location and transit system of interest will be required.

2.4 Summary

Strategic planning helps to reduce the uncertainty associated with future developments so that the transit system will be successful. In this thesis, the impacts of introducing a new rail system into an existing bus network, specifically the introduction of Tren Urbano in the Santurce / Old San Juan corridor, will be addressed with appropriate planning of bus service strategies. The long-term success of the transit system must be ensured and this can only happen if bus service is planned, coordinated, and integrated effectively with the new rail system.

Use of the strategic planning process can reduce some of the effects of the uncertainty prevalent in the analysis and selection of the appropriate service strategies to accommodate the planned introduction of a new rail system and its subsequent extensions. This ensures that bus service strategies will be able to successfully address several critical issues facing the modification of bus service around the implementation of a new rail system.

In addition, the impacts of transfers play a vital role in determining what bus service needs to be provided at the intermodal transfer point. In the context of a phased implementation of a rail system, the transfer issue plays an important role in the

generation and analysis process. Strategic planning provides the ability to assess the short and long-term impacts of transfers on the operating environment, and specifically on overall transit ridership. The bus-to-rail interchange will require transfers, and if they are poorly executed, residents will be discouraged from taking transit. By understanding the impacts of transfers on passengers and the transit system now and in the future, bus service strategies can be designed and selected to reduce the negative impacts associated with transfers, ensure that future ridership growth will not be hindered, and that the transit system will be successful in maintaining high quality service.

Issues related to capacity and coordination at the bus-rail interface can be addressed effectively with the strategic planning of bus service. By anticipating issues related to excess or inadequate service capacity or potential intermodal coordination problems that may arise in the future, service strategies can be designed and implemented in the short-term to reduce the likelihood that these longer-term problems will occur.

Chapter 3: Service Strategy Planning Framework

The identification and analysis of service strategies that will improve the productivity and performance of the transit system in the Santurce / Old San Juan corridor is a critical step in the strategic transit service planning process. Through analysis at the strategic and tactical levels, the factors that influence the selection and implementation of bus service strategies and their implications on the public transportation system can be better assessed.

A planning framework that closely follows the strategic planning process and incorporates the strategic transit service planning concepts discussed in Chapter 2 has been developed to provide a standard process of analyzing bus service strategies and selecting those that will best accommodate developments in the Santurce / Old San Juan corridor. This chapter will discuss the basic components of this framework:

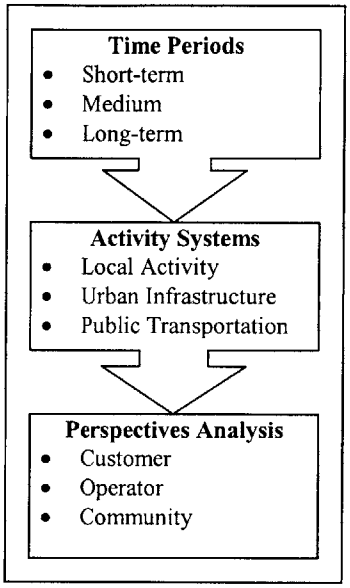
- analysis of the operating environment and the identification of the key issues
- establish the goals and objectives that must be met by the service strategies
- identify alternative bus/rail service strategies
- analysis of the effectiveness of the intermodal transfer environment,
- apply criteria that are designed to measure how well the service strategies fulfill the key objectives to analyze and select the service strategies that best accommodate Tren Urbano developments

3.1 Analysis of the Operating Environment

An evaluation of the operating environment first needs to be conducted in order to identify the key issues that will influence the strategic planning of bus services. As indicated in the strategic planning process in Section 2.2, the opportunities and threats posed by the existing operating environment need to be identified so that they can be effectively managed. The assessment of threats and opportunities will take place on three

levels, with the assessment becoming more detailed with each subsequent level (Table 3-1): time period identification, activity stream assessment, and perspectives analysis.

Figure 3-1. Operating Environment Assessment Process



At the first level, the planning horizon is divided into three time periods that are based on the planned phases of the rail system. With these three time periods, a more focused analysis can be conducted to determine the critical issues in each time period and what needs to take place in earlier time periods to ensure the success of the transit system. The earlier time periods will focus primarily on tactical level decisions that can be made now, based on currently available information. As one progresses farther into the second and third periods, the information becomes less certain, and the focus shifts to the strategic level issues and decisions that need to be made and anticipated. The use of three time periods will help to structure the planning and implementation of short-term service strategies that are also designed to help achieve long-range goals.

The next level of the operating environment assessment focuses on each individual time period. For each time period, any anticipated changes in the operating environment, as well as any threats and opportunities that may arise, are considered classified into the three main activity systems. The first is the *local activity system*. Developments in this stream focus on changes in the operating environment that will result in changes in

demand and ridership on the transit system, demographic shifts, socio-economic trends, and other similar issues. The second stream is the *urban infrastructure system* which deals primarily with developments to the existing infrastructure, roadway structure and network. The final stream is the *public transportation system* developments directly related to the bus or rail system.

The final level of the operating environment evaluation assesses the events occurring within each system and time period, as identified in the previous levels, from three different perspectives. With these three perspectives, the critical issues that have an influence on the success of the bus system and the phased rail system can be identified. The first, most important perspective is that of the customer. It is the customers who are most impacted by changes in the transit system and operating environment. If customers do not perceive changes in the transit system as positive, then ridership may decrease and the success of the system jeopardized. In addition, developments in the operating environment may cause major shifts in travel patterns that will require changes in the transit system.

The second perspective is that of the operator. The operator seeks to minimize the negative impacts of changes in the operating environment on the transit system. Yet, the operator also seeks out new developments as they provide opportunities to expand the reach of the transit system to penetrate new or underserved markets. In addition, major changes in the operating environment also provide a catalyst for bus service modifications to improve and expand the services provided. But, the operator will be constrained by budget and financial resource availability, the availability of equipment and trained vehicle operators, and management capacity.

Finally, the perspective of the community also needs to be considered. The community perspective encompasses the feelings of the local area residents, political institutions, and government. In general, these parties seek to maximize social benefit while reducing costs and negative impacts of any changes that may occur in the transit system or operating environment. The communities also seek to implement developments that will

foster the growth of communities and commerce as well as the formation of new activity centers.

3.2 Generation and Analysis of Service Strategies

Once the key issues influencing the development of the service strategies for a given time period have been identified, the process of generating, analyzing and selecting the appropriate strategies can begin. In the context of this thesis, strategies for transit services in the Santurce / Old San Juan corridor must make special consideration of the phased implementation of Tren Urbano. The introduction of Tren Urbano into the Santurce / Old San Juan corridor presents a number of opportunities and challenges that the service strategies must anticipate and accommodate without causing significant disruption to the existing transit system.

3.2.1 Identification of Objectives

The first step in the service strategy analysis is to establish key objectives for the transit system in each time period. These objectives will guide the planning of bus service changes and will aim to resolve the issues identified for the operating environment in the previous step and help ensure that the long-term vision of the transit system can be achieved. Factors such as travel patterns, developments slated to occur in the San Juan Metropolitan Area, existing transit service, and financial and political issues are important when establishing objectives for the transit system. In the context of the phasing of Tren Urbano and the Santurce / Old San Juan corridor, the following list are some general objectives that apply:

- *Maintain high levels of service*

  There is a need to ensure that changes to the bus system affect all groups positively. Often, service strategies can be directed toward the most important market, and service in other markets may suffer as a result. To ensure that transit system will

remain successful, no service markets should experience a decrease in level of service because of the implementation of the service strategy.

In addition, the service strategies must focus on maintaining high levels of service not only during the peak periods, but also during the off-peak periods, especially during the evening and weekends. It is during these periods when transit service operates at lower frequencies and passengers are more likely to use the automobile. By improving levels of service during these periods, the competitiveness of transit will increase, potentially resulting in an increase in ridership. This objective is particularly relevant for the Santurce / Old San Juan corridor since the city of Old San Juan is a popular off-peak destination.

- *Attract new riders*

  A primary goal of Tren Urbano and the complementary bus service is to attract new transit riders, especially since political pressures demand that ridership expectations be met. Service strategies should be designed not only to attract existing bus riders onto the new rail system but also to facilitate access to the train from points not easily accessible to Tren Urbano.

- *Maintain existing ridership base*

  The opening of Tren Urbano should not cause the existing ridership levels to decrease. If bus service strategies require sudden changes, existing riders may be severely inconvenienced and may be discouraged for taking transit in the future. Thus, service strategies must be designed to attract new riders, as well as ensure that existing passengers are not inconvenienced by providing them enough time to adjust their travel patterns accordingly.

- *Maximize effective use of Tren Urbano*

  Tren Urbano represents a large capital investment and the transit agency must be able to capitalize on its investment and the opportunities provided by this new system. With its ability to provide high quality line-haul service with higher-capacity

vehicles, Tren Urbano can also help to transport passengers more effectively and economically than buses along the high demand transit corridor between Río Piedras and the Santurce / Old San Juan corridor.

- *Maintain high quality transfers*
  As discussed in Chapter 2, transfers have impacts on passengers and their perception of the services provided by the transit system. Strategies must seek to implement services that minimize the transfer penalty that can discourage the passengers' use of transit.

- *Ensure support for future Tren Urbano extensions*
  Because of the large capital investments and time required to implement rail systems, maintaining public and political support for future extensions of Tren Urbano is essential for the long-term success of the rail system. Service strategies that establish a well-integrated transit system can convince passengers, residents, and political institutions that transit is a worthy investment and that future extensions will help increase the benefits provided by the system.

3.2.2 Intermodal Transfer Environment Analysis

An important factor in the planning and coordination of bus services with the phased implementation of a rail system is the intermodal transfer. Not only do transfers improve the transit services' ability to expand its coverage, they are necessary in the integration of bus and rail systems. In addition, transfers can also enhance the transit system by expanding the number of options and service levels provided to the passengers and residents of the SJMA.

However, in addition to improving the quality of the bus service at the intermodal transfer point, the environment within which the transfers take place is also a very influential factor. Transfer facilities are important because they connect the small

capacity feeder service systems with the large capacity line-haul systems. They promote passenger accessibility and enhance the utility of the entire transit system. An efficient passenger interchange between modes will help to promote passenger use of transit. No matter how well the intermodal services are coordinated, if passengers are forced to transfer in an unfriendly and ineffective transfer point, they may be discouraged from using a route that requires a transfer. As discussed in Section 2.4, the transfer penalty for transit users may be exacerbated with a poor transfer environment. In the worst case, the transfer environment can be poor enough to dissuade passengers from taking any form of public transportation and cause them to rely on other modes. Hence, there is a need to ensure that the transfer environment is designed to handle transfers effectively before planning what bus services should be offered to and from the transfer point. An analysis of the layout of the intermodal transfer environment will provide insight into what elements are needed to ensure that service strategies that introduce transfers will be successful in maintaining existing ridership and attracting new riders.

The service strategies are designed in part, to meet the changing needs of the user. The evaluation of transfer facilities is one key step in the design process. Public transportation riders value safe, convenient, and comfortable intermodal connections. Riders do not seek to add transfers to their existing trips unless there is no alternative or the transfer enables them to take advantage of a mode that offers a performance advantage for a given trip. When a transfer is introduced into an existing trip, a number of factors, such as routes, physical environment of the transfer location, and reliability of service are added to the decision-making process of the rider.

In the selection of the service strategies, the intermodal transfer environment needs to be taken into account. As the major intermodal transfer point in the Santurce / Old San Juan corridor, the Sagrado Corazón station's ability to facilitate transfers between the bus system and Tren Urbano Phase I is vital to the success of any proposed strategy for the Santurce / Old San Juan corridor. As a result, an emphasis is placed on the attributes related to the intermodal transfer environment.

Well-designed transfer stations with coordinated services have been accepted favorably by passengers. Thus, passenger requirements should be given priority in the design of the station. Yet, two other concerned parties- operator and community- also have requirements that the station must provide for. The requirements for each of these three parties are defined below.

Passenger Requirements

The transfer penalty review in Chapter 2 highlighted several key characteristics of the passengers' transit trip that can influence the passengers' willingness to transfer. Applying these characteristics to the context of an intermodal transfer station, there are several requirements that need to be met in order to ensure that the passengers' transfer experience is one that will encourage continued use of the transit services. In considering the passenger requirements, it is useful to focus explicitly on the needs of existing customers as well as the new riders the system hopes to attract.

1. Travel time - minimum transfer time, short distances between modes (cross platform boarding), high frequency connecting vehicles, and/or good schedule coordination
2. Convenience - free transfers, adequate circulation patterns and capacity, easy boarding and alighting, minimal level changes, in-station concessions, pedestrian paths should be as direct as possible
3. Comfort - aesthetically pleasing design, weather protection (passenger shelters), large platforms to reduce crowding, and minimal level changes;
4. Safety / security - good visibility and well lit gathering areas to prevent crime, location in a desirable area
5. Fare policy - minimize monetary costs of transferring, discounted/free transfers
6. Passenger information - static and dynamic signs improve passenger comfort and convenience

Operator Requirements

The operator's requirements that the station design must satisfy are:

1. Service capacity - efficient access and egress, bus berths/staging areas, parking lots, kiss and ride lanes, priority bus lanes, flexibility of operation
2. Station design - utilization of the station area from the perspective of facilitating effective service, maximizing public security, provide customer information

Community Requirements

The relationship and impact of the station on its immediate surroundings is a concern of the communities located around the station. The transfer facility can serve as the center of community development. It can be the focal point of the local transportation network and the center for governmental, cultural, commercial, or other development. As a result, the communities also have a set of requirements that the station should meet:

1. Station design - attractive and aesthetically pleasing, quality design, integrates well with existing neighborhoods
2. Improve the land use in the local surroundings - stimulate retail, commercial, residential, and recreational developments that improve viability and attractiveness of the neighborhood
3. Environmental impacts - minimize negative impacts (noise, congestion)
4. ADA compliance

3.2.3 Infrastructure Analysis

Since the majority of bus services utilize the existing road network, bus service strategies are heavily dependent on the available infrastructure. The service strategy must be implemented within the constraints of the current infrastructure and road network in the

Santurce / Old San Juan corridor. If a strategy requires bus services through highly congested areas, on poor roads or through undesirable areas, then its implementation may not be feasible. There are several factors that should be considered when evaluating the infrastructure of the Santurce / Old San Juan corridor:

- Service strategies should seek to take advantage of existing rights of way that are reserved for transit use. Since buses are constrained to operate on the existing road network, the use of protected right of way provides a means to bypass heavily congested areas and major traffic bottlenecks. As a result, the utilization of such right of way is important in improving service reliability, reducing service disruptions, and establishing high levels of service. In addition, in high demand corridors where the bus service must compete with the automobile, the availability of reserved right of way will also increase the competitive advantage of the bus system.

- In addition to utilizing existing rights of way, the service strategy should also seek to preserve any available rights of way for future transit use. First, preserving the right of way will help ensure that bus services will continue to maintain service reliability and levels of service. Secondly, the strategies need to plan for future phases of Tren Urbano and expansion of the bus system, and if rights of way along high demand corridors have been preserved for transit use, the changes to the system can be implemented without having to spend time and money to obtain the necessary rights of way.

- The service strategies can only utilize a Tren Urbano station as an intermodal transfer facility if it is well integrated with the surrounding road network. Proper integration with existing roadways will facilitate the process of entering and exiting the station area. If access to/from the surrounding roadways are hindered due to congestion, then the reliability and quality of the bus services provided will be compromised.

- In the specific case of Santurce/Old San Juan corridor transit amenities such as upgraded bus shelters, new AVL systems, the potential development of exclusive bus

lanes at the bridges to the Isleta and other important infrastructure issues should be reviewed and implemented if possible.

3.2.4 Network Structure Analysis

The analysis of the bus network structure is the main component of the service strategy planning framework. There are three main components in this section: the identification of criteria used in the analysis, the analysis of the relevant routes and respective alternatives, and the formation of a strategic plan for bus service in the Santurce / Old San Juan corridor.

Criteria for Analysis

After establishing broad objectives, criteria need to be developed to measure how well the bus service strategies fulfill those target objectives. Criteria fall into the general categories of levels of service, ridership, and resources, and additional criteria or categories may also be applicable depending on the operating environment and bus route being analyzed.

- *Level of Service Criteria*
    - *Travel time* - Trips that involve transfers can increase waiting time and total time in travel, which can discourage ridership. Service strategies should aim to decrease the amount of time spent in travel, and their implementation should result in considerable improvement over existing travel times.

    - *Service frequency* - While service frequency is a function of demand along a given route, it is also a factor that influences the passengers' decision to take transit. The reallocation of resources to improve service frequencies can reduce overcrowding in high demand corridors and improve service in underserved areas by reducing waiting time and the uncertainty and anxiety

associated with waiting, making transit more attractive to a larger number of existing and potential customers.

- *Service capacity* - The service strategy needs to ensure that the capacity of the bus system is adequate to handle current and future passenger demand along the route. Increasing service capacity along the bus routes will help to reduce crowding and improve levels of service. In addition, at the intermodal transfer station, adequate service capacity needs to be provided to ensure high levels of service (i.e. short transfer and wait times, quick loading and unloading, minimal crowding, available empty seats) to the transferring passengers. If levels of service are not continually improved, existing and potential riders may be discouraged from using the transit system.

- *Transfers* - The number and quality of the transfers will have impacts on the service provided by the operator as well as on the passengers and their perception of the transit system. As discussed in Chapter 2, the presence of a transfer imposes a transfer penalty on passengers that can discourage their use of transit. In addition to improvements to the transfer station, service strategies need to minimize the number of transfers as well as maximize the convenience of the service provided to transferring passengers.

- *Ridership Criteria*
  - *Ridership impacts* - Tren Urbano and the associated bus service modifications will have an impact on ridership. The number of existing and potential customers that are affected by a service strategy need to be determined, and the service strategies will need to ensure that a minimal number of the customers are inconvenienced. Service strategies that result in better service levels will generally result in ridership gains. Moreover, the strategies must not focus just on satisfying the needs of the existing ridership base to ensure that they continue to use transit, but must also aim to attract additional ridership from new or underserved markets.

- *Transit fare impacts* - A large factor which influences the passenger use of transit services is cost. Increased fares imposed on the passenger due to transfers are considerations in service strategy design. The reduction of costs of the transfer can also be a method of making the transfer more attractive to the passenger. Customers may be unwilling to use transit if the implementation of service strategies results in significant increases in cost. As a result, revised fare policies may need to be developed and implemented along with service changes. Free or discounted transfers will help facilitate transfers and improve ridership on both Tren Urbano and the bus system.

- *Resource Criteria*
  - *Vehicle and personnel requirements* - The availability of buses has a substantial influence on the design of service strategies. Service strategies must be structured around any constraints on the number of buses available. If the service strategy requires that routes be redesigned, service be increased, or new routes be implemented, additional buses may be necessary. The implementation of the service strategy may free up a number of vehicles that can be reallocated to other routes. Yet, extra buses will be needed to maintain service quality and avoid service disruptions during peak periods. Since the transit system needs to provide high quality service at all times in order to remain successful, additional vehicle operators will also need to be available to improve the quality of off-peak service.

  - *Operating costs and subsidies* - The operating subsidies and funding available for the provision of service and the costs of operating and implementing the service strategies are all important concerns. The timing of funding availability is a very important determinant of when service strategies can be implemented. In the context of the SJMA, a large capital investment has already been made in Tren Urbano and funds have been allocated for the improvement of the complementary bus system. Yet, availability of funding

for bus system improvements will become more important as changes are implemented. If service strategies call for changes that significantly increase operating costs, these needs must be identified and provided for in advance, or the transit agency may not have the funding or subsidies available to provide the service.

Analyze Bus Routes

After identifying the important issues that need to be resolved and the objectives for the transit system, the analysis of the existing bus services and the identification of the applicable service strategies can be conducted. In this analysis, only the major trunk routes that operate along the Santurce / Old San Juan corridor will be emphasized, though this planning framework can also be expanded to include all bus routes that operate in the corridor. In addition, the analysis of the major trunk routes will be at the tactical level, which provides the level of detail required to make an adequate assessment of the existing route, potential impacts due to Tren Urbano, and strategies available to resolve these potential impacts.

- *Service Market Identification*

The first step in the bus route analysis is to identify the major markets that are served by the route being analyzed. As indicated in the operating environment assessment, in the Santurce / Old San Juan corridor, the major markets are Río Piedras, Hato Rey, Minillas, and Old San Juan. By identifying the primary service markets served by each route, the analysis can be better focused on assessing the impacts of bus service modifications on the passengers, service provider, and communities within the service market.

- *Route Analysis*

The criteria listed in the previous section will now be used in the route analysis to identify the characteristics that are important in the service strategy selection process. The criteria are applied to the existing routes to determine the current service characteristics as well as whether service changes are required. In addition, the analysis

will be conducted by period of day: peak, midday, and evening/weekend. Since, in each time period, the operating environment varies dramatically in the passenger demand and services required, service strategies that apply to one period will not necessarily be the best for another period.

- *Service Strategy Identification / Analysis*

In the identification of the bus service strategies that are available for a given route, several components need to be taken into account. The service strategies need first to address the service characteristics that need improvement, as identified in the analysis of the bus routes. Secondly, the service strategies must be designed to maintain high levels of service, minimize passenger inconvenience and improve the use and perception of the entire transit system in light of the anticipated impacts due to Tren Urbano. Finally, the service strategies must also seek to fulfill the target goals of the transit system.

The service strategies must consider the desired coverage of the transit system. The identification of the present corridors of highest travel demand and the recognition of which corridors will have high demand in the future will influence the design of the service strategy in addressing the present and future needs of the transit system and the residents of the SJMA. Improving service in these heavily traveled corridors is critical to the success of the service strategy in retaining existing ridership and attracting more residents onto transit. In addition, areas that are not currently being served or are underserved create opportunities to expand the potential customer base and improve ridership.

Service strategies must also consider the impacts of the transfer penalty on the users. A transfer penalty does exist, and given that transfers are necessary in order to integrate successfully with Tren Urbano, as well as provide effective transit service in the Old San Juan corridor, the negative impacts of this penalty needs to be identified and mitigated. Strategies to implement free transfers, decrease wait times or to ensure that empty seats on buses are available for transferring passengers, for example, will not only improve the

services provided by the transit system but also will improve the passengers' intermodal transfer experience and their perception of transit.

In the analysis of the bus service strategies, each strategy should be evaluated based not only on the criteria identified in the previous section, but also on their ability to satisfy the objectives identified for the transit system. Each criterion is applied to the service strategies identified for each route to identify the pros and cons of each option for the route and service market in question. The comparison of each service strategy with the existing (base) service will identify the strengths and benefits of each strategy as well as their attractiveness relative to other strategies for the given bus route.

Formulate Strategic Plan

The strategic bus service plan consists of the combination of the attractive service strategies as determined in the bus route analysis for each period of the day. The strategic plan is the set of service strategies that best satisfy each of the above criteria and the objectives identified for the transit system. The selected service strategies, as well as the strategic plan, must also ensure that the short-term needs are met while also meeting the long-term goal of creating a transit system that is successful in providing high quality service and generating ridership.

In selecting which service strategies will comprise the strategic plan for a given period of day and Tren Urbano phase, several factors are taken into account. First, the strengths and weaknesses of each service strategy as identified in the bus route analysis is the most important consideration. All the service strategies that comprise the strategic plan must capitalize on the benefits, as well as compensate for any weaknesses, that may exist for each strategy. The impacts of implementing the service strategy need to be weighed and compared to the other strategies to ensure that when the strategic plan is implemented, any negative impacts to the passengers, transit system, or the Santurce / Old San Juan corridor are minimized

Strategies that can be implemented incrementally are important in reducing the negative impacts of service changes on passengers. Allowing the residents of the SJMA and passengers time to adjust and reducing their inconvenience, helps to ensure a smooth transition between the old and new systems. The adjustment period of the residents and passengers is important in ensuring that the transit system will be used. Residents and passengers will require time to become familiar with the new system and to adjust their travel patterns accordingly. If the service changes called for by the strategic plan are not severe and do not disrupt existing travel patterns, the residents and passengers may be able to adapt to the changes quickly. As a result, the operator may be able to implement the changes required by the service strategies simultaneously, reducing the amount of time required for the implementation of the strategy.

In addition, the feasibility of implementing the service strategies in conjunction with Tren Urbano needs to be assessed. A complex service strategy, such as a major overhaul of the entire bus network, will require additional time for planning and implementation. Major service changes may require additional time to procure additional vehicles or operating funds. Extra time may be required to ensure that vehicle operators are fully trained on the new system. Aggressive marketing campaigns need to be planned and executed to inform residents and passengers of the new service; the more complex the changes to the existing bus system, the more time will be required to educate the users of the system.

Evaluate Strategic Plan

When determining which strategies are best suited for a particular operating environment, they must be thoroughly evaluated based on a number of components. First, as discussed previously any service strategy needs to be evaluated based on its ability to satisfy the objectives as well as provide high levels of service, generate ridership, and utilize operating resources effectively.

Secondly, the service strategy needs to be evaluated based on its strategic contribution. That is, the service strategy must ensure that the long-term goals of the transit system will be met while also accommodating the short-term needs of the passengers, operators, and communities and government institutions. The service strategy needs to include short-term improvements to the transit system that are designed to help establish and maintain the success of the transit system over time. If the service strategy is strictly focused on accommodating the short-term developments in the operating environment without considering the long-term implications on the transit system, the future success of the transit system cannot be ensured.

Finally, the service strategy should be evaluated from a number of perspectives; the strategy needs to satisfy all parties affected by changes in transit service in order for it to be successfully implemented and adopted. In the evaluation of the applicability of service strategies for a specific origin-destination market, a number of social, political and economic factors must be taken into account including:

- impact on existing customers,
- marketability of services,
- potential for new ridership,
- impact on resources (costs and vehicle requirements),
- technical feasibility (limitations of technology, infrastructure, land use), and
- political feasibility (impacts of changes on neighborhoods).

Since the implementation of an alternative can have a number of repercussions, it is convenient to assess the alternatives and any associated impacts from various perspectives to ensure that the alternative selected for implementation will be the one best suited for the market in question. The above factors can also be grouped into three categories that are based on the three parties that are the most affected by the service strategies. Identified below are the perspectives of the three parties that are important in the evaluation of the selected alternatives.

1. *Passenger perspective*

   From this perspective, the level of service variables that impact the passengers' travel experience are evaluated. In order for the bus service to continue to be attractive to existing and new riders, service strategies must aim to minimize the number of transfers, travel time, passenger wait time, and costs, while maximizing passenger comfort and level of service.

   There are also many other service related factors affecting passengers' perception of transit services that service strategies must accommodate. Service reliability and frequency are two such factors. Other factors that can influence the passengers' willingness to use a particular service include crowding on vehicles, the safety and security of the vehicles and waiting areas, as well as the service quality of modes transferred to.

2. *Operator perspective*

   Service strategies are assessed from the perspective of the transit agency that operates the bus service in the market. This perspective has a primary focus on the operational factors that influence the quality of the bus service that the agency provides, such as operating costs, resource availability, service frequency and reliability, peak vs. off-peak service quality, and intermodal coordination. Other concerns that the operator will have to consider when designing service strategies include the availability of right-of-way, the level of use and integration with the existing road network.

3. *Community perspective*

   This perspective takes the institutional point of view, in which the governmental and public views of the service alternatives are assessed. When service is improved in existing markets, and created in new markets, there is the potential for transit-oriented development that utilize the improved accessibility provided by the bus service. Popular bus stops or transfer points provide areas where commercial, retail, and residential developments can be established and easily accessed by many, resulting in the improvement of the vitality of the local area,

major transportation corridors, and activity centers, potentially attracting more riders. In addition, the overall acceptance of the new services by the community at-large is a very important factor. New service strategies may bring about unwanted environmental impacts, which hurt their acceptability.

Institutional barriers to the implementation and acceptance of service modifications also influence the applicability of a service strategy. Issues such as fare structure, marketability of transit services, competition to the new rail system, and the costs of providing the desired services are very important. Institutions would also like to see service strategies that, when implemented, yield immediate benefits to the communities and positive impacts on the transit system.

There is also a tension between the operator and government in regard to the success of the investments made in the transit system. In the case of Tren Urbano, on opening day, ridership will be far below the eventual forecast levels. Ridership growth in response to the new levels of service will take time to develop. Customers do not change their patterns immediately, and land use adjustments will take longer to occur. Consequently, excess capacity on the transit system, especially on the rail system, will be present. However, from a short-term perspective, low ridership numbers may be viewed as the systems' inability to attract riders and excess capacity may be viewed as a waste of resources, generating political pressures to cut service. However, since it will inevitably take time to achieve the forecast ridership on the transit system, service levels should not be reduced. As ridership gradually increases over time, the extra capacity will be needed to ensure that crowding is minimized and high levels of service are maintained. If the government desires that the transit system reduce excess capacity to improve its short-term cost-effectiveness, levels of service will be reduced, and riders will be inconvenienced, interfering with the long-range goal of increasing ridership. In any case, high levels of service need to be provided in order for the transit system to appeal to current and future riders, resulting in increased ridership growth and future success of the transit system.

Chapter 4. The Santurce / Old San Juan Corridor

This chapter provides information on the current and future Santurce / Old San Juan corridor that will be useful in the service strategy analysis. In characterizing the Santurce / Old San Juan corridor, several key markets that are directly affected by the introduction of Tren Urbano will first be identified and discussed. Secondly, developments planned for the local activity system, urban infrastructure, and public transportation system in the Santurce / Old San Juan corridor will be discussed and their impacts on the provision of transit services will be assessed. This assessment will help form a picture of the expected state of the transit system in the Santurce / Old San Juan corridor as each phase of Tren Urbano is completed. This long-range vision of the transit system will then be used in the service strategy analysis to help guide the analysis and selection of bus service strategies for the phased implementation of Tren Urbano.

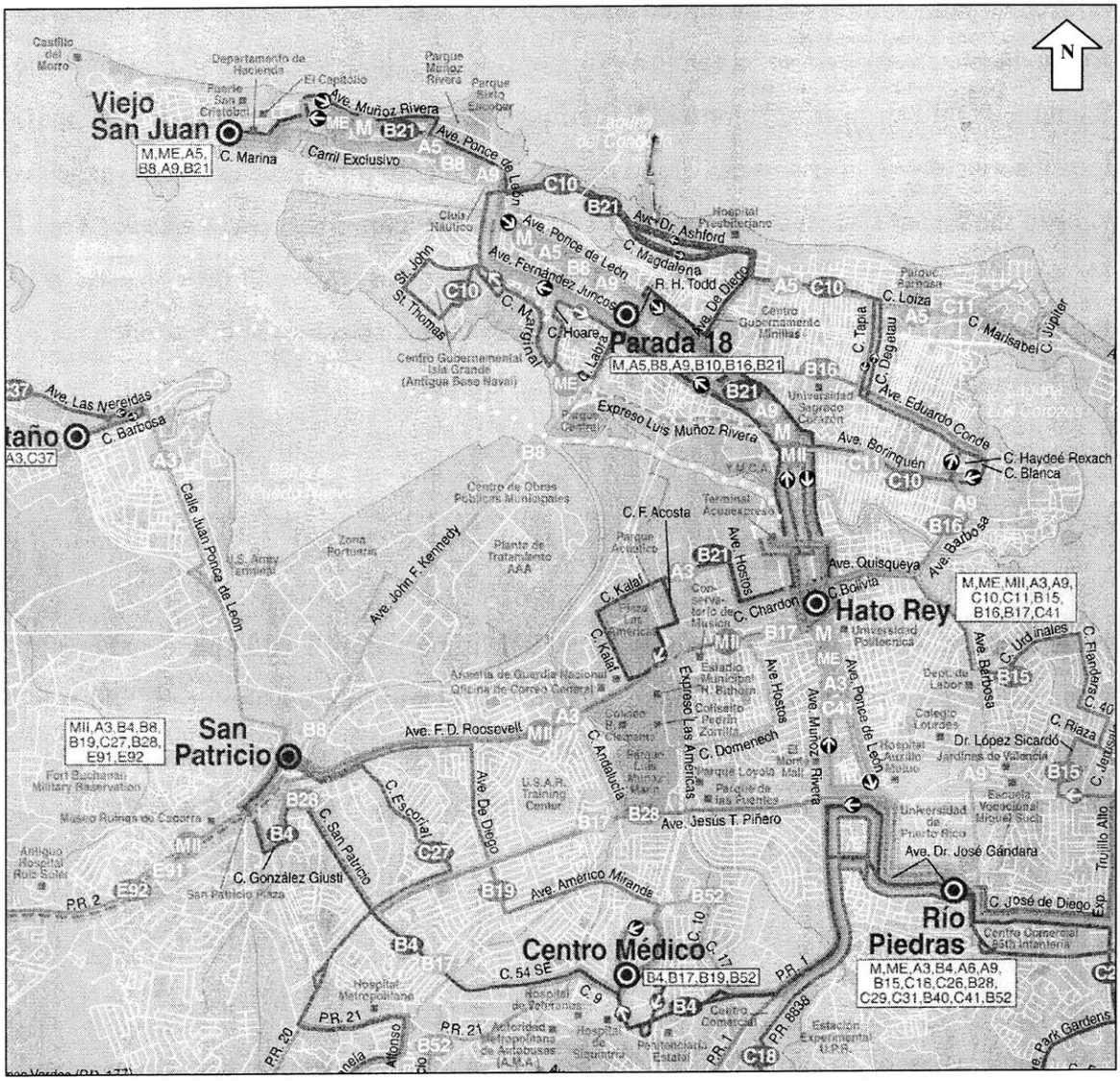
4.1 Background

In this section, the key service markets that will be impacted by Tren Urbano and bus service changes are identified. Major developments planned for the Santurce / Old San Juan corridor are also reviewed. Finally, the time periods that are used in the planning and organization of bus service strategies are detailed.

4.1.1 Service Markets

The municipality of San Juan is characterized by high-density development concentrated in the urban centers of Old San Juan, Santurce, Hato Rey, and Río Piedras. These major activity centers form the "spine" of the SJMA and generates most of the vehicular traffic and transit trips in the metropolitan area (Figure 4-1). As the northern portion of this "spine", the Santurce / Old San Juan corridor connects the historic city of Old San Juan

Figure 4-1. Bus Routes Between Old San Juan and Río Piedras



to Sagrado Corazón, which is located on the southern edge of Santurce. In addition to Sagrado Corazón and Old San Juan, the Santurce / Old San Juan corridor also encompasses other activity centers such as Condado, Miramar, and Minillas.

Bus service in the Santurce / Old San Juan corridor needs to serve the major activity centers of Sagrado Corazón, Minillas, and Old San Juan. Additionally, high levels of bus service are also required from the Santurce / Old San Juan corridor to two major activity centers located south of Sagrado Corazón - Hato Rey and Río Piedras and beyond to Bayamón and Carolina. To narrow the focus of this service strategy analysis, the application of the planning framework will be specifically on the transit services operating in the Río Piedras to Old San Juan service market.

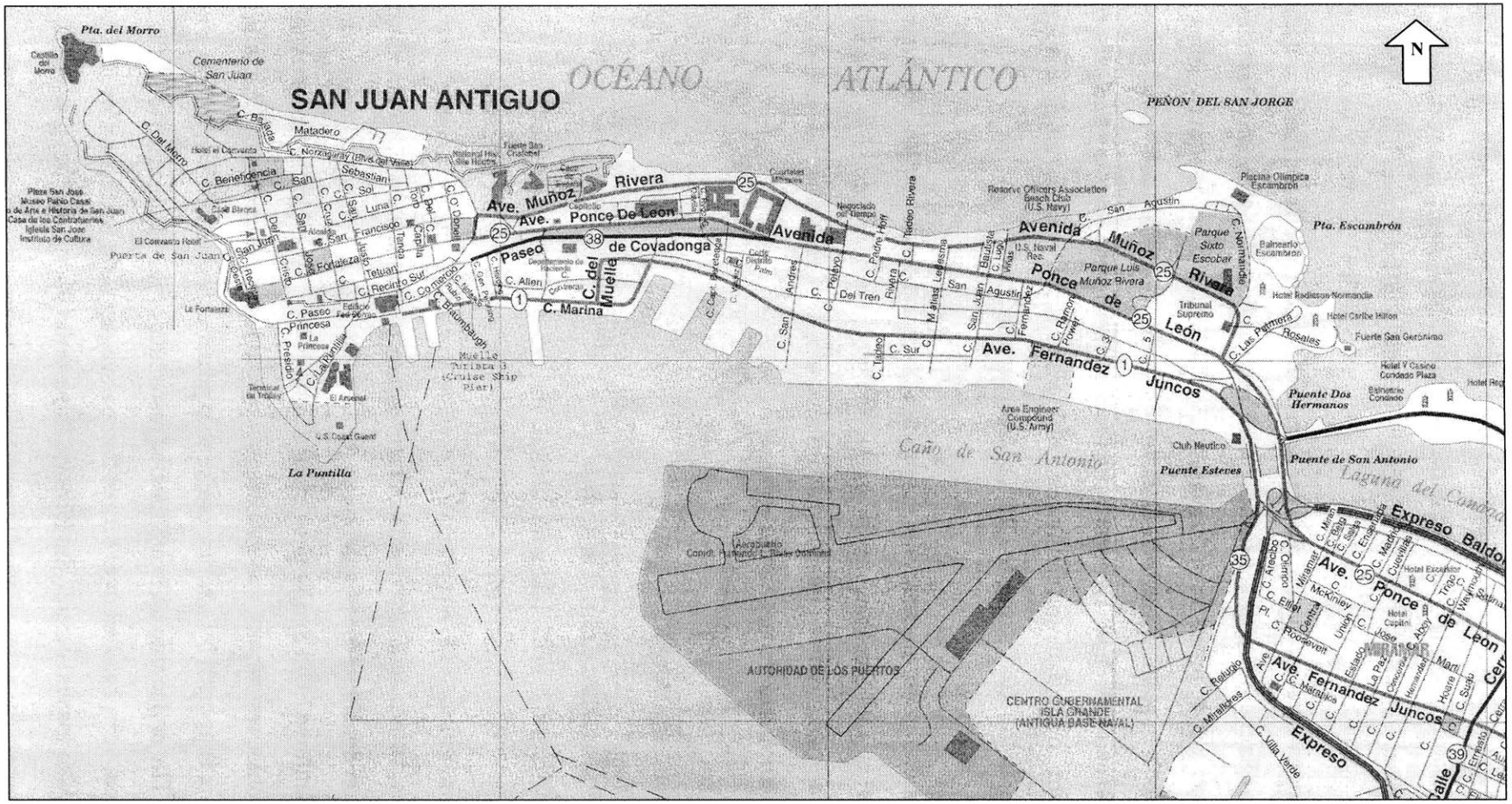
As a foundation for this analysis, the major activity centers in the Río Piedras to Old San Juan market- Old San Juan and the Isleta, Santurce, Hato Rey, and Río Piedras- need to be characterized. Three elements can be used to assess each area: socio-economic, infrastructure, and transportation service.

Old San Juan / Isleta

- *Socio-economic characteristics*

The Isleta corridor is the historic, cultural, and governmental center of Puerto Rico consisting of the ancient colonial city of San Juan with adjacent properties (the Historic Zone), and Puerta de Tierra (Figure 4-2). The Historic Zone is characterized by historic structures, commercial activity, tourist-related recreational activity, and medium population densities; the population in the Old San Juan/Isleta area is approximately 9,700 (Santurce / Old San Juan corridor Study, 1998). Also in this area are numerous shops, banks, restaurants, and galleries supported largely by tourism. The tourism element is supported by a strong cruise ship presence, since Old San Juan is a major port-of-call. The cruise ship piers are located just south of the Historic Zone and in the 1996-1997 fiscal year, handled over 1.1 million passengers (Old San Juan Corridor Study, 1998). Also located outside the Historic Zone is the Puerta de Tierra, which is a

Figure 4-2. Old San Juan and Isleta Areas

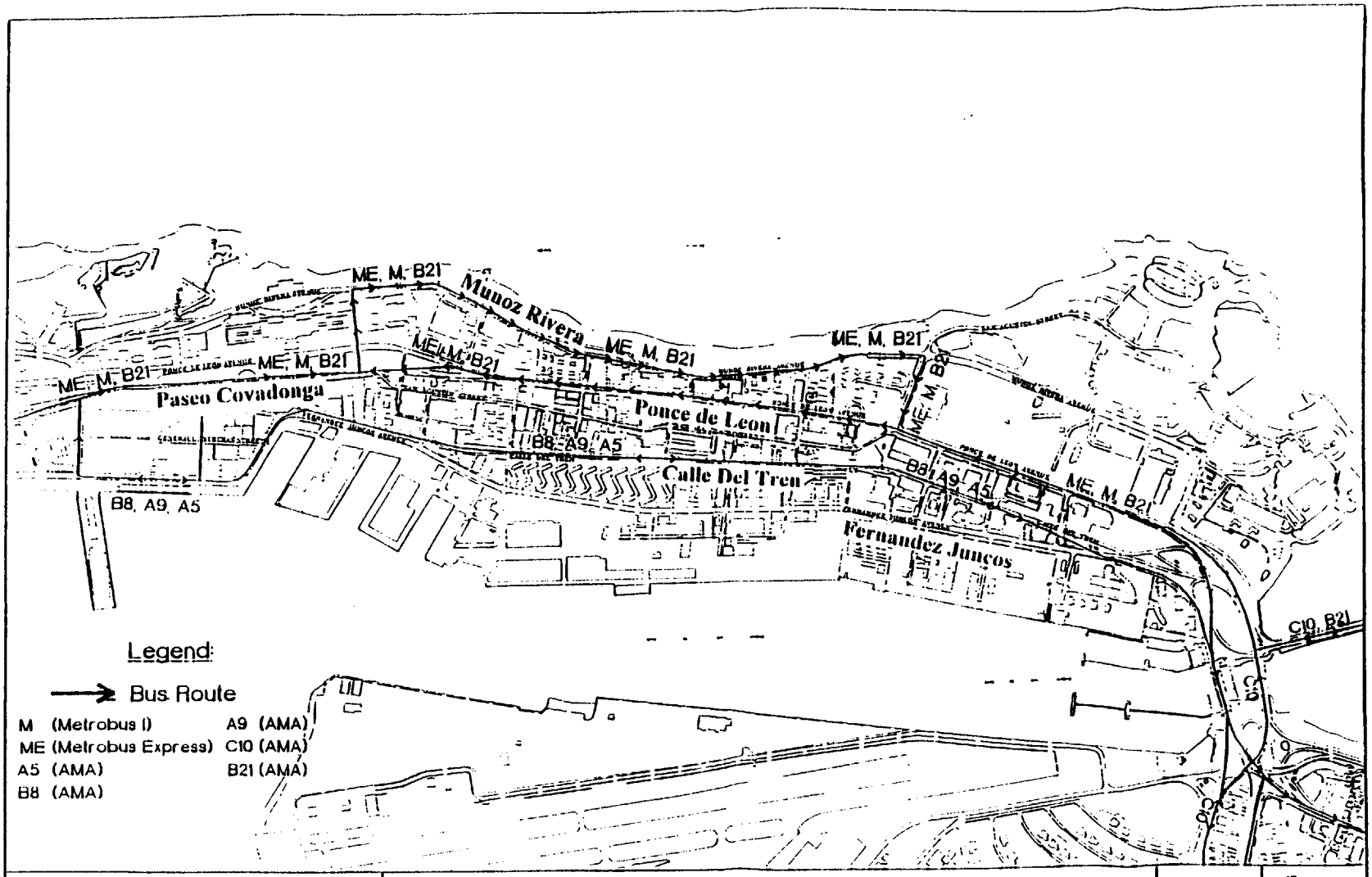


large stretch of land east of the Historic Zone. The Puerta de Tierra is composed of extensive holdings by the Government of Puerto Rico, and includes varying land uses, from public housing to hotels, condominiums, commercial activity, and waterfront and cargo activities.

The Old San Juan area also maintains a high level of recreational and commercial activity during both peak and off-peak periods. The government offices and other businesses located in and around Old San Juan and the Isleta have close to 10,000 employees (Santurce / Old San Juan corridor Study, 1998) that generate large volumes of peak-hour traffic on the major arterials and local streets. Additionally, with a high concentration of museums, restaurants, shops, hotels, and other recreational attractors, Old San Juan is a major destination for tourists and locals alike and generates tourist and recreational traffic that is particularly heavy on weekends. The recreational and vehicular traffic to Old San Juan is especially high when special events, such as the Three Kings and Calle San Sebastián festivals, occur.

- *Infrastructure characteristics*

There are three main arterials that run along the Isleta to Old San Juan: Ponce de León, Fernández Juncos, and Muñoz Rivera Avenues (Figure 4-3). Before entering the Isleta, Ponce de León Avenue serves as a one-way boulevard that handles vehicular traffic traveling north to Old San Juan. However, once on the Isleta, Ponce de León Avenue serves as an outlet for vehicles heading southbound away from Old San Juan. The northbound traffic is diverted onto Muñoz Rivera Avenue, which is located north of Ponce de León Avenue. A contraflow lane currently exists on both Ponce de León and Muñoz Rivera Avenues for use by buses. The third main arterial running along the Isleta is Fernández Juncos Avenue. Fernández Juncos Avenue runs south of the other two main arterial streets, but unlike the other two, it accommodates bi-directional traffic flows.



Old San Juan
Public Bus Routes

Figure
4-3

In addition to the main arterials that handle all vehicular traffic, an old railroad right of way known as Calle del Tren, is currently available for use by transit vehicles. Calle del Tren travels through residential complexes and industrial areas located along the Isleta. Though use of this right of way could improve the bus services in the area, it is now seldom used due to problems with its physical condition as well as the safety and security of the drivers, passengers, and vehicles traveling on it.

All the main streets along the Isleta terminate at the edge of the city of Old San Juan at the Covadonga bus terminal. Aside from a small tourist trolley circulation service, public transportation is virtually non-existent within the old city with the narrow streets making it difficult for large vehicles to operate.

- *Transportation service characteristics*

Old San Juan and the Isleta are served by a number of transportation modes, but the primary means of access for most residents from outside the area is automobile. In terms of public transportation, access to the city and Isleta from other areas is provided primarily by AMA and Metrobús services. The current modal split of commuter trips to the Isleta is presented in Table 4-1.

Table 4-1. Modal Split for the Old San Juan/Isleta Area

	Automobile	Bus	Público
Old San Juan/Isleta Area	63%	32%	2%

Source: U.S. Census data (1990)

Currently, six bus routes (Metrobús I, Metrobús Express, A5, A9, B8, B21) terminate at Old San Juan; four of them are high frequency trunk routes (Metrobús I and Express, A5, A9). The two Metrobús routes travel the entire length of the corridor from Río Piedras to Old San Juan. Acuaexpreso also provides access to Old San Juan via ferry from Cataño, which is located southwest of Old San Juan across the Bay of San Juan; the service from Hato Rey has been suspended indefinitely. Within the historic city of Old San Juan, a tourist trolley provides limited circulation service. Table 4-2 lists all public transportation services that currently operate on the Isleta.

Table 4-2. Public Transportation Services on the Isleta

Mode	Operation Area	Operator
Buses	Santurce / Old San Juan corridor and SJMA	AMA
Buses	Assigned SJMA Routes	Metrobús
Buses	Throughout Puerto Rico, excluding AMA routes	Private bus lines
Públicos (vans/cars)	Caguas-Old San Juan	Private
Taxicabs (vans/cars)	Metropolitan and urban areas	Private
Acuaexpreso (ferry)	Old San Juan - Cataño - Hato Rey	Port Authority
School Buses and Vans	Throughout the Santurce / Old San Juan corridor and SJMA	Municipality of San Juan, private schools and individuals

Source: Santurce / Old San Juan corridor Study (1998)

Old San Juan is quite different from the rest of the San Juan Metropolitan Area and serves as a major trip generator, with its strong recreational and commercial centers. In terms of the transportation service in this area, Old San Juan and the Isleta are also unique. These two areas are served by a large number of bus routes, similar to the services offered in a central business district (CBD). However, Old San Juan's mix of residential and commercial developments in this medium density area, are not typical of a CBD. As a result, travel patterns to this area are different from those to a typical CBD, since there are strong contra-peak flows and midday and afternoon flows are higher than the normal AM peak. Many trips also occur during the non-peak periods, such as the evenings and weekends, when bus service is often reduced or non-existent. Table 4-3 lists the number of passenger trips on the Isleta on the major trunk routes (A5, A9, Metrobús I, and Metrobús Express) that serve the area.

Table 4-3. Ridership Along the Isleta by Time of Day

	Time of Day			
Direction	**AM**	**Midday**	**PM**	**Evening**
Toward Old San Juan (pax/hr)	414	453	428	293
Out of Isleta (pax/hr)	233	283	653	419

Source: Multisystems

Santurce

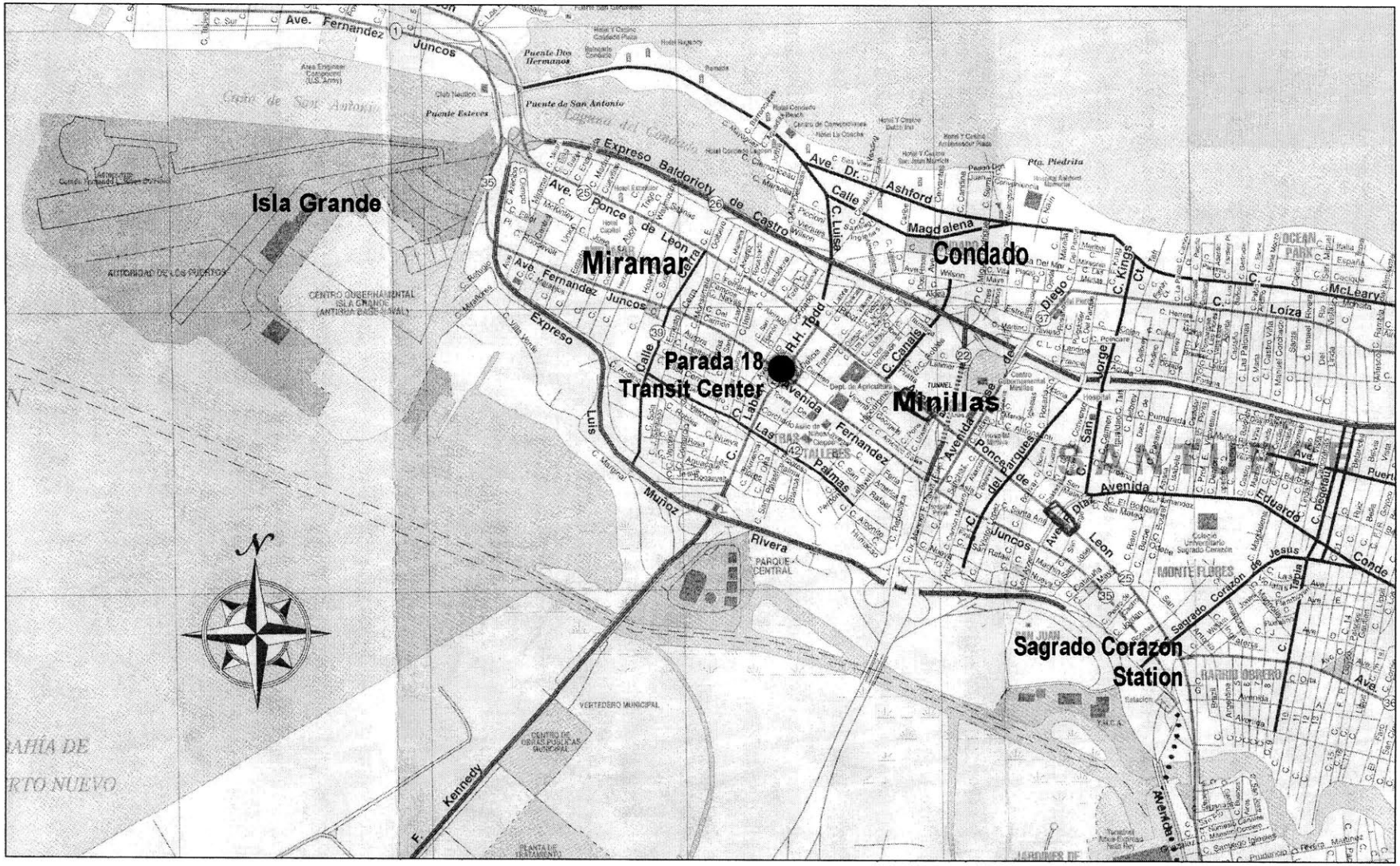
- *Socio-economic characteristics*

Santurce is a densely developed area that encompasses a major activity center at Minillas, which is home to many commercial, governmental, and residential developments including the Minillas Government Center, several art museums, and a hospital (Pavía Hospital). Low-income neighborhoods (Barrio Obrero and Las Casas), and affluent neighborhoods (Miramar and Condado) comprise the remainder of Santurce. From the 1990 Census data, Santurce, which encompasses 4.6 square miles, has approximately 31,000 households and close to 79,000 residents. The many commercial and governmental activities result in approximately 48,000 jobs. Within just the Minillas area itself, there is an estimated population of approximately 18,000 residents and 15,000 jobs. Yet, despite the large number of jobs and residents in Santurce, the area has been experiencing a slow decline in activity over many years. Redevelopment plans have been drafted to help revamp the area to attract new businesses and to provide residents a better living environment.

- *Infrastructure characteristics*

There are four major connectors that run through Santurce (Figure 4-4). The Ponce de León and Fernández Juncos Avenues bisect Santurce, both being unidirectional with contraflow lanes reserved for transit vehicles. Another major roadway in Santurce is the Muñoz Rivera Expressway, which runs from Sagrado Corazón to Miramar, at which point it transitions back into the one-way arterial pair of Fernández Juncos and Ponce de León Avenues as it crosses into the Isleta. Finally, the Baldorioty de Castro Expressway is the second expressway in the area, which terminates before entering the Isleta. In addition, the Condado area is served by Ashford Avenue, which ends at the entrance to the Isleta.

Figure 4-4. Santurce Area

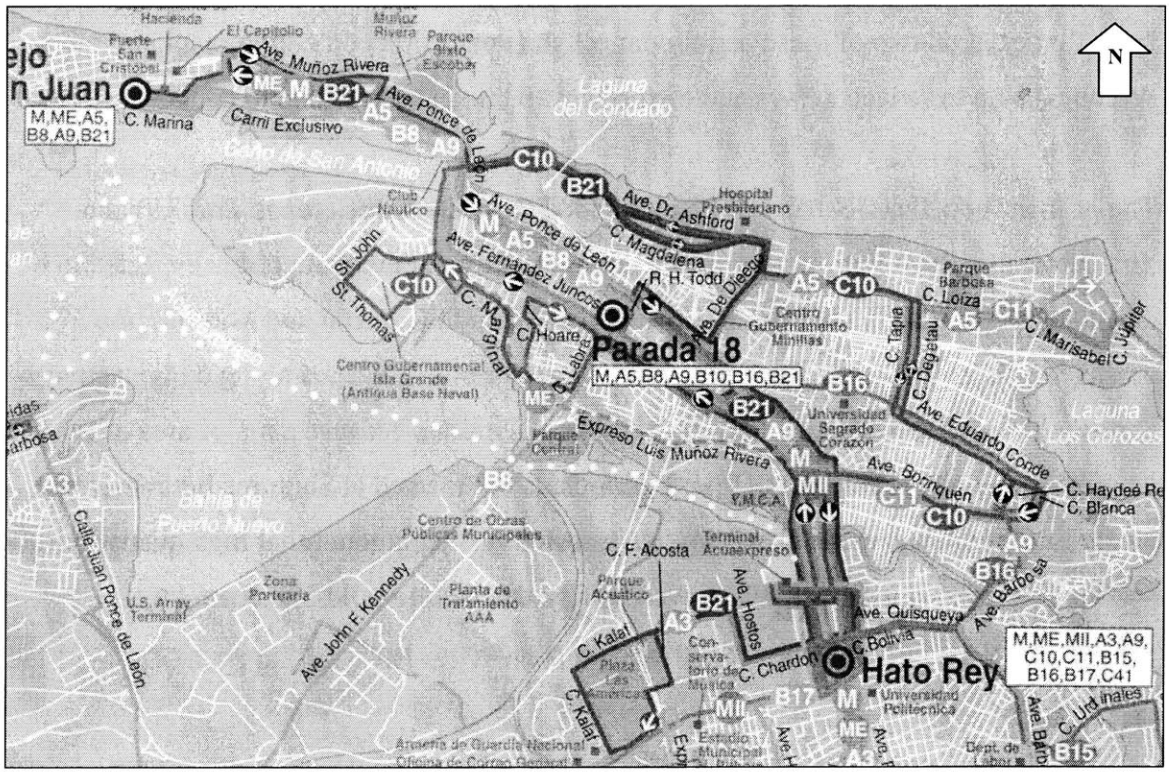


Currently, there are high levels of congestion on both Ponce de León and Fernández Juncos Avenues during peak periods but expansion of street capacity is not feasible due to the lack of available space. In addition, any construction to improve existing roadways or to construct the future Minillas extension could severely disrupt travel to this area as well as inconveniencing a large number of businesses and the community in general.

- *Transportation service characteristics*

The Santurce area is served by a number of bus routes that are focused at the Parada 18 transit center located near Minillas, in the center of Santurce (Figure 4-5). Parada 18 is the major bus-to-bus transfer point not only for Santurce but also for the entire Santurce / Old San Juan corridor.

Figure 4-5. Bus Routes in the Santurce Area



Currently, there are eight bus routes that stop at the transit center: Metrobús I, Metrobús II, A5, A9, B8, B10, B16, and B21. Only the major high frequency trunk lines (Metrobús I, A5, A9, and B21) continue north to Old San Juan. Currently, the Santurce area attracts

close to 22 percent of the daily passenger trips (12,500 trips) on the major trunk lines, and 31 percent of all transit trips in the SJMA are destined for Santurce. Of these generated trips, 14 percent (1800 trips) head into the Isleta and 23 percent (3000 trips) head south to Hato Rey and Río Piedras (Multisystems, 1999), while the rest either head east to Iturregui and Carolina or to points west, such as Bayamón and San Patricio. In addition to the AMA and Metrobús routes, several público routes also stop at Parada 18. The modal split for the Santurce area is shown in Table 4-4 below.

Table 4-4. Modal Split for the Santurce Area

	Automobile	Bus	Público
Santurce Area	73%	24%	2%

Source: U.S. Census data (1990)

Service throughout the Santurce area is focused on the four major connectors and consequently are vulnerable to high congestion levels during peak periods. Contraflow lanes that exist on two of these major connectors (Ponce de León and Fernández Juncos Avenues) help to reduce delays and disruptions to transit service due to congestion.

The primary new feature that will be introduced in the Santurce area is Tren Urbano. This new rail system will first terminate at Sagrado Corazón although it is expected to be extended to Minillas in the future. However, at Sagrado Corazón and Minillas, the presence of Tren Urbano will create bus-rail transfer points located along a high activity corridor. Yet, as stated previously, this problem is unique because a major area of activity, especially during the off-peak periods, is not located at Santurce but rather is located further away in Old San Juan. As a result, it is paramount that high quality bus service be provided to effectively serve the trips destined for Old San Juan.

Hato Rey

- *Socio-economic characteristics*

Hato Rey, south of the Martín Peña Channel, is Puerto Rico's principal business and financial center (Figure 4-6). From U.S. Census figures, there are an estimated 15,000 people employed within a half-mile radius of the Hato Rey center. The Hato Rey area, which originally developed as an extension of the Santurce commercial corridor, now contains the largest collection of banks, accounting firms, insurance companies, and law firms on the island (Phase I FEIS, 1995). Also located in this area are key civic and governmental institutions, including the Federal Office building and the Judicial Center, as well as several hospitals, educational institutions, and churches.

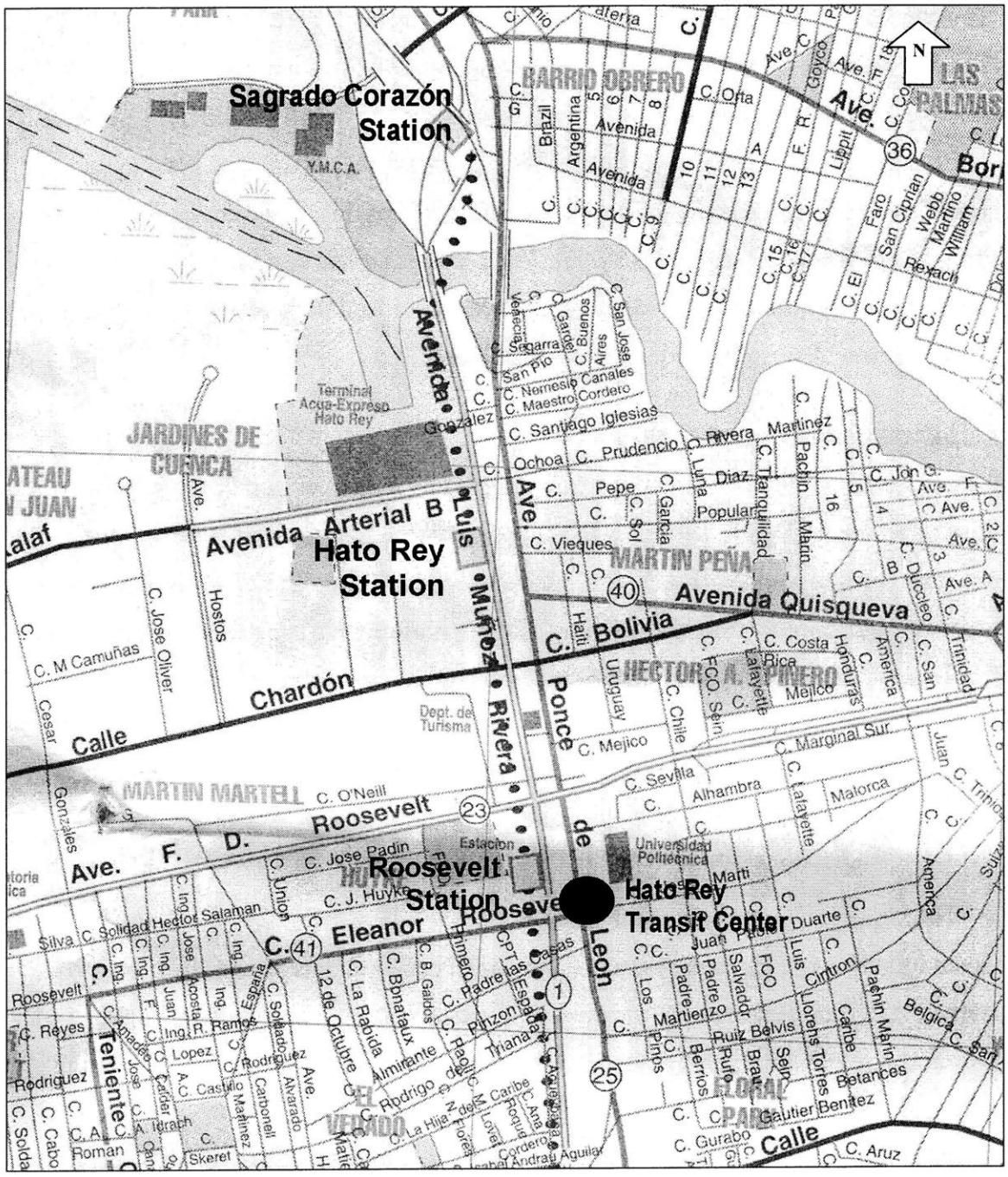
- *Infrastructure characteristics*

Commercial and public uses in the area are served by a number of roadways, with the most important being PR-1 (Muñoz Rivera Avenue), a six-lane street running essentially one-way north to south with a contraflow bus lane, and Ponce de León Avenue, a one-way two to three lane street also running south to north with a contraflow bus lane. Hato Rey is also intersected by a number of other important commercial corridors. West of Muñoz Rivera Avenue, F.D. Roosevelt Avenue contains a dense commercial district leading to the Plaza Las Americas shopping center and a municipal sports complex, and connecting to the Las Americas Expressway.

- *Transportation service characteristics*

Given its status as a key business and commercial center and its proximity to major arterials, the Hato Rey area is very accessible by the current transit system (Figure 4-5). Eleven bus routes have stops at the Hato Rey transit center, including five main trunk routes (A3, A9, Metrobús I, Metrobús Express, Metrobús II). A3, Metrobús I and Metrobús Express provide high frequency bus service between the Hato Rey business district and the Río Piedras transit center. Of the eleven routes, six travel north into Santurce, with three (Metrobús I, Metrobús Express, B21) continuing on to Old San Juan. From AMA and Metrobús trip data, the Hato Rey area currently generates close to 7,500

Figure 4-6. Hato Rey Area



passenger trips (13 percent of all SJMA bus trips) per day on the major trunk lines. Despite the large number of bus routes that serve the area, the Hato Rey area is very much centered around the automobile as the primary mode of transportation, as indicated in Table 4-5.

Table 4-5. Modal Split for the Hato Rey Area

	Automobile	Bus	Público
Hato Rey Area	86%	13%	1%

Source: U.S. Census data (1990)

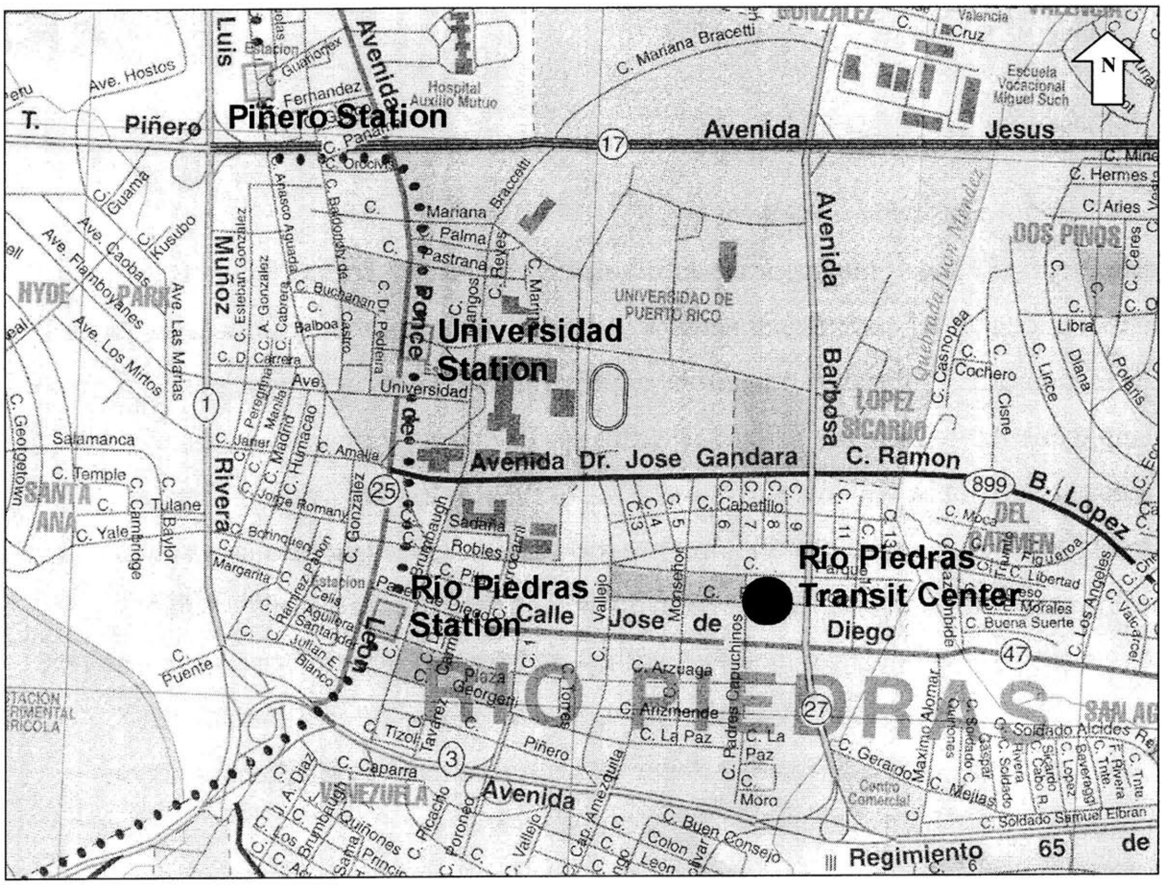
Río Piedras

- *Socio-economic characteristics*

Río Piedras is one of the major urban sub-centers served by Tren Urbano. It is an important center of commercial activity and public transportation (públicos and buses). Its numerous high-density commercial developments make it one of the major employment centers in the SJMA; according to 1990 census figures, approximately 1,500 jobs currently exist within a half-mile radius of the Río Piedras center. There are significant public spaces and buildings in Río Piedras: open spaces, a fruit and produce market, several churches, a post office, public and private schools, and a public university. Other land uses include the Plaza de Recreo, Plaza de Convalencia, and the Paseo de Diego, a three block pedestrian street connecting the area's most active commercial streets, De Diego and Ponce de León Avenues. In addition, numerous residential neighborhoods are located to the south and east.

A key activity center is the traditional town center of Río Piedras with its vital commercial activity serving moderate-income levels, and its highly developed público network that distributes passengers to and from many points throughout the metropolitan area and the island. Surrounding the town center are dense, low-rise neighborhoods for low to moderate-income residents, along with residential areas for schools and other smaller institutional uses. According to the 1990 U.S Census, in the half-mile radius around this town center, there are close to 3,600 households and 10,000

Figure 4-7. Río Piedras Area



residents. Close to the town center is another important activity center, the University of Puerto Rico (UPR). The UPR is the island's largest educational institution, and Río Piedras is its main campus. At Río Piedras, approximately 22,500 students, faculty, and personnel are educated and employed.

- *Infrastructure characteristics*

Two heavily traveled arterials, Ponce de León and Muñoz Rivera Avenues, originate at Río Piedras and extend north all the way to the Old San Juan area (Figure 4-7). While Ponce de León Avenue remains a unidirectional arterial throughout its length to Old San Juan, Muñoz Rivera Avenue transitions into an expressway for a short distance between Sagrado Corazón and the Isleta. In the Río Piedras area, numerous high-density commercial and residential developments are situated next to these arterials, making them very popular transportation corridors. Given the high traffic levels along these corridors, congestion is often a problem; roadway expansion to relieve these traffic problems is not feasible due to the overall high-density nature of the area, but contraflow lanes help to mitigate congestion for public transportation.

- *Transportation service characteristics*

Río Piedras has long been a transit-oriented town center, and stands to gain the most from the improved accessibility provided by Tren Urbano. Given the proximity to local expressways, major roads, and residential areas, the Río Piedras transit center is easily accessible. Fifteen bus routes have stops at the Río Piedras transit center (Figure 4-1), including five main trunk routes (A3, A6, A9, Metrobús I, Metrobús Express) that originate there. The Río Piedras area generates 8,700 daily passenger trips on the bus system, approximately 15 percent of the total system ridership. The A9 and the two Metrobús routes travel the entire distance from Río Piedras to Old San Juan via different routes. Of all bus trips generated in the Río Piedras area, approximately 15 percent, or 1,400 trips are destined for Old San Juan. In addition, the Río Piedras transit center is a major hub for público service to the residential areas to the south and east. The current modal split for the Río Piedras area is shown below in Table 4-6.

Table 4-6. Modal Split for the Río Piedras Area

	Automobile	Bus	Público
Río Piedras Area	70%	24%	6%

Source: U.S. Census data (1990)

4.1.2 Major Development Plans

There are several major development plans for the Santurce / Old San Juan corridor that will place significant new demands on the public transportation system and the provision of services in general. The Isleta is the focus of many development plans that would intensify land use, particularly along the south shore of the Isleta on the San Juan Bay. However, the exact time frames and dates required for each development have yet to be determined. In order to ensure that the public transportation system continues to provide high quality service and remains vital, the impacts of these developments must be factored into the strategic planning and selection of service strategies that are to be implemented over time.

El Triángulo Dorado

The Old San Juan / Isleta area is the focus of a major development plan known as "El Triángulo Dorado", or The Golden Triangle. Expected to run through the year 2010, this plan focuses on three areas: the Isleta, Condado, and Miramar/Isla Grande (Figure 4-5). Planning this initiative started in 1996 and emphasizes land uses that include: retail, entertainment, transportation and infrastructure, hotels, cultural and educational, residential and commercial. The plan aims to provide developments that are oriented both to tourism and to the needs of the resident population.

The Golden Triangle development plan includes a number of major development objectives (Parmegiani, 2000):

- Build on existing assets: Old San Juan historic preservation, Condado hotels and restaurants, Frente Portua Río Projects

- Recapture high value waterfront sites: connect Miramar to Isla Grande and waterfront, reevaluate use of land north of the San Antonio Canal, expand home port functions at Isla Grande
- Improve transportation: Intersection 5 (connecting Santurce, Condado, and Isleta), Baldorioty De Castro and Muñoz Rivera Expressways, Isla Grande port access, ground transportation including Tren Urbano extensions, pedestrian friendly traffic solutions
- Create a mix of attractions: high quality public spaces and waterfront experience, cultural and entertainment venues, interactive learning activities
- Offer new residential and commercial options: waterfront loft residences and offices, timeshares and condominiums, courtyard housing, alternative mass transit connections to employment centers, increased urban densities to create both local and tourist demand for retail, restaurant, and recreational areas

Waterfront developments

Some of The Golden Triangle development plan's main projects will be built along the Isleta and Santurce waterfronts that are adjacent to the San Antonio Canal, which separates the Isleta from Santurce (Figure 4-2). The waterfront development plans have the vision of redeveloping the Isla Grande area into a major activity center. As a result, this plan includes a broad range of components that will introduce a number of commercial, residential, and recreational developments into this area. A listing of the major components that are planned includes (Parmegiani, 2000):

1. Convention, World Trade, and Port Center
2. 80,000 square foot aquarium
3. Redevelopment of piers and the addition of berths along the Isleta by cruise ship operators
4. IMAX motion picture theater
5. Renovation of the Caribe Hilton Hotel and the redevelopment of several US Navy buildings to create an upscale entertainment and retail center, complete with 2,300 parking spaces

6. Redesign of the "Parque del Tercer Milenio", or Park of the Third Millennium, once Escambron Park
7. Construction of the Condado Beach Resort that includes a hotel, time-shares and residential units.
8. Galeria del Puerto Project includes 75,000 square feet for commercial establishments and 80,000 square feet for office space
9. Barrio Capitolio Sur (Capitolio Plaza) project is a four-block mixed-use development with 308 apartments, 2 parking lots and 12,000 square feet of retail space.
10. A new shopping center
11. An urban revitalization plan for the Puerte de Tierra community, designed to replace the existing five building public housing complex.

The completion of these development plans are expected to increase employment and population levels in the Isleta and the Isla Grande area. Approximately 15,000 new permanent jobs will be created from the new developments. In addition, the new residential developments and the renovation of existing housing complexes are expected to add 2,000 residents to the current residential population in the Isleta and Isla Grande areas. The commercial and residential developments in these areas are expected to increase the number of work and recreational trips by at least 50 percent (Parmegiani, 2000).

4.1.3 Major Transportation Plans

Transportation Master Plan for the Isleta

Aside from the construction of Tren Urbano Phase I and IA, the only other major development plan that is focused on improving the transportation system in the Santurce / Old San Juan corridor is the Isleta transportation master plan. There are no major changes to the existing roadways along the Isleta due to the fact that there is no space available for this expansion. As a result, the plan proposes that traffic flows be improved through more effective use of the existing roadways.

However, there is major road construction planned for the interface between the Isleta and the Santurce and Condado areas (Figure 4-2). The Isleta is connected to these two areas via three bridges (San Antonio, Esteves, and Dos Hermanos). These three access points create a bottleneck that often causes severe congestion and traffic delays during peak periods. In 1996, it was found that the expressway approaches to the bridges have a peak hour level of service of F (Steer, Davies & Gleave, 1996). Compounding the problem is the fact that the bridges are also in need of repair. To improve the traffic at this important junction, there are several construction projects, listed below, that are slated to occur in conjunction with the master plan (Transportation Master Plan, 1999).

- Replace and/or renovate the San Antonio, Esteves, and Dos Hermanos bridges
- Construct the San Antonio Boulevard along the Isleta's southern waterfront that will function as a two-way four lane boulevard
- Construct a new six-lane tunnel under the San Antonio Canal

This master plan has major implications for the transit service to and from the Isleta. The current bridges do not provide contraflow lanes, causing transit vehicles to be impacted by congestion. Currently, there are no accommodations for transit vehicles during or after construction, though the plan does account for a Tren Urbano extension to a point slightly north of the Isleta entrance. But, it is unclear when the expansion of Tren Urbano to the Isleta will occur, and the bridge replacement/renovation will certainly occur sooner. The changes proposed by the transportation plan are dependent on the bus services along the Isleta to help reduce the traffic levels. If 15,000 new jobs on the Isleta are to be served without creating gridlock, current bus services will need to be substantially increased by a factor of two to three. Hence, accommodations for buses on the bridges need to be introduced to ensure that public transportation will be successful in attracting the SJMA residents who would otherwise drive into the Isleta. Moreover, the extension of Tren Urbano to the Isleta should predate or coincide with the highway tunnel to avoid a weakening of transit mode share.

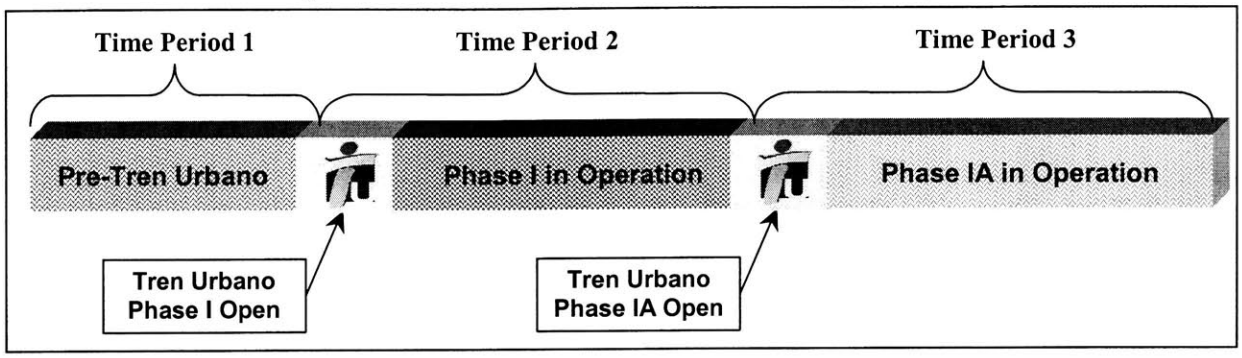
4.1.4 Time periods for Analysis

The focus of the service strategies is on the transportation system in the Santurce / Old San Juan corridor, and specifically how existing bus services can be designed to complement and support Tren Urbano in all its phases. Tren Urbano is the largest and most significant public transportation project undertaken in Puerto Rico in over 50 years. Given that the completion of the first phase of Tren Urbano is approaching, the immediate needs of the public transportation system must be addressed. Hence, there is a focus on the short to medium-term time frame, which implies a planning horizon of five to ten years.

Throughout this planning horizon, numerous developments will occur and have an impact on the transportation, infrastructure, and local activity systems in the Santurce / Old San Juan corridor. However, the development with the most significant impact will be Phase I of Tren Urbano. In addition to the first phase, there are also advanced plans to build the first extension (Phase IA) in the medium-term future, as well as other potential extensions in the longer-term (FSEIS, Minillas, 1999). Since the primary focus of the bus service strategies is to accommodate changes in the transportation system, namely Tren Urbano and its future phases, it is logical to divide the planning horizon into time periods based on the timing of the Tren Urbano service developments. Thus, the planning horizon can be divided into the following time periods (Figure 4-8):

1. Present day up to Tren Urbano Phase I opening day (Fall 2002)
2. Phase I opening day up to Tren Urbano Phase IA opening day (~2006)
3. Phase IA opening day onward

Figure 4-8. Time Periods Used for Service Strategy Analysis



The first time period is the immediate future up to the opening day of the first phase of Tren Urbano. Changes to bus services in this period are aimed at ensuring that good service is in place for Tren Urbano opening day, extending hours of service, improving amenities such as bus shelters and on-time performance through AVL technology, and building ridership as much as possible.

The second period encompasses the period starting on the opening day of Tren Urbano and leading up to the opening day of the next extension, Phase IA. Tren Urbano is a major development in the transportation system, and major changes to the existing bus services will need to be made to ensure that the Tren Urbano opening is successful. The success of Tren Urbano, and the public transportation system as a whole, is dependent on maintaining high levels of transit service during this period. After the Tren Urbano opening, the ridership on the system will take time to grow to forecast levels. During this period, there will be excess capacity on Tren Urbano. While this will be needed to accommodate future growth, during this period there may be short-run pressures to reduce service levels. The success of Tren Urbano in this period will pave the way for future approval of additional investments in the public transportation system.

The final time period begins with the opening of the Minillas extension. The events and strategies that take place in this time period are dependent on the outcomes of the strategies that have been implemented in earlier periods. Ridership is expected to grow at least to levels forecast in the Minillas EIS. There are also developments that will occur in this time period that cannot be accurately predicted, resulting in increased demands on

the transit system. The service strategies implemented in this period must accommodate any new developments as well as build upon what was established during the previous time periods.

4.2 Time Periods Analysis Framework

The identification of the service strategies in a given time period is usually based on the short-term pressures of accommodating existing levels of ridership subject to budget and resource constraints. However, focusing purely on the short-term needs of the transportation system can result in the system's inability to adapt to future developments. Hence, service strategies that are implemented in earlier time periods must also take into account likely developments in later time periods. Implementing strategies with attention to the longer-term will ensure that they will improve the transit system in the short-term without jeopardizing the achievement of longer-term objectives. As a result, implementing strategies that consider future time periods will help ensure that the transit system will remain successful over time.

The time period assessments will provide snapshots of the expected state of the transportation system and the operating environment during each time period. By combining these snapshots, a larger picture can be formed of what developments need to occur in earlier time periods to ensure that the transportation system in each time period meets expectations. This picture will then help plan appropriate bus service strategies that will meet the expectations for each time period. Moreover, by meeting the expectations of each period, the long-term success of the transportation system in the Santurce / Old San Juan corridor can be ensured.

The developments that occur in the Santurce / Old San Juan corridor during each time period can be organized into three distinct areas. The first incorporates changes occurring in the local activity system, and includes retail, commercial, and residential developments, and the expansion of existing developments. The second encompasses

highway infrastructure developments critical to the urban structure; these developments focus on the reconstruction, modification of roadways, bridges, and construction of tunnels. The third consists of direct changes to the public transportation system, which includes changes related to Tren Urbano or the introduction of new transportation technology.

- *Local Activity System*

Developments in this stream focus on changes in the Santurce / Old San Juan corridor that will impact the demand for mobility and access to other resources. Demographic shifts, socio-economic trends, and other similar issues are also considered as part of this system.

- *Urban Infrastructure*

The urban structure stream deals primarily with developments in the roadway network in the SJMA, focusing specifically on the network in the Old San Juan, Santurce, and Condado areas. Any developments altering the existing roadway structure and network are included in this system.

- *Public Transportation System*

This area encompasses the public transportation system in the Old San Juan, Santurce, and Condado areas. This system also incorporates infrastructure and operational developments related to Tren Urbano, such as the building of stations and the coordination of services.

4.2.1 Time Period 1: Pre-Tren Urbano Opening

Local activity system

During this time period, which is basically the next two years, there will be no major changes in the operating environment or in demand or demographics of the Santurce / Old San Juan corridor. However, there will be changes in ridership and demand that will

require minor modification of existing services in order to maintain high levels of service (reduce crowding, improve service frequencies, etc.). The density and nature of activities suggests latent demand which can build ridership with appropriate improvements to bus service, particularly extending evening and weekend service hours.

Urban Infrastructure

Aside from the construction directly related to Tren Urbano, there are no major infrastructure developments planned for the Santurce / Old San Juan corridor before Tren Urbano opens. In regard to the roadways, in most areas along the corridor, expansion is not possible due to physical constraints. However, the reconstruction of the bridges to the Isleta are currently being planned in this period, so an opportunity to introduce accommodations for transit with the new bridges exists and should be further pursued

Recently the Committee for the Urban Development of Old San Juan proposed a new plan to improve the flow of traffic into Old San Juan. One of the recommended proposals is the opening of the Calle del Tren to general traffic and public transportation carriers entering and leaving Old San Juan. The plan also proposes that the Paseo Covadonga, which runs east-west along the Isleta from Old San Juan and intersects with Ponce de León Avenue, allow two-way transit usage for the purpose of discouraging increased vehicular traffic on the weekends. If the Calle del Tren proposal were to be approved, the preservation of the restricted use of this right of way would be in jeopardy, which could impact the quality of bus service provided in future time periods.

In addition, improvements to the transit facilities along major arterials should also be planned. Bus shelters should be constructed or improved in this period to ensure that continual improvements in the transit system are made, so that levels of service and the residents' perception of the transit system are improved. In addition, the implementation of AVL technology can be implemented or planned in this period to ensure that in the future, this new technology will result in improved coordination with Tren Urbano.

Public Transportation System

In regard to the transportation system, no major developments are slated to occur in this period. No Tren Urbano stations will be fully operational before Opening Day, but there may be adequate station work completed to initiate bus service at the Sagrado Corazón station.

In 1998, AMA undertook significant route restructuring to improve reliability and consolidate service onto fewer, but higher frequency and more direct routes that connect at transit centers. The introduction of frequent, reliable service along the main corridors has helped to halt the long-term ridership decline. Hence, the AMA and Metrobús services in this period need to continue to improve levels of service in order to further improve transit usage within the Santurce / Old San Juan corridor and establish credibility before Tren Urbano opens.

In order for Tren Urbano Phase I to be a success, high bus service levels during the peak and off-peak periods need to be ensured. By doing so, increased public interest and use of Tren Urbano will result. Bus service currently ends at 9:30pm, but in order to provide strong off-peak service, the hours must be extended to match those of Tren Urbano, which will run until 1:00am. In the peak period, the service levels must remain high in order to continue to attract an increasing number of commuter trips during this period.

Along with the extension of service hours, it is likely that AMA fares will be increased. If so, the fare increase should be accompanied by modern fare collection systems with a focus on improving transfers to mitigate the effect of the fare increase and avoiding loss of riders. In addition, this is an opportunity to familiarize both the public and AMA with a new cash fare payment system that will be similar to that employed by Tren Urbano.

4.2.2 Time Period 2: Tren Urbano Phase I

Local Activity System

Several development plans are expected to be underway, if not completed, in this time period, most notably the Golden Triangle Development plan. This plan will introduce a number of commercial and residential developments that will increase the number of work and recreational trips to the Isla Grande and Isleta area by at least 50 percent. Since the existing road network is operating at close to capacity, it is essential to the success of these new developments that transit captures a larger share of the existing market and a substantial share of the new trips. Making improvements in the bus and rail services to the major employment, residential, and recreational centers in the Santurce / Old San Juan corridor will provide better service for the work and recreational trips and improve the attractiveness of transit. Creating a positive impression of bus and Tren Urbano services can lead to increased demand for transit access to these activity centers, since residents will be convinced that taking transit to these areas will be fast, convenient, and safe. By making transit attractive to current and potential riders, a strong ridership base can be established that will promote the use and ensure the success of Tren Urbano.

Urban Infrastructure

The implementation of several components of the transportation master plan for the Isleta (discussed in Section 4.1.3) will have major implications on the transportation system in this time period. Listed below are the major construction projects associated with the master plan that are expected to be completed in this time period (Santurce / Old San Juan corridor Study, 1998).

- Reconstruction of bridges connecting Condado and Isla Grande to the Isleta
- Construction of a new boulevard along the Isleta's southern waterfront
- Construction of a six-lane tunnel connecting Isla Grande and the Isleta
- Construction of the Minillas extension (Phase IA) of Tren Urbano

It is vital that the bus routes serving the Isleta maintain high quality services as these projects are under construction. The construction will cause major traffic and congestion problems that provide great opportunities to increase the residents' awareness of transit as an alternative means of traveling to the Isleta. The traffic problems will help to showcase the advantages of taking transit (improved level of service, fast, efficient, and convenient) provided that proper accommodations are made for the buses to bypass the construction and congestion. The reconstruction project should also be used as an opportunity to gain dedicated bus lanes on the bridges to the Isleta.

Furthermore, the existing rights of way that are allocated for bus services need to be preserved. The bus services will need to continue using the contraflow lanes along Ponce de León and Fernández Juncos Avenues and Calle del Tren along the Isleta until better rights of way for transit are made available.

In addition, as mentioned in the discussion of the previous time period, the amenities available to the passengers should be upgraded. The renovation or addition of bus shelters along the high demand corridors should be pursued in this period to ensure that the transit system retains existing passengers and attracts new riders. AVL technology should be implemented in this period to further improve the levels of service provided and ensure a seamless connection with Tren Urbano at Sagrado Corazón.

Public Transportation System

The second time period is the most critical to the success of the public transportation system in the Santurce / Old San Juan corridor. Within this time period, the most important development in the transportation system is the opening of Tren Urbano. Since Tren Urbano is the island's first heavy rail system, as well as its first high quality mode of public transportation, the success of the system must be ensured. Early in this period, the priorities are on ensuring that the Tren Urbano feeder services and the Sagrado Corazón station are both operating effectively.

When Tren Urbano opens, there will be a large number of trips taken on the new system by casual transit riders who are curious about the new system. Many of these curiosity riders will not previously have used transit and will most likely be traveling for recreation and social reasons. Since the Sagrado Corazón area itself is not a major trip attractor, the likely major recreational destination in the Santurce / Old San Juan corridor are Old San Juan and Condado. Those traveling to Old San Juan will also be more likely to travel in the evening and weekend periods, when the transit system is currently planned to operate on an off-peak schedule. Hence, both Tren Urbano and the bus system need to provide higher quality services during the off-peak periods to create a positive first impression with these curiosity riders and to create positive word-of-mouth reports on Tren Urbano. By doing so, these curiosity riders can be converted to choice riders who will consider transit as a viable alternative to the automobile when traveling throughout the Santurce / Old San Juan corridor. Furthermore, by improving the presence of high quality transit services, a strong transit presence in the Minillas area can be established, which will help ensure the success of the upcoming Minillas extension.

The opening day of Tren Urbano will create fundamental changes that must be planned for and accommodated. On opening day, Tren Urbano will terminate at Sagrado Corazón, and bus services will need to provide access from the station to the major activity centers located throughout the Santurce / Old San Juan corridor. There are two scenarios that are possible. The first scenario is that ridership levels are low, due to the fact that most residents may not be willing to change their commuting patterns immediately. As ridership and demand gradually increase over time, the service levels on the bus system must increase as well. On the other hand, the second scenario that may occur is that Tren Urbano experiences a surge of riders in the first six months after opening. Much of this surge may be due to curiosity riders who wish to "test" the new system as well as existing transit riders who wish to take advantage of the improved service now available.

With either scenario, the transit services need to be of high quality in order to create a positive first impression. Additionally, these services must be ensured throughout this

period. As time goes on, residents will adjust to Tren Urbano and the improved accessibility to the major activity centers located throughout the Santurce / Old San Juan corridor (Condado, Old San Juan, Minillas) that it provides. As a result, an increase in demand for peak, and especially off-peak, transit services to these areas will occur. Consequently, Tren Urbano and the bus services to Old San Juan and Condado need to be prepared to provide high levels of service at all times to ensure that a positive initial public perception of transit is established.

Another major element contributing to the success of Tren Urbano is the Sagrado Corazón station. Given that the Sagrado Corazón area is not now a major trip attractor, passengers will be reliant on the rail-to-bus transfers to access the activity centers in the Santurce / Old San Juan corridor. Hence, the Sagrado Corazón station must be able to effectively facilitate the intermodal transfers that will take place, during the peak and off-peak periods, in order for Tren Urbano to be successful. Further analysis of the station's effectiveness in handling the intermodal transfers will be presented in Chapter 5.

4.2.3 Time Period 3: Tren Urbano Phase IA

Since this period is further off in the future, this assessment is subject to greater uncertainty. At the start of this period, the Minillas extension will have just opened, so it is important to ensure that the extension is successful in serving and attracting riders. However, given the uncertainty that exists in this period, the specific impacts on the extension of developments in this period are unknown. Additionally, while the status of the Isla Grande developments is uncertain, for this assessment they are assumed to be either complete or close to complete in this time period.

Local Activity System

The completion of the development plans described in Section 4.1.3 will create a number of commercial, retail, and residential complexes in the Isla Grande area that will place new demands on the transportation system in the Santurce / Old San Juan corridor.

Moreover, these new developments may become new activity centers and attract a large number of work and recreational trips. As a result, effective transit service to these new developments will need to be established to accommodate the increases in demand that will arise.

Urban Infrastructure

New roadways and expansion of existing roadways will create opportunities to obtain right of way for transit use, helping to improve the service quality. Congestion along the Isleta will increase, and in order for transit services to remain attractive and be competitive with the automobile, the service provider needs to ensure that rights of way are available. The new four-lane San Antonio Boulevard running along the Isleta waterfront will help improve traffic flows, and will also provide a good opportunity to improve transit services in the area. Transit services will improve considerably if reserved rights of way are also provided. Yet, in addition to securing new right of way, the service provider also needs to preserve existing rights of way that are utilized by transit.

This preservation is very important for the transit services that operate along the Isleta using the Calle del Tren and the contraflow lanes. First, by restricting the use of the Calle del Tren to transit vehicles, the construction of the future Old San Juan extension will not need to include provisions to purchase this costly right of way. Secondly, the preservation of contraflow lanes becomes even more important in light of bridge reconstruction or Tren Urbano-related construction in Santurce or along the Isleta. Establishing priority lanes on the bridges will allow the buses to bypass increased vehicular congestion caused by new development and the construction of the vehicular tunnels or Tren Urbano, improving levels of service and service reliability as well as improving the credibility of the bus system as an alternative to the automobile.

Public Transportation System

There is much uncertainty in this period about what developments will occur in the public transportation system. Much of what occurs in this period will depend on what happens in the interim. Demand for additional Tren Urbano services and the success of both Phase I and IA will mean that future investments in Tren Urbano and the public transportation system are more likely. It is assumed that the ridership forecast in the Minillas FSEIS will be reached. Yet, given the developments now being planned, it is also likely that later in this period, the volume of passengers traveling through the Santurce / Old San Juan corridor and on Tren Urbano will be significantly greater than the FSEIS estimates.

The Minillas station's status as the new terminus of Tren Urbano will require that it, like the Sagrado Corazón station, effectively facilitate intermodal transfers. The fundamental issues that face the Sagrado Corazón station will also apply to the Minillas station. However, given its location, the effectiveness of the Minillas station during the peak and off-peak is even more critical. The opening of the Minillas extension will result in considerable improvements in accessibility to the Minillas area. As a result, the Minillas station will need to accommodate increased peak period commuter traffic that uses Tren Urbano to access Minillas from the rest of the SJMA. However, increased off-peak recreational traffic that will transfer onto buses destined to Old San Juan and Condado would make it desirable to establish strong bus service at the Minillas station early in its existence so that the new extension will be utilized effectively, adopted quickly by residents, and be successful in improving the transit system in the Santurce / Old San Juan corridor.

However, available space and service capacity issues at Minillas make it unrealistic to plan Minillas as a major high quality transfer station. As a result, it is likely that Sagrado Corazón will remain as a major intermodal transfer point. The other new station on the Phase IA alignment, San Mateo may also supplement Sagrado Corazón as a major bus/Tren Urbano transfer station since it can be designed to provide more space to accommodate buses and is better located than Minillas with respect to certain street

connections. The capacity issue also presents the opportunity to push for the extension of Tren Urbano to Parada 18. The Parada 18 facilities as well as the number of buses that serve the area would help resolve the bus access issues that might otherwise undermine the effectiveness of the Minillas station.

Chapter 5. Service Strategy Analysis

This chapter focuses on the identification and analysis of service strategies oriented toward satisfying the long-term needs and goals of the transit system in the Santurce / Old San Juan corridor. The first two time periods, which range from the present-day operating environment to just before the opening of the Minillas Extension of Tren Urbano, are the primary focus. The long-term strategic decisions that must be made in the third time period are also discussed. For each time period, the objectives and service options for bus service between Río Piedras and Old San Juan are identified and their applicability to the current and future operating environments are analyzed and evaluated.

5.1 Introduction

The long-term vision for the Santurce / Old San Juan corridor is that of a metropolitan area that will utilize and promote the use of public transportation. This vision can be broken down into several long-term goals. The first goal is to utilize Tren Urbano effectively when it opens. A second goal is to provide high levels of bus service to retain existing ridership. A third goal is to provide service levels that attract additional riders on to Tren Urbano and the bus system. A fourth goal is to improve the mobility of the residents in the Santurce / Old San Juan corridor and the SJMA. Finally, the transit system needs to improve the accessibility of Old San Juan, the Isleta and Santurce to encourage transit oriented revitalization and reinvestment.

To accomplish these long-term goals, a number of short-term strategies must be implemented in each time period. Within each time period, priorities are placed on the service strategies that can be implemented and produce results that support the long-term goals while satisfying short-term constraints of the operating environment. Hence, it is useful to establish a framework for identifying attractive short-term and long-term service strategies.

In addition to ensuring that both short-term and long-term goals are achieved, the analysis and selection of service strategies must also account for the differences in objectives and constraints among the customer, operator, and institutions that are prevalent throughout the planning process. Each party possesses different, and at times conflicting, perspectives on the implications of each strategy.

The most important perspective is that of the customer, since the success of the transit system is fundamentally dependent on ridership. Customers desire high quality and convenient service at all times; if high levels of transit service are not provided, customers may be discouraged from using the transit system, affecting the potential ridership. While peak period conditions affect the highest number of customers, off-peak quality of service is also very important to many customers.

On the other hand, the operator is usually focused on operating a cost-effective service and may not always be concerned with providing high quality service. Some major operator concerns are the costs, availability, and procurement of the resources required to provide service to the customer. The operator is especially concerned with the peak-period service, since it is during the peak period when the operator's resources and performance are pushed to the limit. The operator may also be tempted to cut service frequency during the off-peak periods to reduce agency costs.

Finally, the institutional point of view expresses the desires of the government and communities. These two groups want the public transportation system to provide the maximum benefit to society while effectively managing operating costs and any negative impacts on the environment, and may have goals such as stabilizing land values and encouraging economic growth. In addition, the views of the government and institutions toward the development of the transit system are also very important. The Puerto Rico Secretary of Transportation is the main decision-maker for the Tren Urbano and Metrobús services and has a role in the AMA decision-making process. The analyses and recommendations for the transit system in this thesis are based on the assumption that the

Secretary and other institutions are focused on resolving the transportation problems that exist in the SJMA through the development and improvement of the transit system. Yet, the individual institutions (AMA, Metrobús, públicos) will tend to have differing perceptions of the public good, and the institutional structure can either facilitate or hinder intermodal integration. Further analysis of the institutional landscape is an area for future research.

5.2 Time Period 1: Pre-Tren Urbano Opening

Service strategies to be implemented over the next two years must be designed to maximize the probability of a successful launch for Tren Urbano. In order for this to happen, the residents of the SJMA need to be ready to make full use of Tren Urbano. In this period, the image of transit can be improved by ensuring that the bus system is operating effectively at all times (peak, evenings, and weekends). The implementation of high quality bus services before opening day will help ensure that Tren Urbano will appeal to, and be used by, a larger number of residents. Tren Urbano will provide a sudden large expansion of capacity, and a major objective in this period is to encourage growth in transit ridership to ensure that the new capacity is well utilized.

As a result, the services provided by the bus system must attract residents during all periods of the day. Peak-period service will continue to attract peak-period riders who are primarily commuters. However, in order to attract the discretionary riders who often make recreational trips during the off-peak, evenings, and weekends, the service during these times of day needs to be improved. It is important to establish early, before Tren Urbano opens, that off-peak transit service is reliable, effective, convenient and secure. Doing so will help the residents become accustomed to taking transit during the evenings and weekends, and will help ensure that when Tren Urbano opens, it will be used at all times.

Hence, keeping in line with the goal of ensuring a successful launch of Tren Urbano, the objective for the bus service strategies in this period is to establish strong transit at all times, with a particular focus on improvements in evenings and weekends. Improvements in service will improve the perception and credibility of transit and will likely result in a larger transit ridership base when Tren Urbano opens. Given the importance of establishing a strong off-peak ridership base, the primary service strategy to be implemented to achieve this objective is the extension of the service hours of the bus system. Implementing this strategy in this time period will promote off-peak ridership as well as allow for smoother coordination once Tren Urbano opens.

5.2.1 Infrastructure

Currently, there are no changes planned for existing roadways in most of the Santurce / Old San Juan corridor. The contraflow lanes and Calle del Tren are still available and reserved for transit usage. Though the contraflow lanes are being utilized by a number of routes, the Calle del Tren is currently very poorly utilized, as problems were encountered using the right of way due to safety and security reasons. Since the use of Calle del Tren can reduce the travel time along the Isleta by several minutes, the safety and security of the area should be addressed in this period so that the bus services will benefit from the ability to utilize this valuable right of way.

The roadways in the Sagrado Corazón area (see Figure 4-5), specifically Ponce de León and Fernández Juncos Avenues, will be affected by the construction of the new Sagrado Corazón station. The current AMA and Metrobús routes that utilize these two avenues will require minor modifications to operate around the construction. The station design provides good integration with the existing road network. Since the station is accessible from both Ponce de León and Fernández Juncos Avenues, the effectiveness of the station in accommodating intermodal transfers in future time periods will be improved. The Sagrado Corazón station could be available for bus purposes as much as a year before the

opening of Tren Urbano, and may provide an opportunity to allow both passengers and drivers to become accustomed to the new facility.

5.2.2 Network Structure

In 1998, a major bus service restructuring plan was implemented. Before the restructuring, the bus system in the SJMA consisted primarily of numerous long and circuitous routes that connected many individual origin - destination pairs. Not only were the travel times on these routes long, the services provided were unreliable, and operated at low frequencies. The 1998 restructuring plan was motivated by the poor service, as well as the necessity of a high quality bus system to complement Tren Urbano. This plan transformed the initial point-to-point type of service structure into one consisting of fewer but more frequent, more reliable, and less circuitous- routes that focused on a set of transit centers.

The service structure implemented in 1998 has resulted in dramatic improvements in service quality and reliability. Immediately before the restructuring, only nine AMA routes had scheduled weekday headways of 30 minutes or less (Multisystems, 1999). After the restructuring, every AMA route operates at headways of 30 minutes or less during all service hours. Bus routes are designated with a letter based on the service frequencies provided: "A" routes operate with headways of 15 minutes or less on weekdays, the "B" routes operate every 20 minutes on weekdays, and the "C" routes operate every 30 minutes.

With the new structure and service levels, ridership on the bus system increased 8.5 percent and farebox revenues increased by $1.2 million (Multisystems, 1999). Service reliability on most routes is improving, with over ninety percent of scheduled service in operation. Although this restructuring has been quite successful, continuing to improve toward the goal of providing 100 percent of scheduled service by the time Tren Urbano

opens will require additional effort on the operator's part. However, this task is made easier given that extra vehicles are now available for operation.

The option of extending service hours of the bus system provides an opportunity to expand service within the context of the existing service structure. Currently, most AMA and Metrobús routes operate between the hours of 5:00am and 9:30pm. The improvement in weekend service frequency and reliability produced by the 1998 restructuring resulted in a significant increase in weekend ridership of close to 30 percent. Extending the service hours to midnight or 1:00am will require no changes to the existing transit center structure, making the change relatively easy to plan and implement. This change will also make the bus service compatible with the Tren Urbano service, which will operate twenty hours a day, from 5:00am to 1:00am. Moreover, the expansion of service hours will also be compatible with the groups of riders that travel primarily in the evening and weekend periods, such as hospital personnel, late-night recreational customers, and restaurant and retail workers.

By implementing this strategy before opening day, the credibility of the transit system can be firmly established among the residents of the SJMA. A credible system will stimulate passenger interest, and over time, should develop strong off-peak ridership. Hence, extending service hours before opening day can help ensure that there will be passengers using Tren Urbano during the off-peak periods. In addition, retaining existing riders and attracting new riders will help to improve transit ridership and decrease the amount of excess capacity, during both the peak and off-peak periods, that is anticipated on opening day.

Boosting evening and weekend service will not only improve the customers' perception of transit, but communities and local governments will also benefit. The improved accessibility provided by the extension of service hours will promote evening and weekend activity, which will benefit local shops, restaurants, and potentially the local economy. From the operator perspective, this strategy will require additional resources, but will also simplify coordination with future Tren Urbano service as well as ensure that

some of the excess Tren Urbano capacity that will exist in the evening and weekends will be utilized.

Additionally, public transportation accessibility in Santurce can be further emphasized if service from Sagrado Corazón to the Condado is implemented at the new station. The Condado service could operate from Sagrado Corazón to Parada 18 via two main roads to the area- R.H. Todd and Ashford Avenues. Improved evening and weekend service to Condado would also provide access to a popular but currently underserved market.

5.2.3 Transfers

The transit center concept relies strongly on bus-to-bus transfers. The implementation of the transit center structure in early 1998 has resulted in improved ridership. The key factors in its success appear to be high quality transfer center, improved service reliability, and strong marketing of the new structure to the public. Even though the use of bus-to-bus transfers does not appear to have had a negative impact on the passengers' use of transit, the transfer issue remains a concern. Given that intermodal transfers with Tren Urbano will be important in the near future, attention needs to be focused on improving the quality of the transfer center, service reliability, and the dissemination of public information. In addition, the financial impact of transfers at $0.25 fares is substantially lower than the Tren Urbano and Metrobús fares of $1.00 and $0.50, respectively, or indeed with a possible increased fare on AMA routes.

As the northern terminus of Tren Urbano, the Sagrado Corazón station will play a large role in defining the public transportation system in the Santurce / Old San Juan corridor. The Sagrado Corazón station will provide Tren Urbano riders access to the Santurce / Old San Juan corridor, and customers in the Santurce / Old San Juan corridor will travel to Sagrado Corazón to ride Tren Urbano. For these reasons, the Sagrado Corazón station will become the major point for bus-to-bus and bus-to-rail transfers in the Santurce / Old San Juan corridor. Hence, it is necessary in this time period to ensure that the Sagrado

Corazón station is designed and constructed so that the service providers using the station will be able to coordinate and execute the intermodal transfers effectively.

Additionally, creating a well-designed transfer environment is even more important when examining the long-term impacts on the passengers' image of the public transportation system. On opening day, the Sagrado Corazón station is the point where many Old San Juan residents will first be exposed to Tren Urbano, and a lasting, positive first impression needs to be made. Creating a comfortable and convenient station environment will help in establishing this positive image along with the public perception of transit as a viable alternative to the automobile. A positive impression will also help to establish a base of riders that will continue to grow in the future, helping to achieve the long-range goal of creating a successful transit system that is used and supported by a transit-oriented culture.

5.2.4 Resources

The most important resource that must be considered is the size of the operating budget which dictates how much can be spent to procure, operate, and maintain the existing bus services. The operating costs, vehicles, and personnel required to implement a service strategy and the potential constraints of the operating budget all play large roles in the identification and selection of the service strategies for this period. Currently, the AMA budget for 1999 is over $43 million and the PRHTA five-year Construction Improvement Program (CIP) incorporates a $4 million annual Metrobús operating subsidy and a similar supplemental subsidy for AMA. The CIP also anticipates that the $10 million annual increase in FTA urbanized area formula program apportionments will be devoted entirely to transit (FEIS, Tren Urbano, 1995). There is also the planned purchase of 72 AMA replacement buses in 2000/2001 (Multisystems, 1999).

Given that the operator will be receiving a steady stream of financing and vehicles, resource availability should not be a major problem in this time period. The extension of

service hours will not significantly increase the number of vehicles required, but will require increases in the number of drivers and the operating budget and increases the complexity of managing to ensure 100% schedule performance. Table 5-1 lists the vehicle requirements for the three trunk routes operating between Río Piedras and Sagrado Corazón. From this table, there are no major differences between the peak and midday vehicle requirements. However, there are noticeable differences between the peak-period and evening/weekend vehicle requirements; the decrease in the number of vehicles in service ranges from seven vehicles (from 17 to 10) for Metrobús I service to ten vehicles (from 18 to 8) with A9 service. Metrobús Express has no evening or weekend service, since it does not provide major time savings over Metrobús I during these periods due to low congestion levels. However, should express service to Old San Juan be needed during the evening and weekend periods to accommodate heavy demand, such as during special events, service can be implemented with the use of the existing vehicles and additional drivers. Assuming that Metrobús Express maintains the same 10 minute headways as it does during the weekday peak periods, only 7 or 8 vehicles would be needed.

Table 5-1. Current Vehicle Requirements

Route	Time of Day			
	AM	Midday	PM	Evening
Metrobús I	17	15	15	10
Metrobús Express	8	7	7	n/a
A9	18	18	18	8
TOTAL	43	40	40	18

Source: AMA Operating Schedules

For the routes in the Santurce / Old San Juan corridor, no additional vehicles are required to boost off-peak service, since the vehicles that are used to provide peak period service can be utilized. Nevertheless, an increase in the number of buses and operating funds would greatly improve the ability to provide high quality evening and weekend services. This will allow the transit system to tap into and serve the latent demand that exists during this period. Additionally, this market will be important once Tren Urbano opens, and using additional resources to boost off-peak service early will help ensure that future evening and weekend service levels and ridership will be strong.

Additional vehicles and operating funds can also help to establish improved service to Condado from Sagrado Corazón. This service will not only help to make public transportation more accessible to Condado and vice versa, it will improve the quality of service to the area as well as establish a strong presence in the area, potentially resulting in increased transit usage in the future.

The customers also benefit from the operator's use of additional resources. Improved evening and weekend bus service during holidays and special events, such as festivals in Old San Juan, would further help to establish the credibility of the transit system in serving the Santurce / Old San Juan corridor. If the operator does not have enough funds in this year's operating budget to facilitate high quality evening and weekend service at all times, it may be prudent to provide such services only during these special events. The credibility gained by such services can help to secure an adequate operating budget for the full-scale evening and weekend service in the next year, still in advance of Tren Urbano Opening Day.

Additionally, plans for allocation of additional resources to improve service levels and relieve overcrowding are currently being finalized. AMA has 29 buses available for operation that were procured in 1999 to accommodate the Special Olympics. Fifteen of these buses have been included in preliminary plans that are currently being developed by Multisystems to improve the frequencies on the original "C" routes (every 30 minutes) to those of the "B" routes (every 20 minutes). In addition, the remaining 14 buses will be used to reduce overcrowding on several of the "A" routes, namely routes A3, A5, A6, and A9. It will also be possible to utilize the extra vehicles for the extension of service hours. This will ensure that these service changes are in line with future expansion and modification of the system to serve Tren Urbano.

5.2.5 Timing of Implementation

The extension of AMA and Metrobús service hours should be planned and implemented before Tren Urbano opens. However, time is necessary in order to plan, market, and test the service changes. Looking at the time required for the 1998 bus service restructuring, the implementation of the new plan was completed approximately three months after the approval of the changes. However, it is important to note that the restructuring that took place in 1998 was a major overhaul of the bus system throughout the SJMA, and was a very complex undertaking. Nevertheless, though the extension of service hours may be a minor change, it should also take several months to implement, because the process of training, marketing, and testing will be similar regardless of the complexity of the strategy.

The extension of service hours should be implemented at least a year before the Tren Urbano opening in summer 2002. This will provide enough time to implement service changes and establish strong evening/weekend transit service. In addition, once the SJMA residents become accustomed to the new service hours and improved mobility during the evening and weekends, ridership in these periods will also become stronger. With the early implementation, the operator will have enough time to evaluate and refine the bus services to ensure that when Tren Urbano is opened, there will be high quality complementary services available as well as strong passenger interest in transit.

In addition, if an AMA fare increase is required, from $0.25 to $0.50, it can be implemented in conjunction with the extension of service hours. First, this fare increase can be justified to the residents of the SJMA by associating it with the improvement in off-peak levels of service. Additionally, the fare increase will help reduce the shock of the higher Tren Urbano fare when the system opens. Employing the fare increases will help the riders realize that there is a correlation between fare and levels of service, and that paying the extra fare to ride Tren Urbano is justified by the rail system's higher levels of service. As a result, passengers can be made more aware of the benefits of the new rail system and the likelihood of them using it will increase. In addition, the

operator can also implement new fare payment systems, such as magnetic fare cards, or new fare policies (free or discounted transfers, off-peak discounts, and prepaid or student/elderly discounted passes) can help the operator develop expertise in managing more sophisticated fare collection systems. In addition, this would provide an opportunity to determine the potential impacts of transfers on rider behavior when more substantial fares than $0.25 are involved.

As mentioned earlier, if the operator is unable to provide the extension of service hours all at once, the service hours can first be extended during special events or holidays, when there is a large potential for new passenger demand in the off-peak. By providing high quality service during these events, the transit system can establish credibility among the residents of the SJMA as an alternative to driving. Continued improvement of off-peak service can lead to increased off-peak ridership once the service hours are extended. In addition, by first "testing" the service change with these special events, the operator will get a better picture of the time, costs, and vehicles required to maintain extended service hours. Using this information, the operator can more effectively implement this strategy, helping to ensure that high quality off-peak service will be provided when Tren Urbano opens. Moreover, because the focus on off-peak service will be new to the transit system, special attention will be required by the agency's management to monitor off-peak schedule adherence and service delivery. New technology, such as AVL, could be implemented to help increase the operator's ability to manage off-peak services during these important periods.

5.3 Time Period 2: Tren Urbano Phase I

The decisions that must be made to prepare for the second period, which begins with the opening day of Tren Urbano, are critical. Tren Urbano will be operational, radically changing the face of the transportation system in San Juan. Success in this time period will help determine the long-term future of Tren Urbano and the public transportation

system. This requires that service quality for current riders be retained and improved while capacity to attract and service new riders is added.

The priorities in this period are to establish a high quality intermodal system that transports passengers effectively between Tren Urbano and points along the Santurce / Old San Juan corridor. By creating a system that maintains high levels of service, the passengers' perception of transit will be of a system that provides high quality service and improves mobility and accessibility throughout the Santurce / Old San Juan corridor. Creating a positive image for transit will help to improve the chances of future success.

Curiosity riders will be a large factor during the early days of Tren Urbano operation. Many of these riders will most likely take Tren Urbano for social and recreational trips in the off-peak periods. Furthermore, many of the recreational trips made in the Santurce / Old San Juan corridor are likely to be destined for Old San Juan. Providing high quality services to accommodate these curiosity riders well will improve the credibility and image of transit as a viable alternative to driving.

The convenience of the automobile during off-peak periods is very significant. Therefore, in order to motivate residents to get out of their automobiles and onto transit, it is essential that high quality services be provided. Only by establishing a strong and effective bus service to Old San Juan from Sagrado Corazón will the off-peak ridership potential of both Tren Urbano and the bus system be realized. Since the availability of parking in Old San Juan and throughout the SJMA is limited, residents may be more inclined to park at Tren Urbano stations and use transit to access Old San Juan. But to ensure that a strong ridership base will develop, a high quality intermodal connection at the Sagrado Corazón station between Tren Urbano and the buses to Old San Juan needs to be established immediately.

The objective for the bus system in this period is to ensure that high quality services are provided at the Sagrado Corazón station to effectively accommodate the passengers that will be traveling throughout the Santurce / Old San Juan corridor. Tren Urbano will

clearly provide a high quality service, and represents a significant investment in improving the public transportation system in the SJMA. As a result, there are community and government pressures on the service providers to show high returns, notably in terms of high ridership, on this investment. It is important that the operator focus on the needs of the customer while also trying to maximize the use of Tren Urbano to meet the expectations placed upon the system. Since it will take some time for Tren Urbano ridership to grow to its projected level, the operator needs to effectively integrate the bus and rail system to provide high levels of service, ensuring that ridership is generated to meet the expectations placed on the transit system.

Providing high service levels is especially important at the Sagrado Corazón station since it will become the major hub for transit service in the Santurce / Old San Juan corridor. As the transit hub, a large volume of passengers, especially during the peak periods, will be transferring between Tren Urbano and the buses. As a result, the bus service at the Sagrado Corazón station must provide sufficient service capacity to accommodate the volume of transferring passengers. Ideally, empty buses should be available at the station waiting to serve passengers that need connecting service to the rest of the Santurce / Old San Juan corridor. Providing empty buses that operate at headways that match the Tren Urbano headways will also help to create a high quality transfer experience. The presence of high quality transfers at the station will have a large impact on the success of the transit system in the Santurce / Old San Juan corridor.

As identified in Chapter 2, the presence of the transfer penalty can have a significant impact on the passengers' willingness to take transit. The analysis of bus service strategies for this time period is based on the assumption that the transit system is successful in keeping the transfer penalty close to zero by effectively managing the transfer environment and intermodal integration. The waiting bus concept, as described above, will reduce the time spent in transfer, helping to keep the transfer penalty low. In addition, to ensure that the transfer penalty is minimal, there is also a need for free transfers, since the cost component of the transfer also plays a significant role in defining the transfer experience.

One effective method of providing high quality transfers and ensuring empty buses are available at the Sagrado Corazón station is to terminate routes at the station. However, terminating routes would impact the levels of service provided by the bus system to current passengers. Some through service at the station would be eliminated, so some passengers would be forced to transfer. The routes most likely to be affected are those operating between Río Piedras and Sagrado Corazón: Metrobús I, Metrobús Express, and A9. Since service to Old San Juan is a priority, and since Tren Urbano will then be operating along this segment, it is desirable for the operator to eliminate bus service between Río Piedras and Sagrado Corazón. However, from the passengers' perspective, the elimination of service may result in inconvenience that will be magnified if they are forced to use the unfamiliar and more expensive Tren Urbano system. As a result, the operator must ensure that high levels of service are provided at the Sagrado Corazón station to reduce the negative impacts of the transfer, and consider retaining some one-seat ride capacity.

The opening of Tren Urbano will certainly have impacts on the service provided between Río Piedras and Sagrado Corazón. Currently, the capacity during the peak hour of the major trunk lines between Río Piedras and Sagrado Corazón is about 1,500 seated passengers or 2,500 seated and standing passengers (Table 5-2).

Table 5-2 Current Peak Bus Service Capacity: Rio Piedras to Sagrado Corazón

Route	Headway (min)	Frequency (veh/hr)	Seated (pax/hr)	Standing/ Seated (pax/hr)
Metrobús I	6	10	440	700
Metrobús Express	10	6	264	420
Metrobús II	10	6	264	420
A3	10	6	264	420
A9	8	8	352	560
TOTAL	--	**22**	**1584**	**2520**

However, once Tren Urbano opens, there will be a major increment in the capacity provided along the Río Piedras to Sagrado Corazón corridor. Tren Urbano is planned to operate four-car trains between 5:00 am and 9:00pm. After 9:00pm and on evenings and weekends, two-car trains will be provided. Table 5-3 gives the service characteristics of

Tren Urbano by time of day. In the peak period, given that the total capacity of one four-car train is around 288 seated and 700 seated and standing comfortably, with peak hour headways of four minutes, the total peak-hour capacity of Tren Urbano is over 10,000 passengers. According to Tren Urbano forecasts, the peak load point will be at Río Piedras. For the year 2002, there will be approximately 4,500 passengers on Tren Urbano at Río Piedras during the AM peak period (Cambridge Systematics, 1999) that are traveling toward Sagrado Corazón. The passenger volume that is forecast to travel along the Río Piedras to Sagrado Corazón segment is twice the current service capacity of the bus system (2,500 passengers seated and standing) along this segment. As a result, Tren Urbano will be able to handle the demand easily, with less than half its capacity used and the ability to accommodate an additional 6,000 passengers per hour.

Table 5-3. Tren Urbano Peak Load Service Characteristics

Characteristic	Peak Period	Midday	Evening/Weekend
Peak Period Headways	4 minutes	8 minutes	12 minutes
Capacity / Vehicle (seated/max)	72/180 pax	72/180 pax	72/180 pax
Capacity / Train (seated/max)	288/720 pax	288/720 pasx	144/360 pax
Number of Vehicles / hour	60	32	10
Number of Trains / hour	15	8	5
Capacity / Train-hour (seated)	4,320 pax	2,304 pax	720 pax
Capacity / Train-hour (seated/standing)	10,800 pax	5,760 pax	1,800 pax
TU Pax/ hour (*in 2002*)	4,500	2,000	900
Average Load (*pax/train*)	300 (*~42%*)	250 (~35%)	180 (~50%)
Remaining Capacity (seating/standing)	~6,000 pax	~3700 pax~	~900 pax

Note: Tren Urbano peak load point occurs at Río Piedras

Moreover, in the midday period, the utilization of Tren Urbano decreases considerably. With Tren Urbano operating four car trains during the midday, a significant amount of excess capacity will exist, particularly if combined with the existing bus service (Table 5-4). Since strong levels of curiosity riders are expected during the off-peak initially, the excess capacity will ensure that passengers will not have to stand. Most of the Tren Urbano seats will be filled but there should be little if any standing.

Table 5-4 Current Midday Bus Service Capacity: Rio Piedras to Sagrado Corazón

Route	Headway (min)	Frequency (veh/hr)	Seated (pax/hr)	Standing/ Seated (pax/hr)
Metrobús I	6	10	440	700
Metrobús Express	10	6	264	420
Metrobús II	10	6	264	420
A3	10	6	264	420
A9	10	6	264	420
TOTAL	--	**22**	**1496**	**2380**

In the evening and weekend period, with longer headways and shorter trains, the utilization of Tren Urbano is about 50 percent. With both the bus services (Table 5-5) and Tren Urbano in operation, the capacity of the transit system along the Río Piedras to Sagrado Corazón segment more than doubles.

Table 5-5 Current Evening Bus Service Capacity: Rio Piedras to Sagrado Corazón

Route	Peak Hour Headway (min)	Frequency (veh/hr)	Seated (pax/hr)	Standing / Seated (pax/hr)
Metrobús I	10	6	264	420
Metrobús II	10	6	264	420
A3	15	4	176	280
A9	15	4	176	280
TOTAL	--	**20**	**880**	**1400**

As shown above, if there are no changes in bus service there will be excess capacity provided by Tren Urbano and the bus service along this corridor during both the peak and off-peak periods. The most dramatic increase in capacity is during the peak-period where total capacity (seated and standing) increases five-fold: from a bus service capacity of 2,500 passengers to over 13,000 with both Tren Urbano and the existing bus services. Given this, it is appropriate to consider strategies designed to reduce or more effectively utilize this capacity through the gradual shifting of bus services. Yet, also identified above is the fact that there are service capacity issues that will exist at the Sagrado Corazón station. The availability of empty bus seats is necessary to provide a convenient and high quality transfer experience for the passengers arriving on Tren Urbano. Hence, not only should the bus service strategies focus on the effective utilization of capacity, they must also focus on providing sufficient capacity at Sagrado Corazón to establish high levels of service for transferring passengers that will lead to increased passenger interest in and use of the new rail system. In addition, the service strategies need to avoid

adversely affecting the current customers who are receiving one-seat rides from Old San Juan and Santurce to Hato Rey and Río Piedras at 6-minute headways during the peak periods.

5.3.1 Sagrado Corazón Station Analysis

The analysis of the Sagrado Corazón station is a key component of the planning and analysis of bus service strategies in the Santurce / Old San Juan corridor. The first phase of Tren Urbano will terminate at this station, and buses will provide service onward to Old San Juan. Once operational, Sagrado Corazón will be a major transfer point for the transit services in the Santurce / Old San Juan corridor, and will remain so at least until the Minillas extension is completed. The effective handling of transfers between Tren Urbano and the buses is paramount to providing high service levels and attracting significant levels of ridership. If transfers are not handled effectively, those traveling to the Santurce / Old San Juan corridor will be inconvenienced and may be discouraged from taking transit in the future. As a result, the Sagrado Corazón station must be designed effectively to ensure that these passengers will not be inconvenienced, and that ridership will not be discouraged.

Several goals and objectives must be met by the Sagrado Corazón station. One goal is for the Sagrado Corazón station to become an effective interim hub for bus services operating throughout the Santurce / Old San Juan corridor. As the hub, the station plays a large role in influencing the design of service strategies and the improvement of the transit system. Another goal is to improve the operator's ability to provide high levels of service on both bus and rail systems. A third goal is to ensure that a friendly transfer environment is established so that passengers will be comfortable with the idea of transferring and taking transit, which in the future, can potentially lead to the improved use and image of transit in this corridor.

Passenger Requirements

The passengers that will be using the Sagrado Corazón station to transfer between buses and Tren Urbano comprise the most important party that the Sagrado Corazón station must accommodate. The station environment has significant impacts not only on the passengers' willingness to transfer, but also on their desire to take transit. A positive transfer experience will encourage further transit use, while a poor experience will discourage current and future passengers from using transit.

When evaluating the layout of the station and its ability to facilitate intermodal transfers, one must consider the level of service variables that are important to passengers. These elements, which include comfort, time, security, and cost, will play a critical role in determining whether passengers will use transit. Hence, the Sagrado Corazón station must be organized so that the potential negative impacts of transfers on the passengers are minimized.

The current station design provides station amenities that will help to increase the friendliness and appeal of the station as well as the overall transfer experience. Several small concessions are planned inside the station, but most of the retail, recreation, and restaurant concessions will be located in the surrounding area. There are also plans to introduce art and cultural displays, information kiosks, and other interactive elements that will also increase the convenience of the station.

Passenger safety and security will also be enforced in several respects. Areas such as the waiting platforms are open and visible from station attendant booths, increasing the passengers' sense of security. Second, station amenities, such as retail concession stands, will be incorporated into the station area to promote activities that put more people on the street and in the station, creating a self-enforcing environment. In addition, all indoor and outdoor spaces will be well lit, both during the day and at night, further improving safety and security. The station attendant will also be trained to circulate in the waiting areas to assist with security and customer information.

Though a number of the passenger requirements that have been met with the current station design, there are others that still need to be addressed in order to create a transfer environment that will reduce the penalty associated with transfers and encourage increased use of transit.

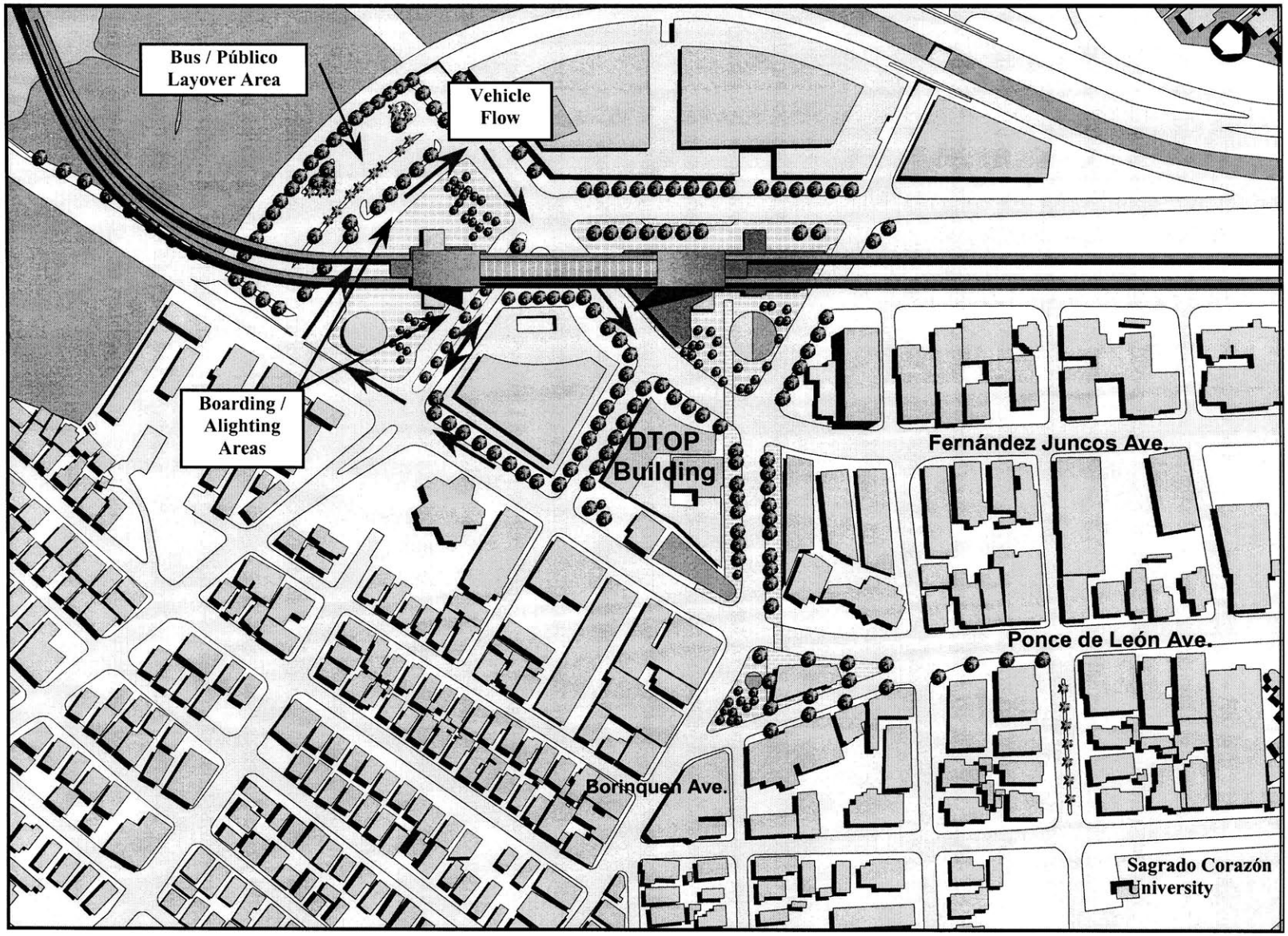
- *Travel time*

The time-related elements of the transfer are very important. Prior research has shown that that one minute spent in the transfer process is equivalent to two to three minutes of in-vehicle travel time. Hence, it is important to keep to a minimum the time passengers spend transferring at the station.

There are a number of different design elements that impact the time spent during a transfer. First, the time it takes physically to transfer from the rail platform to the bus stop is dependent on the walking distance between modes and the presence of level changes. Currently, the station has a level change, and there is a walk required from the head house to the bus stops. As a result, bus boarding areas need to be located close to the entrance to the head house in order to minimize the time required to transfer between modes (Figure 5-1). Additionally, during peak periods, large volumes of passengers can result in bottlenecks and queues if passenger circulation is hindered. Hence, it is important that the layout of the station minimize conflicts in passenger flows to reduce the time spent transferring.

Another element that affects the passengers' transfer time is the waiting time for the connecting service. Passenger waiting time, as well as passenger satisfaction, will be improved dramatically if there is a bus waiting for the transferring passengers. Wait times are even more important in the evenings, since it is during this time when safety and security concerns become critical. Hence, it is recommended that buses be waiting at the station or high frequency connecting routes be established so that passengers will not have a lengthy wait.

Figure 5-1. Sagrado Corazón Station Area



- *Comfort and convenience*

The station's interior and exterior environment needs to be designed to enhance the ease with which passengers are able to transfer between modes. The distance and travel path between the station and bus stops are important considerations. Long walks can be uncomfortable, especially given the high temperatures and frequent showers that occur in Puerto Rico. Walking and waiting areas with protection from weather improve passengers' comfort and transfer experience at the station. Since many residents in the SJMA do not like to walk, especially in extreme weather conditions, a shorter path between the bus stop and head house and protection from the weather will improve the convenience and attractiveness of the transfer.

The layout of the bus stops is important, since they must effectively accommodate the passengers waiting for, or transferring to buses. The bus stops for the heavily utilized routes such as Metrobús I, Metrobús Express, and A9 should be placed strategically. There are a number of unloading and loading areas that are possible at the station, and they should be located such that passenger and bus flows are not hindered. The loading/unloading areas should also be separated from the vehicle layover area to reduce passenger confusion as they transfer from Tren Urbano. As a result, these high demand, high frequency routes will be able to shuttle more passengers to and from the station, and the transfers can be conducted with minimal disruption to service.

The use of passenger information systems could also help reduce the inconvenience of transfers. Not only could these display broadcast news and other general information, they could also display real-time information on arriving and departing trains and buses. Providing this information would help ensure that passengers make a successful transfer. For the passenger, knowing when a vehicle is expected to arrive or depart, uncertainty about the transfer will be eliminated, reducing anxiety about missing a connection, and improving the overall convenience of the transfer.

Currently, there are tentative plans to implement AVL technology on the buses. AVL systems can support dynamic signs at bus stops and Tren Urbano stations displaying real-time status information to passengers. Passenger information can be integrated with existing displays at Tren Urbano stations to display both bus and train arrival and departure time. The additional information can help improve the convenience of the transfer for the passenger, as they can adjust their travel patterns as needed to ensure that the transfer is completed. Real-time passenger information is especially beneficial during the evening, when service frequencies are lower and passenger concerns about safety and security are amplified.

However, several institutional issues must be resolved before the AVL system can be fully implemented. In order for AVL to be truly effective, both AMA and Metrobús buses need to be equipped, and drivers trained on the use of the new systems. In addition, these systems must also be integrated with the Tren Urbano information systems so that the transferring passengers will have information on the status of both the buses and trains. Adopting the new technology may require additional operating and procurement costs, but it is in the best interest of *all* service providers to implement AVL systems to ensure that high levels of service can be provided for the passengers. However, implementing such changes for AMA, Metrobús, público and Tren Urbano services will require strong management and high levels of coordination and communication.

- *Safety and security*

Passenger safety and security is important; by maintaining the feeling of a safe and secure environment while using the system, the perception of Tren Urbano as a safe, secure, and dependable mode of transportation will improve. Maintaining a high sense of safety and security is important at all times, but is especially important in the off-peak periods, particularly after dark. Many residents are reluctant to take transit due to the perception that transit is unsafe and insecure, and these reservations are amplified in the evening. Locating the bus stops closer to the station entrance will help reduce the time passengers spend walking outdoors, improving their sense of security. Having a waiting bus at the

station will also reduce that number of passengers that wait alone on station platforms or at bus stops, improving their sense of security. The use of well-trained station attendants and the implementation of passenger information systems can also help increase the passengers' sense of safety and security. These systems will provide real-time information on the status of buses and trains, which will help reduce the passengers' sense of insecurity while they wait for their connecting vehicles. Establishing a safe and secure station environment will help attract off-peak ridership, increasing off-peak use of Tren Urbano and contributing to the overall success of the system.

- *Fare policy*

One of the most influential aspects of the transfer is the monetary cost that the passenger must incur. Making passengers pay an extra fare when transferring will discourage use of transfers, which can cause reductions in ridership. Free or discounted transfers may be appropriate to help reduce the cost penalty associated with the transfer and make transfers more attractive to the passenger.

The use of free transfers would greatly simplify the transfer process. When entering the station, passengers would be able to quickly pass through the station entrance without having to queue at ticket machines or fare gates. Free transfers also speed up the bus boarding process, and if passengers are allowed to board through either to the front or rear doors, boarding times will further decrease. Additionally, if the payment systems in the station are easy to use, passenger queues can be reduced, improving the flow of passengers into and out of the station.

Operator Requirements

The Sagrado Corazón station must not only satisfy the passengers, but it must be designed so that the service providers can execute and coordinate services to successfully handle passengers transferring between modes. Hence, the operator wants to ensure that the Sagrado Corazón station simplifies the process of managing intermodal transfers. By

doing so, it will be less difficult for the operator to provide high service quality and reliability.

Given the current layout of the station, the accessibility to Ponce de León and Fernández Juncos avenues is adequate. There are streets that allow buses to easily enter and exit from the station area. For the buses terminating or waiting for passengers at Sagrado Corazón, the current station design provides adequate curb space and parking. The buses used by AMA and Metrobús service are 40 feet in length (Multisystems, 1999). Current designs provide approximately 200 feet of curb space, with around 80 feet in the central boarding area and 60 feet on both Ponce de León and Fernández Juncos Avenues (FEIS, Tren Urbano, 1995). Given the space provided, traffic congestion and service disruption can be avoided since buses will be able to enter and exit the boarding areas easily.

- *Service capacity*

A critical aspect of the Sagrado Corazón station is its ability to handle the volume of passengers and vehicles that are expected. If the operator is unable to provide enough capacity to handle the forecast passenger volumes, then the transfer experience for the passenger will suffer. The priority for the operator should be to ensure that that transferring passengers are not inconvenienced by crowding in the station or on the buses. As discussed earlier, rail station platform crowding should not be a serious issue. However, the operator must make sure that buses arrive frequently enough during the peak-period to avoid excessive crowding at the bus stops.

In addition, the separation of the loading/unloading and layover areas is important. By differentiating between these two areas, vehicle flows through the station can be improved as potential disruptions due to layover buses obstructing the travel lanes can be avoided. The separation of the two areas will also improve the availability of curb space next to the station, increasing the number of buses that can load and unload passengers at the station, improving service capacity.

- *Station design*

Scheduled bus services will use the Sagrado Corazón station as the primary terminal and transfer facility in the Santurce / Old San Juan corridor. For the buses stopping at the station, there will need to be an adequate boarding/disembarking area close to the station entrance to ease transfers. The stops that are the closest to the station entrance should be reserved for the more heavily utilized routes, which will further improve transfers. Short distances will reduce the amount of wait time required to accommodate the transferring passengers, helping to improve service quality and reliability.

The integration of the station with the existing road network in the Sagrado Corazón area is another component that is important to the provision of high quality services. The Sagrado Corazón station will be situated at the intersection of Fernández Juncos and Ponce de León Avenues. Priority contra-flow lanes reserved for buses are already in place in these avenues. The improved accessibility of the Sagrado Corazón station will also help increase the number of passengers who use the station, not only because buses will be more effective in bringing passengers into the station, but it will also open the station to those who desire to be picked-up or dropped-off via automobile.

Públicos that may stop at the station will require special accommodations. Conflicts may occur between the buses and públicos for access to passengers and the rights of way to and from the station and boarding areas. To help resolve these potential conflicts, one solution is to make público boarding areas separate and distinct by providing curb space at the station to be used only for público loading and unloading. Moving público layovers to a separate location away from the curb will help reduce the competition for space and passengers at the bus stops. Passenger confusion at the station may also be reduced, since público layovers will not interfere with the passengers that are transferring onto AMA or Metrobús buses.

The operator also needs to address a number of issues related to the maintenance of the station environment. First, the responsibility of maintaining the station area, particularly the curb space, need to be shared among the modes that utilize it. In addition, funding for

improvements such as dynamic information signs, AVL technology, and the construction of additional bus shelters will need to be secured. In addition, the curb space that is allocated for the buses and públicos must be managed properly by station personnel to avoid potential conflicts between the AMA, Metrobús and público services. Strong management and coordination of the agencies utilizing the station area need to be present in order to resolve these issues.

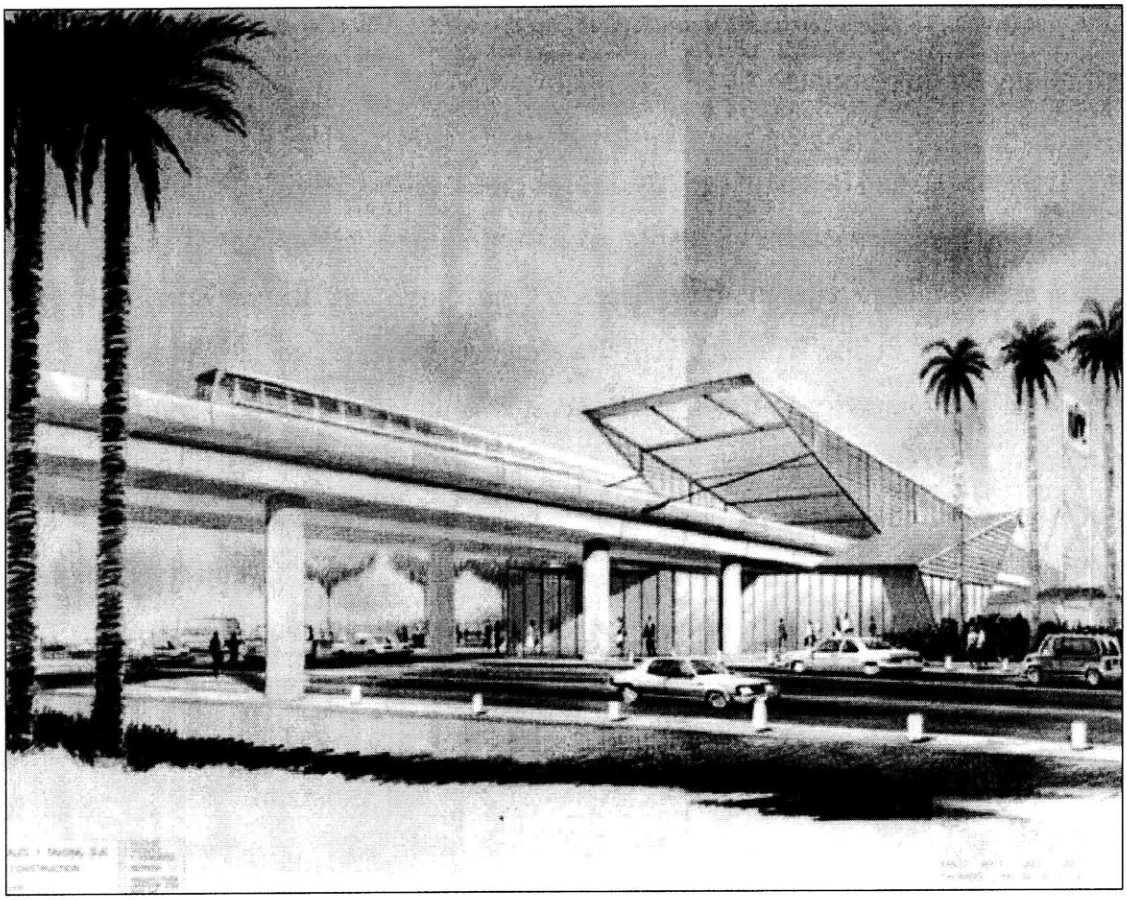
Community Requirements

The current design and layout of the station area meets several community requirements. First, development planned for the station area will improve the vitality of the Sagrado Corazón area. Situated adjacent to the Sagrado Corazón station, the new Department of Transportation and Public Works (DTOP) building will be mixed use; it will house government and commercial offices, retail shops, restaurants, and athletic facilities. In addition to the DTOP project, smaller restaurants, shops, and offices will be constructed on the streets around the station. Second, the environmental impacts of the station are a concern of the community that is already being addressed. During the construction of the station, there are traffic and congestion problems that are being mitigated to avoid undesirable environmental impacts. However, once the construction is completed, since the station will be well-integrated with the surrounding roadways, any increases in vehicular congestion due to transit vehicles will be kept to a minimum.

- *Station design*

In order for the station to be fully integrated into the surrounding community, its design (Figure 5-2) needs to be aesthetically pleasing so as to blend into the existing neighborhood. The station will change the face of the local environment, and an attractive station environment can help promote pedestrian activity and additional developments in the area as well as improve the image of Tren Urbano.

Figure 5-2. Artists' Conception of the Sagrado Corazón Station



The station design is also important to the improvement of the safety and security of the surroundings, especially during the off-peak periods. The station must foster a safe and secure environment to ensure that the area remains crime free and that residents do not associate negative impacts with Tren Urbano. The Sagrado Corazón station will attract large volumes of people, of different social status and income levels, from all over the SJMA. With the increased number of people traveling to the station, the presence of passenger traffic will create a self-enforcing environment that will increase the safety and security of the residents, passengers, and the surrounding community. The presence of security personnel should reinforce the sense of safety and security, particularly during the off-peak periods when the station may feel more desolate. The station is designed to protect passengers from the elements, but to preserve visibility should enhance passenger security.

- *Local area development*

The station also needs to help promote the development of the local area. The introduction of Tren Urbano provides numerous opportunities to improve the vitality of the currently lackluster Sagrado Corazón area. As the terminus of the first phase of Tren Urbano, the Sagrado Corazón station will attract large volumes of people. High quality services from the station to destinations throughout the Santurce / Old San Juan corridor will increase the number of passengers transferring at the station, improving both the peak-period and off-peak period activity in the Sagrado Corazón area. By combining increased activity and redevelopment of the station surroundings, there is potential to transform Sagrado Corazón into a major activity center. The proposed new transportation building, which will bring a large number of employees into the area with its ground floor that includes commercial activities which continue active use into the night, should complement the station in encouraging this transformation.

5.3.2 Infrastructure

Most of the roadways in the Santurce / Old San Juan corridor are not affected by Tren Urbano construction. However, as discussed in the first time period section, the road network located around the Sagrado Corazón area will be impacted by the new station. If proper integration of the Sagrado Corazón station with Ponce de León and Fernández Juncos Avenues was stressed in the previous time period, transit access to the station from these roadways should not be a concern.

Looking further into this time period, there are several major changes that will impact the transportation system. First is the construction of the Minillas extension. This construction will take place along Ponce de León, and will result in considerable disruption to the bus routes that operate along this avenue. The construction could not only cause severe traffic congestion, but could also eliminate the transit contraflow lane. Hence, service strategies in this period need to remain flexible so as to accommodate any potential disruption to service.

A second major change slated for the transportation system is the roadway construction at the Isleta. This construction will renovate the existing bridges and result in a multi-lane tunnel connecting the Isleta and Miramar. Though this construction will help relieve short-term congestion problems, the improved capacity and traffic flows may encourage increased vehicular flow onto the Isleta. This could potentially result in severe traffic problems in the future, since the arterials along the Isleta are already quite congested and cannot be expanded to accommodate further increases in traffic levels. In light of this construction, it is critical that the transit system continues to provide high quality service so that residents will be encouraged to take transit onto the Isleta.

Additionally, the construction provides an opportunity to reserve some form of right of way for transit usage. Whether it is a commercial vehicle lane to accommodate taxis, públicos and emergency vehicles as well as buses, or a contraflow lane, the provision of dedicated right of way can help to ensure that transit will be able to maintain service

reliability and quality. Accommodations for transit should provide the ability to bypass major congestion points, improving the transit system's image as a fast and convenient alternative to driving as well as making it very attractive to the residents.

5.3.3 Network Structure

To ensure that the success of Tren Urbano is established and maintained, there are a number of issues that must be addressed with the bus service strategies. First, the strategies must ensure that high levels of service are provided at all times by the bus system to and through the Sagrado Corazón station. Providing high levels of service will help maintain the current ridership base as well as attract additional riders. Secondly, the service strategies must be designed such that passengers are provided the opportunity to adjust smoothly to the Tren Urbano system. Ensuring a smooth transition will not only retain riders, but it will also help improve the public perception of the transit system. If passengers are forced to quickly change their travel patterns to adapt to the new rail system, they may be inconvenienced and could potentially be discouraged from taking transit in the future. Finally, the transfer environment must be designed to effectively facilitate transfers so that the passengers' transfer experience will encourage further use of the transit system to travel along the Santurce / Old San Juan corridor.

To provide high levels of service as well as to ensure an effective transfer environment, enough capacity needs to be provided to accommodate the passengers transferring at the Sagrado Corazón station as well as attract potential passengers onto transit. This will require that bus services in the Santurce / Old San Juan corridor be integrated well with Tren Urbano at the Sagrado Corazón station. A critical element to the success of the first phase of Tren Urbano is what occurs at the Sagrado Corazón station and its ability to handle the transfer volumes expected during revenue service. Table 5-6 gives the forecast number of passengers boarding and alighting Tren Urbano at Sagrado Corazón in 2010. To estimate the number of passengers using the station when Tren Urbano service commences in 2002, 70 percent of the 2010 forecasts is used (Multisystems, 1999).

Thus, the morning peak period will bring an estimated 1,700 passengers who will be disembarking at the Sagrado Corazón station (Table 5-6).

Table 5-6. Sagrado Corazón Forecast Daily Boardings and Alightings

Year	Station	Alightings	Boardings
2010	AM Peak	2,394	1,083
	Entire Day	14,374	12,146
2002	AM Peak	1,690	700
	AM Peak Transfers	~1,100	~520
	Entire Day	9,775	8,260

According to Cambridge Systematics estimates, the number of passengers needing to transfer will be approximately 1,100, or 70 percent of the AM peak period alightings at the station, with the remainder of the passengers walking or taking automobiles to/from the station. However, the Cambridge Systematics estimates were based on a feeder plan that truncated both Metrobús I and Metrobús Express at Sagrado Corazón and as a result reflect both Tren Urbano generated trips and diverted bus trips. If the Metrobús routes are not truncated, the number of transfers taking place at Sagrado Corazón will decrease due to the decreased number of trips diverted onto Tren Urbano. Hence, additional assumptions based on Cambridge Systematics estimates are that if Metrobús I and Metrobús Express service is not truncated, approximately 65 percent of the trips made on the existing bus services along the Río Piedras to Old San Juan corridor would be diverted onto Tren Urbano, while the rest would remain on the buses. Given these assumptions, approximately 900 passengers during the peak hour would be transferring at Sagrado Corazón should Metrobús service be retained. However, in the analyses conducted for the rest of this section, the original transfer volumes estimated by Cambridge Systematics were used. First, these numbers were used to keep the service capacity analyses consistent across all time periods. Secondly, by taking into account larger transfer volumes, the bus service strategies implemented in each time period will be prepared for any potential fluctuations in ridership that may not be accounted for in the estimates, such as a surge of "curiosity" riders on Opening Day or unexpected increases in demand related to the completion of new developments in the Santurce area.

All of the transfers that are forecast to take place at Sagrado Corazón are assumed to be from Tren Urbano to buses traveling northwest in the Santurce / Old San Juan corridor. Furthermore, based on using origin-destination data from AMA and Metrobús, half of those transferring at the station are likely to be traveling to Old San Juan and the Isleta, while the other half will have destinations in Santurce. The three main trunk routes that stop at the station and run along the corridor (A9, Metrobús I, Metrobús II, and Metrobús Express) will need to handle most of these transferring passengers (Figure 5-3).

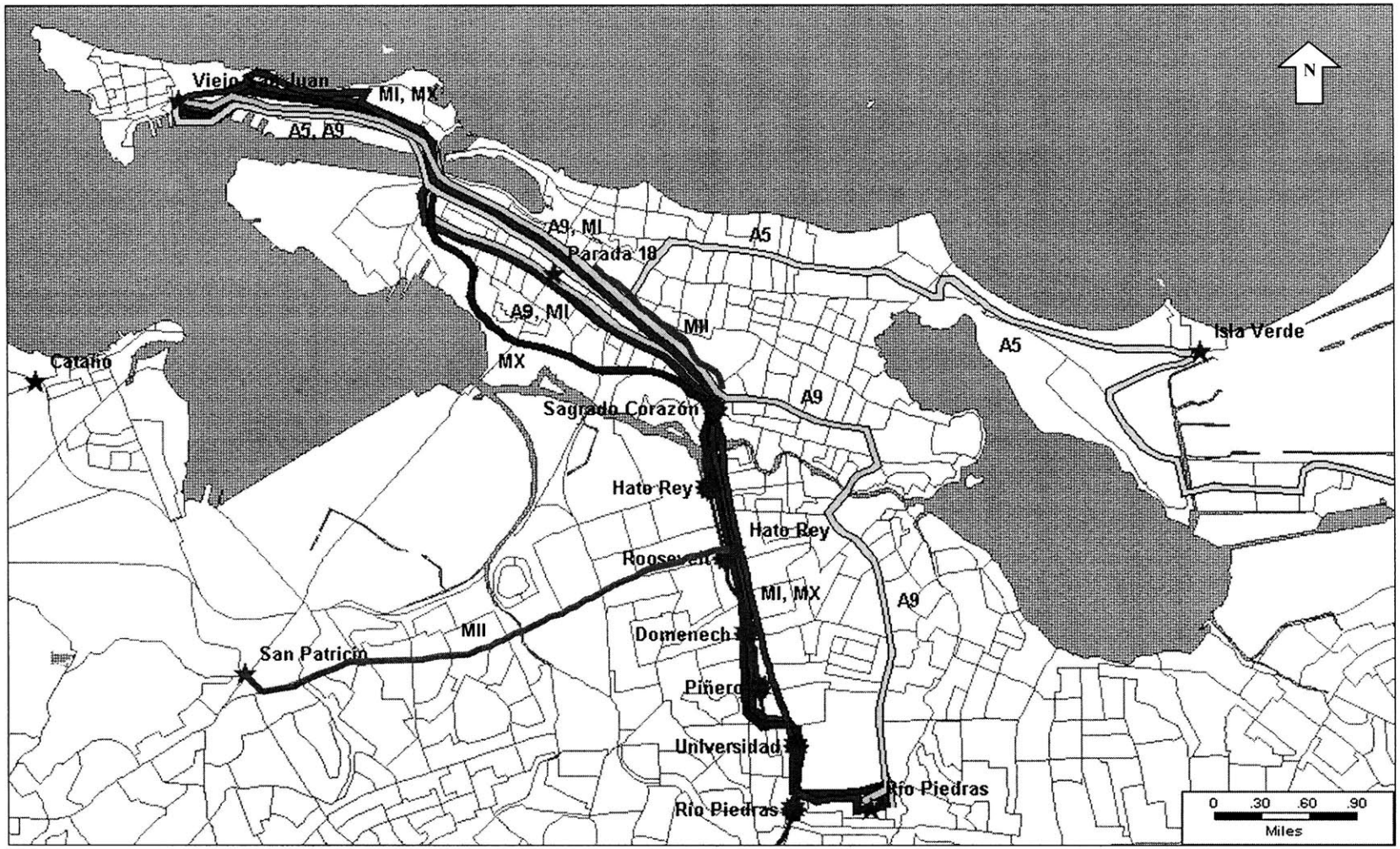
The AMA statistics report that for the bus fleet currently in operation, the seated bus capacity is 44 seats or 70 with standees. From current AMA/Metrobús ridership data, the current seat availability on A9 during the morning peak period is low; at the Sagrado Corazón station, the buses have an average of 31 passengers. On the other hand, Metrobús I and Express routes currently have average loads of 16 and 10, respectively[1]. Table 5-7 gives the potential AM peak hour service capacity at Sagrado Corazón using the current bus routes that operate in the area. Given the current passenger loads that exist on the buses when they reach this station area, there will not be enough capacity to accommodate comfortably the forecast number of Tren Urbano passengers that will be transferring.

Table 5-7. Current AM Peak Hour Bus Service Capacity at Sagrado Corazón

Route	Headway (min)	Vehicles in Service	Vehicles / hour	Avg. Load at Station (pax/veh.)	Capacity Available	
					Seated (pax)	Standing / Seated (pax)
A9	8	18	8	31	104	312
Metrobús I	6	17	10	16	276	536
Metrobús II	10	17	6	18	156	312
Metrobús Express	10	8	6	10	203	359
TOTAL		**60**	**30**		**739**	**1519**

[1] The Metrobús load estimates reflect adjustments made for passengers that are diverted onto Tren Urbano. It is also assumed that Tren Urbano has no significant impact on A9 ridership.

Figure 5-3. Current Bus Route Structures



In the selection of service strategies, there is a focus on identifying strategies that provide high levels of service at the Sagrado Corazón station. Moreover, these strategies should also focus on reducing the negative impacts of transfers on the passengers. As discussed in Section 5.3.1, the Sagrado Corazón station environment has been designed to provide a friendly transfer environment. The transit system should also provide convenient service. Providing high frequency connecting routes, as well as ensuring that empty seats are available for all transferring passengers, will greatly improve the convenience of the transfer.

Each of the major trunk lines (Figure 5-3) that are affected by Tren Urbano (A9, Metrobús I and Metrobús Express) will be analyzed in the following sections to determine the combination of service strategies that can best accommodate the new Tren Urbano service while also improving the quality of service provided along the Santurce / Old San Juan corridor. There are, in addition, other less major AMA services which will provide some service at Sagrado Corazón, but they do not provide major seated capacity, and since they will operate in the contraflow lanes and will not compete for space in the station area, they are not critical in this analysis. In order to focus the service strategy analysis and to provide additional detail on the performance of each bus routes, four sets of origin-destination pairs that are reflective of most trips taken in the Santurce / Old San Juan corridor will be used: Río Piedras – Old San Juan, Hato Rey – Old San Juan, Río Piedras – Minillas, and Hato Rey – Minillas. These pairs were chosen based on the fact that they are the major activity centers in this corridor, and also because the passenger volumes along these segments comprise a large percentage of the total daily trips taken on the bus system.

Route A9

The A9 service operates between Río Piedras and Old San Juan and also serves the Minillas activity center providing service primarily to those traveling between Río Piedras and Minillas and Río Piedras and Old San Juan. However, the A9 route provides

service to a different set of riders than does Metrobús I or Metrobús Express. Along the Río Piedras to Sagrado Corazón segment, unlike the two Metrobús routes that serve a commercial corridor, the A9 route runs through a primarily residential corridor and provides high quality transit service to this market. These residents along the A9 will not have easy access to Tren Urbano, since the A9 route runs approximately one mile east of the Tren Urbano alignment. Since there is no overlap with the Tren Urbano system or any other bus routes, the ridership and service provided along the A9 Río Piedras to Sagrado Corazón segment may not experience significant changes when Tren Urbano is opened.

Currently, the capacity of the A9 is adequate to handle the demand along the Rio Piedras to Sagrado Corazón segment. From the AMA ridership data, A9 buses arrive at the Sagrado Corazón station with an average of 31 passengers per bus during the peak period (Table 5-8). During the midday and evening hours, the A9 still provides enough capacity to provide seats for passengers along the route as well as at the station. However, in the evening period, the average bus load at the station is 33, which is greater than during the peak period. This result indicates that there is significant demand for transit services during the evening period that is currently being underserved. By extending service hours and improving service levels the existing riders could be better served and the transit system could tap into the latent demand for transit service that exists during this period

Table 5-8. Current A9 Service Capacity by Time of Day

Time of Day	Headway (min)	Vehicles in Service	Vehicles / hour	Average Bus Load at Sagrado C.	Remaining Capacity	
					Seated (pax/hr)	Standing / Seated (pax/hr)
Peak Hour	8	18	8	31	104	312
Midday Hour	8	18	8	23	165	373
Evening Hour	15	8	4	33	46	150

Tables 5-9 and 5-10 list the service characteristics for the A9 route by time of day for the Río Piedras to Old San Juan and Río Piedras to Minillas service markets. Though the A9 route operates at considerably higher travel times compared with the Metrobús I and Metrobús Express routes, its fare is only half that for Metrobús service, consistent with

the service differential. While Metrobús II service does not serve this entire market, its presence would provide capacity that helps resolve the capacity issue at Sagrado Corazón. Additionally, it must be noted that though the A9 service does not look as attractive as the other options, since it does not compete directly with either Metrobús route between Río Piedras and Sagrado Corazón and provides service to a unique market, ridership on the route is relatively high.

Table 5-9. A9: Rio Piedras to Old San Juan Service Market

Options	In-Vehicle Travel Time (min)	Total Wait Time (min)	Total Travel Time (min)	Fare (USD)
Peak				
MX	28	5	33	0.50
MI	38	3	41 (+8)	0.50
A9	*48*	*4*	*52 (+19)*	*0.25*
Midday				
MX	28	5	33	0.50
MI	34	3	37 (+4)	0.50
A9	*35*	*4*	*39 (+6)*	*0.25*
Evening/weekend				
MI	34	5	39	0.50
A9	*35*	*8*	*43 (+4)*	*0.25*

Metrobús II and Metrobús Express are not relevant to the Río Piedras to Minillas service market.

Table 5-10. A9: Rio Piedras to Minillas Service Market

Options	In-Vehicle Travel Time (min)	Total Wait Time (min)	Total Travel Time (min)	Fare (USD)
Peak				
MI	24	3	27	0.50
A9	*33*	*4*	*37 (+10)*	*0.25*
Midday				
MI	24	3	27	0.50
A9	*30*	*4*	*34 (+7)*	*0.25*
Evening/weekend				
MI	19	5	34	0.50
A9	*28*	*8*	*36 (+2)*	*0.25*

Route A9 currently carries over 11,000 daily trips of which 3,000 are destined for Santurce, 1,300 are destined for the Isleta and Old San Juan and 7,500 take place between Rio Piedras and Sagrado Corazón. Given the high number of trips served and the reliance of the residents on A9 service along the Río Piedras to Sagrado Corazón segment, maintaining this segment is essential to the provision of high quality service to the residents of the SJMA.

Thus, the A9 route should be kept as it is during all periods of the day in order to maintain high quality transit service and minimize any potential inconvenience for existing passengers. The termination of A9 at Sagrado Corazón would eliminate transit service between Río Piedras and Sagrado Corazón and would result in 7,500 passenger trips that would need to find an alternative means of travel to Río Piedras or the Santurce / Old San Juan corridor. If A9 were to be truncated so that the Old San Juan segment were eliminated, the passengers from the neighborhoods served by A9 that originally had one-seat rides into the Santurce / Old San Juan corridor would be forced to get off at the station and wait for connecting service. Not only would passenger inconvenience be increased with the transfer, but equivalent substitute bus capacity and increased wait time and terminal time for the resultant two trips would increase bus operating cost. In addition, since the station would also have to accommodate both A9 and Tren Urbano passengers, excessive crowding may result, further degrading the passengers' transit experience. If A9 is maintained and frequency improved at night, these negative impacts on passengers and levels of service can be avoided. Moreover, any excess capacity that becomes available on A9 upon reaching Sagrado Corazón can be used to accommodate some of the passengers desiring connecting service from Tren Urbano to points along the Santurce / Old San Juan corridor. Finally, the maintenance of a low cost, but higher travel time/one-seat ride from Río Piedras to Santurce and Old San Juan provides an escape route for particular fare sensitive passengers.

- *Short-turn A9 at the Isleta*

According to AMA statistics, the A9 route currently serves 3,000 trips heading to/from Santurce compared to only 1,300 to the Isleta. Given that there are currently five other bus routes that also operate along the Isleta, there is excess capacity in this section of the corridor. It is possible to short-turn the A9 route at Parada 18 to improve service at the Sagrado Corazón station and throughout Santurce, while reducing the excess capacity on the Isleta. Looking at the 2002 forecast average loads on the bus routes with Tren Urbano in operation (Figures 5-4 through 5-6), the A9 route experiences a large drop in the number of passengers after Parada 18 during all time periods. At the entrance to the

Figure 5-4. Forecast 2002 AM Peak Hour Bus Loads to Old San Juan

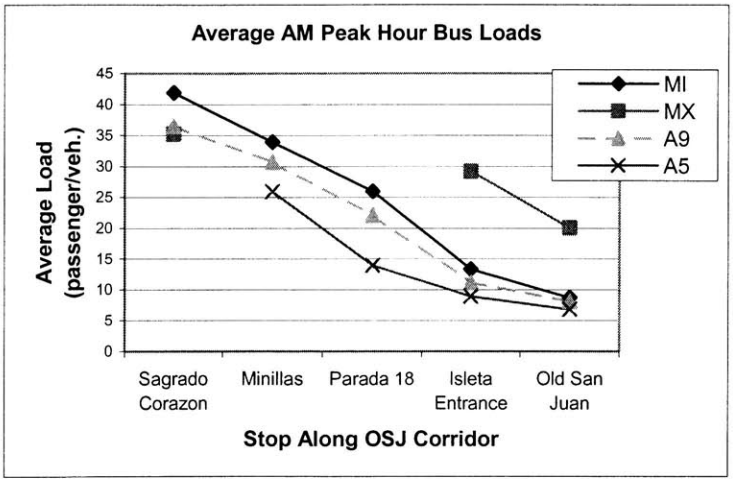


Figure 5-5. Forecast 2002 Midday Hour Bus Loads to Old San Juan

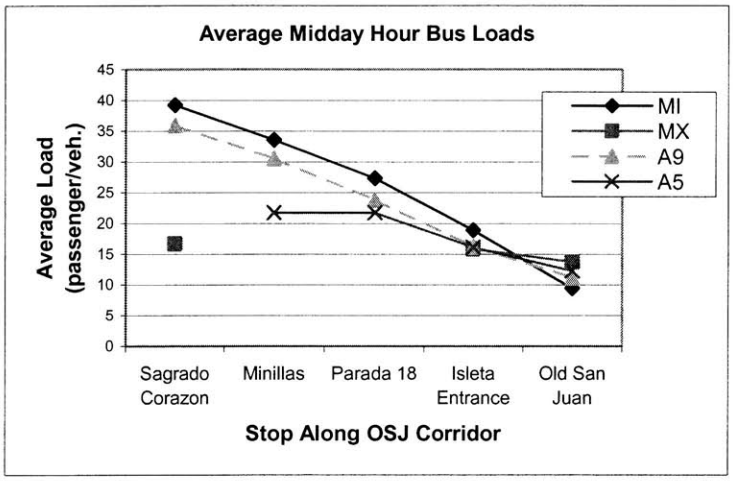
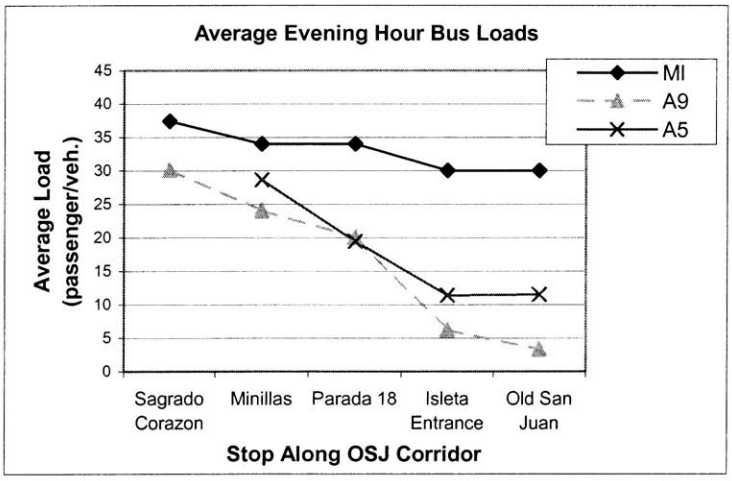


Figure 5-6. Forecast 2002 Evening Hour Bus Loads to Old San Juan



Isleta, during the peak, the A9 buses will carry an average of only 12 passengers, and will be quite empty when running along the Isleta. While it is possible to truncate Metrobús I, since it is the higher quality and more widely used service, it would not make a good candidate for short-turning, especially when considering the high average loads during the evening periods.

Short-turning A9 at the Isleta would require that other bus services be able to accommodate the displaced passengers, assuming that there are some passengers that desire to continue into the Isleta. Given that at this point, the average loads on both Metrobús I and A5 during the peak period are below 15 passengers per vehicle, any extra passengers that require service into the Isleta could be accommodated easily. However, the Isleta entrance currently does not have any transfer center, so any passengers who need to transfer will need to do so at Parada 18 or Sagrado Corazón and will have to endure a transfer.

In addition, since A9 shares the same rights of way as A5 and Metrobús I, there is no difference in in-vehicle travel time as a result of the short-turning strategy. Passengers traveling between Río Piedras and Old San Juan have a number of options, as shown in Table 5-11. The passengers that currently take A9 during the peak period for the entire length of the trip spend a little over 50 minutes traveling, but they only pay a $0.25 fare and receive a one-seat ride. Short-turning A9 would not only increase the fare, but eliminates the one-seat ride and introduces a potential transfer penalty that could result in significant travel time differences.

The values given in the transfer penalty column of Table 5-11, and in other tables used later in this thesis, represent the fact that there is uncertainty associated with the value or penalty associated with a transfer. The value of the transfer can range from 0 minutes to 12 minutes, or some other value of minutes and is affected by a number of factors, including the design of the transfer and transfer environment. For San Juan, since there is currently no evidence of the value of the transfer, a range of values is used.

Table 5-11. Short-turn A9: Rio Piedras to Old San Juan Service Market

Options	In-Vehicle Travel Time (min)	Total Wait Time (min)	Transfer Penalty (min)	Total Travel Time (min)	Fare (USD) *(free/no free xfer)*
Peak					
Current A9	48	4	0	52	0.25
A9 / MI	48	7	0 - 12	55-67 (+3-15)	0.25 / 0.75
A9 / MX	48	9	0 - 12	57-69 (+5-17)	0.25 / 0.75
A9 / A5	48	9	0 - 12	57-69 (+5-17)	0.25 / 0.50
MX	28	5	0	33 (-19)	0.50
MI	38	3	0	41 (-11)	0.50
Midday					
Current A9	35	4	0	39	0.25
A9 / MI	35	7	0 - 12	42-54 (+3-15)	0.25 / 0.75
A9 / MX	35	9	0 - 12	43-55 (+4-16)	0.25 / 0.75
A9 / A5	35	9	0 - 12	43-55 (+4-16)	0.25 / 0.50
MX	28	5	0	33 (-6)	0.50
MI	34	3	0	37 (-2)	0.50
Evening/weekend					
Current A9	35	8	0	43	0.25
A9 / MI	35	13	0 - 12	48 -60(+5-17)	0.25 / 0.75
A9 / A5	35	15	0 - 12	50 - 62 (+7-19)	0.25 / 0.50
MI	34	5	0	39 (-4)	0.50

Thus, short-turning the A9 route would also introduce some problems. Assuming that Metrobús Express service will not operate in the evening and weekends, the short-turning of the A9 route will leave Metrobús I as the only service providing one-seat rides between Tren Urbano and Old San Juan during these periods. During the midday and evening/weekends, Metrobús I and A5 will be able to provide enough capacity at Parada 18 or at the Isleta to accommodate the increased demand for service between Sagrado Corazón and Old San Juan. However, there is still the likelihood that any surge in evening/weekend demand such as when special events take place in the Santurce / Old San Juan corridor, will result in overcrowded buses. In addition to crowding on the buses, since the passengers that desire service to Old San Juan will need to transfer at Parada 18 or Sagrado Corazón, overcrowding in these areas may result due to the added number of transferring passengers, resulting in further inconvenience for the passengers. Finally, the transfer at Parada 18 also imposes an additional fare on the passengers.

In addition, the development of the Condado, Isla Grande and Isleta areas will increase the number of work and recreational trips to those areas. By short-turning A9 at Parada

18, some needed service close to these areas will be eliminated and the opportunity to attract a portion of these new trips will be lost. Thus, to ensure that the transit system has the opportunity to effectively serve the new trips that will develop in the future, it is recommended that the current structure of route A9 should be maintained initially. But, diversions to Parada 18 via Condado (using De Diego, Ashford, and RH Todd Avenues) may be worth considering, as well as a simple short-turn at Parada 18 after an initial period of monitoring.

Metrobús Express

The Metrobús Express service currently provides direct service between Old San Juan and Río Piedras, but only during the peak and midday periods. It serves the major markets of Río Piedras, Hato Rey and Old San Juan. Since Metrobús Express bypasses Minillas during its express portion of its route, the focus of this analysis will be strictly on the Río Piedras/Hato Rey to Old San Juan service markets.

Along the Isleta and between Río Piedras and Sagrado Corazón, Metrobús Express shares the right of way with its counterpart, Metrobús I. Along these segments, Metrobús Express does not provide significant travel time savings over Metrobús I. However, between the Isleta and Sagrado Corazón area, the Metrobús Express service travels along the Muñoz Rivera Expressway. It is this portion of the route that is the "express" portion, providing Metrobús Express with a travel time savings of up to 8 minutes over Metrobús I. During the midday periods, the travel time savings for Metrobús Express drops slightly since Metrobús I times benefit from decreased traffic congestion in Santurce. Tables 5-12 and 5-13 give the current travel times for the transit options available to passengers that travel to Old San Juan from Río Piedras and Hato Rey, respectively.

Table 5-12. Metrobús Express: Rio Piedras to Old San Juan Service Markets

Options	In-Vehicle Travel Time (min)	Total Wait Time (min)	Total Travel Time (min)	Fare (USD)
Peak				
MX	*28*	*5*	*33*	*0.50*
MI	38	3	41 (+8)	0.50
A9	48	4	52 (+19)	0.25
Midday				
MX	*28*	*5*	*33*	*0.50*
MI	34	3	37 (+4)	0.50
A9	35	4	39 (+6)	0.25

Table 5-13. Metrobús Express: Hato Rey to Old San Juan Service Markets

Options	In-Vehicle Travel Time (min)	Total Wait Time (min)	Total Travel Time (min)	Fare (USD)
Peak				
MX	*16*	*5*	*21*	*0.50*
MI	26	3	29 (+8)	0.50
Midday				
MX	*16*	*5*	*21*	*0.50*
MI	24	3	27 (+6)	0.50

The Metrobús Express route currently handles close to 4,000 trips, or 7 percent of the total daily trips on the major trunk routes in the SJMA. Approximately half of these trips are between Río Piedras/Hato Rey and Sagrado Corazón with the remainder between the Isleta and the Río Piedras/Hato Rey areas. On Metrobús Express, the Tren Urbano adjusted average bus load at Sagrado Corazón for both directions (northbound and southbound), as shown in Table 5-14, is 10 passengers during the peak period, or 22 percent of the total seated capacity. During the midday period, the utilization drops to an average of 8 passengers for both directions, or 18 percent of the total seated capacity. Given that Metrobús Express service is not well utilized, it can be restructured so that the excess capacity is used to accommodate the passengers that are transferring from Tren Urbano and heading to Old San Juan.

Table 5-14. Current Metrobús Express Service Capacity at Sagrado Corazón

Time of Day	Headway (min)	Vehicles in Service	Vehicles / hour	Average Bus Load at Sagrado C.	Remaining Capacity	
					Seated (pax/hr)	Standing (pax/hr)
Peak Hour	10	8	6	10	203	359
Midday Hour	10	8	6	8	216	372

Note: Average bus loads are adjusted to reflect passengers diverted to Tren Urbano.

- *Truncate Metrobús Express at Sagrado Corazón*

To improve the service and provide empty seats at Sagrado Corazón as well as to help reduce excess bus capacity between Río Piedras and Sagrado Corazón, the truncation of Metrobús Express is a strong candidate for Opening Day. In terminating Metrobús Express at the station, the operator can take advantage of its express portion to provide a fast, high quality connection to the Isleta and Old San Juan from Tren Urbano.

The Metrobús Express route is quite underutilized, as it serves a relatively low number of total trips between Río Piedras and Sagrado Corazón (2 percent of all daily trips on the major trunk routes). As a result, its truncation will not severely inconvenience a large portion of the riders along this segment. Additionally, there will be other popular bus routes (A3, Metrobús II, Metrobús I) as well as Tren Urbano operating along this segment that would be able to accommodate the close to 2,000 trips that would be displaced. The truncation should also permit shorter peak service headways (currently ten minutes) to match those of Tren Urbano (four minutes), further improving the appeal of the express service to the Isleta.

In order to match Tren Urbano headways during the peak period, there are two options for Metrobús Express service (Table 5-15). The first option is to provide 8-minute headways on Metrobús Express, which would provide an empty bus at the station for transferring passengers for every other Tren Urbano train. However, in order to ensure that empty buses are available at the station, this option would need to be implemented in conjunction with another high quality route, such as Metrobús I, also operating at 8-minute headways. Alternating both routes would result in a bus leaving the Sagrado Corazón station every four minutes. Given that Metrobús Express only serves the Isleta, Metrobús I would be able to provide high quality frequent service for those traveling through Minillas.

Table 5-15. Truncate Metrobús Express: Peak Hour Capacity at Sagrado Corazón

Route	Headway (min)	Vehicles in Service	Vehicles / hour	Capacity Available	
				Seated (pax/hr)	Standing / Seated (pax/hr)
Current MX	10	8	6	203	359
Truncate MX (1)	8	5 (-3)	8	330	525
Truncate MX (2)	4	10 (+2)	15	660	1050

However, if the 8-minute headways do not provide enough capacity to handle the transferring passengers, the Metrobús Express service can be increased to the second option of four-minute headways. The truncation of Metrobús Express would result in a requirement of five vehicles, since its cycle time is cut almost in half, to 40 minutes. With four-minute headways, a total of ten vehicles would be needed; an additional 2 vehicles which would increase the capacity at the station three-fold. Assuming that a little over 500 passengers, or half the forecast number of AM peak hour transfers at the station, would take Metrobús Express, the use of four-minute headways guarantees that empty seats will be available for all these passengers.

In addition to capacity issues, the impacts of the Metrobús Express truncation on the levels of service provided to the passengers traveling from Río Piedras and Hato Rey to Old San Juan need to be examined. Tables 5-16 and 5-17 list the service options available and their respective characteristics for passengers traveling between Río Piedras/Hato Rey and Old San Juan, given the truncation of Metrobús Express and the fact that buses will be waiting at the station for passengers. As with Table 5-11, the range given in the transfer penalty column reflect the uncertainty associated with the value of the transfer for San Juan.

Table 5-16. Truncate Metrobús Express: Rio Piedras to Old San Juan Service Markets

Options	In-Vehicle Travel Time (min)	Total Wait Time (min)	Transfer Penalty (min)	Total Travel Time (min)	Fare (USD) *(free/no free xfer)*
Peak					
Current MX	28	5	0	33	0.50
Tren Urbano / MX transfer	19	2	0 - 12	21 - 33	1.00/1.50
MI	38	3	0	41 (8-20)	0.50
A9	48	4	0	52 (19-31)	0.25
Midday					
Current MX	28	5	0	33	0.50
Tren Urbano / MX transfer	19	4	0 - 12	23 - 35	1.00/1.50
MI	34	3	0	37 (2-14)	0.50
A9	45	4	0	49 (14-26)	0.25

Table 5-17. Truncate Metrobús Express: Hato Rey to Old San Juan Service Markets

Options	In-Vehicle Travel Time (min)	Total Wait Time (min)	Transfer Penalty (min)	Total Travel Time (min)	Fare (USD) *(free/no free xfer)*
Peak					
Current MX	16	5	0	21	0.50
Tren Urbano / MX transfer	13	2	0 - 12	15 - 27	1.00/1.50
MI	26	3	0	29 (2-14)	0.50
Midday					
Current MX	16	5	0	21	0.50
Tren Urbano / MX transfer	13	4	0 - 12	17 - 29	1.00/1.50
MI	26	3	0	29 (0-12)	0.50

From both tables, it is clear that the combination of Tren Urbano and the truncated Metrobús Express results in travel time savings over Metrobús I and A9. Though the Río Piedras customers experience larger time savings, the Hato Rey passengers still benefit from the truncation. Given the travel time savings listed above, it is also clear that the benefits of taking Tren Urbano and truncated Metrobús Express can potentially outweigh the disbenefits of the presence of a transfer. With the presence of a hypothetical transfer penalty of 12 minutes, there are still some modest travel time savings (compared to Metrobús I and A9) with this strategy. On the other hand, compared to the current Metrobús Express service, the transfer penalty and the increased fare do not make the Tren Urbano/truncated Metrobús Express combination very attractive. However, if free

or discounted transfers, an efficient station layout, and waiting buses with empty seats are also provided, the transfer penalty can be reduced to close to zero. Minimizing the transfer penalty ensures that the Tren Urbano/truncated Metrobús Express combination will result in the lowest travel times compared to the current bus routes and increases the benefits of implementing this strategy.

Metrobús I

The Metrobús Express analysis focused on the Río Piedras to Old San Juan service market that is one of the major service markets in the Santurce/Old San Juan corridor. The focus now shifts to the other major service market in the corridor, from Río Piedras to Minillas. The primary bus route that operates within this market is Metrobús I. The Metrobús I route is the highest ridership in the SJMA, handling close to 25 percent of all daily trips. Metrobús I also operates at 6-minute headways that are lower than any other bus route in the SJMA. Metrobús I serves all the major activity centers between Río Piedras and the Santurce / Old San Juan corridor: Río Piedras, Hato Rey, Minillas, and Old San Juan. However, when Tren Urbano is implemented, those taking Metrobús I service along the Río Piedras to Sagrado Corazón segment and heading into Santurce will be most affected. Moreover, though Metrobús Express also travels along this segment, it does not serve Minillas. As a result, the service markets that will be used in the analysis of Metrobús I are the markets of Río Piedras to Minillas and Hato Rey to Minillas.

In the Río Piedras to Minillas service market, the passengers have the option of taking the less expensive, but slower and lower frequency A9 or the high quality Metrobús I service (Table 5-18). During all periods, the differences in travel time between the two routes is quite significant and makes the Metrobús I service quite attractive.

Table 5-18. Metrobús I: Rio Piedras to Minillas Service Markets

Options	In-Vehicle Travel Time (min)	Total Wait Time (min)	Total Travel Time (min)	Fare (USD)
Peak				
MI	*24*	*3*	*27*	*0.50*
A9	33	4	37 (+10)	0.25
Midday				
MI	*24*	*3*	*27*	*0.50*
A9	30	4	34 (+7)	0.25
Evening/weekend				
MI	*19*	*5*	*24*	*0.50*
A9	28	8	36 (+12)	0.25

The passengers traveling in the Hato Rey to Minillas service market also have a couple of options available to them (Table 5-19). This service market is served by both Metrobús I and Metrobús II. Metrobús I operates at headways as indicated in Table 5-20, while Metrobús II runs at 10 minute headways throughout the day and 15 minute headways in the evenings. Given that both routes operate along the same right of way, the in-vehicle travel times are identical. Since there is no significant difference between the two routes, the customers regard both services to be equal. Metrobús I handles approximately 8,500 daily trips that originate or are destined for Minillas from Hato Rey while Metrobús II handles 3,000 trips. These high trip counts underline the importance of maintaining high quality transit service to Minillas.

Table 5-19. Metrobús I: Hato Rey to Minillas Service Markets

Options	In-Vehicle Travel Time (min)	Total Wait Time (min)	Total Travel Time (min)	Fare (USD)
Peak				
MI	*10*	*3*	*13*	*0.50*
MII	10	5	15 (+2)	0.50
Midday				
MI	*10*	*3*	*13*	*0.50*
MII	10	5	15 (+2)	0.50
Evening/weekend				
MI	*10*	*5*	*15*	*0.50*
MII	10	8	18 (+3)	0.50

While maintaining the current Metrobús I route structure would reduce inconvenience the passengers may face when Tren Urbano opens, it does not help to fulfill the capacity requirements at Sagrado Corazón. Table 5-20 gives the capacity of Metrobús I (adjusted to reflect passenger shifts to Tren Urbano) during the peak, midday and evening periods.

From this table, one can see that since Metrobús I vehicles arrive at the station partially loaded, the empty seats provided by the service will not be adequate in handling half of the forecast 1,100 peak period passengers transferring from Tren Urbano. Hence, in order to assist Metrobús Express and Metrobús II in accommodating the passenger transfer volumes at Sagrado Corazón, some restructuring of the route may be required. The A9 service makes no real contribution to the service capacity since it is operating with substantially full vehicles.

Table 5-20. Current Metrobús I Service Capacity at Sagrado Corazón

Time of Day	Headway (min)	Vehicles in Service	Vehicles / hour	Average Bus Load at Sagrado C.	Remaining Capacity		Total Tren Urbano Transfers
					Seated (pax/hr)	Standing / Seated(pax/hr)	
Peak Hour	6	17	10	16	276	536	~1100
Midday Hour	6	17	10	14	300	560	~500
Evening Hour	10	10	6	16	276	536	~200
Note: Average bus loads are adjusted to reflect passengers diverted to Tren Urbano.							

- *Truncate Metrobús I at Sagrado Corazón*

The first service strategy to consider is the truncation of Metrobús I at Sagrado Corazón. Truncating Metrobús I at Sagrado Corazón would ensure that empty buses are available and waiting for passengers at the Tren Urbano station. However, if Metrobús I were to be truncated at Sagrado Corazón, over 5,600 daily one-seat trips from Rio Piedras and Hato Rey to Minillas would be affected. Fortunately, those that would be affected by the Metrobús I truncation are able to select among several different options (Tables 5-21 and 5-22) although most of them would still require transfers.

The truncation of Metrobús I, even with the use of Tren Urbano, does result in travel time savings over the existing configuration for trips between Río Piedras and Minillas. During the peak period, a passenger traveling from Río Piedras to Minillas on the current Metrobús I route (Table 5-21) experiences a total travel time of 27 minutes, while the travel time for the Tren Urbano-Metrobús I option would be 19 minutes. However, though the truncation of Metrobús I may result in some time savings, the current Metrobús I route might be more attractive. Passengers on the current route will have a one-seat ride to Minillas and since they do not have to transfer, the substantial fare

increase can be avoided. Thus, for the passengers traveling between Río Piedras and Minillas, the truncation of Metrobús I provides small benefits, in terms of travel time savings, that may be negated by the transfer and higher fares. If a free transfer is provided, the time savings probably outweigh the transfer penalty.

Table 5-21. Truncate Metrobús I: Rio Piedras to Minillas Travel Times

Options	In-Vehicle Travel Time (min)	Total Wait Time (min)	Transfer Penalty (min)	Total Travel Time (min)	Fare (USD) *(free/no free xfer)*
Peak					
Current MI	24	3	0	27	0.50
Tren Urbano / MI transfer	17	2	0 – 12	19 – 31	1.00/1.50
Tren Urbano / A9 transfer	17	6	0 – 12	23 – 35 (+4-16)	1.00/1.25
Tren Urbano / MII transfer	17	6	0 – 12	23 – 35 (+4-16)	1.00/1.50
Midday					
Current MI	24	3	0	27	0.50
Tren Urbano / MI transfer	17	4	0 – 12	21 – 33	1.00/1.50
Tren Urbano / A9 transfer	17	8	0 – 12	25 – 37(+4-16)	1.00/1.25
Tren Urbano / MII transfer	17	8	0 – 12	25 – 37(+4-16)	1.00/1.50
Evening/weekend					
Current MI	19	5	0	24	0.50
Tren Urbano / MI transfer	15	6	0 – 12	21 – 33	1.00/1.50
Tren Urbano / A9 transfer	15	15	0 – 12	30 – 42 (+9-21)	1.00/1.25
Tren Urbano / MII transfer	15	15	0 – 12	30 – 42 (+9-21)	1.00/1.50

Since MI buses are terminated at SC, transfer time is zero, so wait time for TU/MI option is based on TU headways.

The truncation of Metrobús I does not provide any apparent benefits for the Hato Rey to Minillas passengers. Compared to the current Metrobús I travel time of 13 minutes during the peak period (Table 5-22), assuming that there is little or no transfer penalty the truncation of Metrobús I would result in equivalent total travel times. During the midday and evening/weekends, the total travel times are also similar to the existing Metrobús I service. Moreover, as in the Río Piedras to Minillas service market discussion, the penalties associated with transferring could make the Tren Urbano/truncated Metrobús I option much less attractive. However, unlike the previous service market, assuming no

changes to Metrobús II, some one-seat service between Hato Rey and Minillas would still exist. Thus, passengers traveling along this route would still have an alternative that would cost less than Tren Urbano and not require them to transfer.

Table 5-22. Truncate Metrobús I: Hato Rey to Minillas Travel Times

Options	In-Vehicle Travel Time (min)	Total Wait Time (min)	Transfer Penalty (min)	Total Travel Time (min)	Fare (USD) *(free/no free xfer)*
B. Truncate Metrobús I (peak)					
Current MI	10	3	0	13	0.50
Tren Urbano / MI transfer	10	2	0 - 12	12 - 24	1.00/1.50
MII	10	5	0	15 (-9 - +3)	0.50
Tren Urbano / A9 transfer	10	6	0 - 12	16 - 28 (+4-16)	1.00/1.25
B. Truncate Metrobús I (midday)					
Current MI	10	3	0	13	0.50
Tren Urbano / MI transfer	10	4	0 - 12	14 - 26	1.00/1.50
MII	10	5	0	15 (-11 - +1)	0.50
Tren Urbano / A9 transfer	10	8	0 - 12	18 - 30 (+4-16)	1.00/1.25
B. Truncate Metrobús I (evening/weekend)					
Current MI	10	5	0	15	0.50
Tren Urbano / MI transfer	9	6	0 - 12	15 - 27	1.00/1.50
MII	9	8	0	17 (-10 - +2)	0.50
Tren Urbano / A9 transfer	9	15	0 - 12	24 - 36 (+9-21)	1.00/1.25

Since MI buses are terminated at SC, transfer time is zero, so wait time for TU/MI option is based on TU headways.

The discussions above show that service strategies that introduce transfers also need incentives such as discounted or free transfers in order to minimize the negative impacts transfers may have on riders. The 1998 service restructuring showed that with aggressive marketing and the maintenance of 25-cent fares, transfers do not necessarily affect ridership severely. However, with Tren Urbano, the cost of a bus and rail trip will increase considerably as discussed above, so drops in ridership are more likely to occur, unless a fare policy to mitigate this effect, such as utilizing free transfers or discounted monthly passes, is introduced.

Thus, the success of the planned intermodal system will depend heavily upon an integrated fare policy. Currently, AMA and Metrobús rides cost $0.25 and $0.50,

respectively, with no free transfers issued within or between systems. Tren Urbano trips are expected to cost $1.00. So far, no specific intermodal or intramodal fare arrangements have been determined. Without any discounts, a trip from Río Piedras to Old San Juan (or even Hato Rey to Minillas) that now costs $0.50 on Metrobús I could cost up to $1.50 (the sum of Tren Urbano and Metrobús fares). With this fare increase, ridership could drop and opposition to Tren Urbano develop. On the other hand, if bus-to-rail transfers are free, the cost of a trip between Río Piedras and Old San Juan, or Hato Rey to Minillas, would be $1.00, double the current Metrobús I fare. Although these fare and transfer impacts may seem dramatic, Tren Urbano's higher level-of-service (speed, reliability, frequency, service hours) may help alleviate their effects. In addition, free transfers would provide an incentive for passengers to use transit and improve the convenience of the transfer.

The convenience of the transfer can be further improved with high quality connecting service at Sagrado Corazón (which is assumed in this analysis). The matching of truncated Metrobús I service headways with the Tren Urbano peak-period headways at Sagrado Corazón can help to improve the intermodal connection, as will empty buses waiting at the station for the transferring passengers. Similar to Metrobús Express, this strategy could be implemented in two ways. The first option is to operate truncated Metrobús I service at 8-minute headways (Option (1) in Table 5-23). This option would only improve the capacity at the station by approximately 60 seats while halving the Metrobús I vehicle requirements. However, alternating Metrobús I and Metrobús Express can result in extended wait times for passengers traveling to Minillas. For these passengers, there is a 50 percent chance when they arrive at the Sagrado Corazón station, there will be a Metrobús Express bus waiting for them. As a result, these passengers will need to wait a maximum of an additional four minutes before they can board a truncated Metrobús I route. Fortunately, there will be other routes at the station, such as A9 and Metrobús II, which will help accommodate these passengers and reduce the potential of a lengthy wait. The 8-minute headway option is also a good option for implementation during midday and evening/weekend periods when passenger volumes are at lower levels but high quality service is still needed.

Table 5-23. Truncate Metrobús I: Peak Hour Capacity at Sagrado Corazón

Route	Headway (min)	Vehicles in Service	Vehicles / hour	Capacity Available	
				Seated (pax/hr)	Standing / Seated (pax/hr)
Current MI	6	17	10	276	536
Truncate MI (1)	8	8 (-9)	8	330	525
Truncate MI (2)	4	15 (-2)	15	660	1050

If additional capacity is needed at the station to accommodate the AM peak period passengers, a second option would be to operate truncated Metrobús I service at 4-minute headways. This strategy provides a capacity of almost three times the current capacity at the station, while also requiring two fewer vehicles. It is also obvious that when compared to the first option, doubling the frequency will require twice the number of vehicles, but will also double the capacity at the station. However, this option would virtually guarantee that a bus will be waiting at the station and will help to avoid the extended wait times that are possible with the first option. While this option is attractive, the constraints placed upon the operator in terms of operating budget and vehicle procurement may require that the operator implement the lower frequency service and reallocate the extra vehicles to other routes that also need improvements in level of service.

The elimination of Metrobús I along the Río Piedras to Sagrado Corazón segment might inconvenience some riders, potentially hurting ridership. In order to use transit, most riders along this corridor would need to adjust their travel patterns, which would often require additional walking to the nearest Tren Urbano station. Moreover, it is widely believed that the majority of Puerto Rican residents do not favor walking, particularly in light of weather-related issues such as high temperatures and frequent rainstorms. Therefore, forcing riders to walk further to Tren Urbano stations is a concern.

Prior research has suggested a need for parallel bus service when the rail stations are spaced more than a half-mile (800 meters) apart (Bernick and Cervero, 1997). Between Río Piedras and Sagrado Corazón, the average distance between the stations (Table 5-24)

is 0.46 miles (754 meters). The Tren Urbano stations between Río Piedras and Sagrado Corazón are within walking distance of the majority of Metrobús I and Metrobús Express bus stops, making it relatively easy for the passengers to adjust their travel patterns.

Table 5-24. Río Piedras to Sagrado Corazón Station Spacing

Station Pairs	Distance (km)	Distance (miles)
Río Piedras - Universidad	0.644	0.399
Universidad - Piñero	0.833	0.517
Piñero - Domenech	0.669	0.415
Domenech - Roosevelt	0.839	0.520
Roosevelt - Hato Rey	0.677	0.420
Hato Rey - Sagrado Corazón	0.862	0.534
AVERAGE	**0.754**	**0.460**

It must be noted that the Domenech-Roosevelt segment is a very important section slightly more than half a mile in length. This segment is situated in Hato Rey and should serve a significant number of customers. In contrast, the Hato Rey-Sagrado Corazón distance is not significant because nothing substantial exists between the Acuaexpreso terminal and Sagrado Corazón. The Universidad-Piñero pair, on the other hand, could be of some significance since it does include the UPR and Auxilio Mutuo Hospital areas. However, a portion of the segment also runs along Piñero expressway, which will not have significant pedestrian traffic.

Thus, some stations are spaced far enough apart that walking to a Tren Urbano station might be inconvenient for some passengers particularly given the San Juan climate. In an analysis conducted by Lee (2000) of the passengers traveling within the Río Piedras-Santurce / Old San Juan corridor (Table 5-25), the majority (60 percent) will continue to enjoy direct bus service and have the option of taking Tren Urbano, assuming that A3 and Metrobús II service will continue to provide some local service when Tren Urbano opens. Of the remaining passengers, about 6 percent (643 passengers) will require minimal additional walking, while another 7 percent will have to walk up to four blocks at one end of their trip. The truncation of Metrobús I at Sagrado Corazón would impose lengthy walks at both ends of the trips for only 1.5 percent (164 passengers) of the passengers.

Río Piedras trips were classified separately since the effects the neighborhood station would have on transit access distance was unclear.

Table 5-25. Passengers on Metrobús I from Río Piedras to Old San Juan

	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**

Source: Modified from Lee (2000)

- *Short-turn half of Metrobús I at Sagrado Corazón*

In order to accommodate the passengers transferring at Sagrado Corazón as well as to continue serving some passengers along the Río Piedras to Sagrado Corazón segment, it may be possible to short-turn some of the Metrobús I route buses at Sagrado Corazón station. By doing so, the service would allow the implementation of two different service frequencies along the Metrobús I route. For the longer segment that also travels between Río Piedras and Sagrado Corazón, the service frequencies could be reduced from its current 6-minute headways to free resources as needed or as passenger demand changes. Service reductions would provide less competition to Tren Urbano and encourage customers to switch to the higher quality Tren Urbano system. However, Metrobús I would still provide service for those who are reluctant to change their travel patterns.

Along the shorter segment from Sagrado Corazón to Old San Juan, it is also possible to match the Metrobús I frequencies with the Tren Urbano peak headways. For the operator, matching headways will help improve the intermodal coordination, ensure smooth transfers between modes, and provide highly reliable service. For the customer, the transfer experience will be greatly improved, since connecting buses with empty seats will be waiting at the station for the transferring passengers, essentially eliminating wait times. However, the selection of the frequencies will be dependent on capacity and the operator's budgetary and vehicle resource constraints. In addition, the partial short-turning of Metrobús I can introduce some complexity into bus operations which may be

costly. The partial short-turning would require additional training and coordination of services, as well as improved marketing to the public, to ensure that the services are operated effectively and well-utilized. On balance, if operating budgets are constrained, the full short-turning on Metrobus II to provide one-seat rides for the Minillas to Hato Rey market is probably a better option than sacrificing the common schedule for Metrobús I, and Metrobús I truncated with Tren Urbano.

With the short-turning of Metrobús I, there are two options for service to match the Tren Urbano headways during the peak, which are dependent on the capacity required to serve demand and the amount of resources available. The first option is to operate both the long and short segments at 8-minute headways. Alternating these two routes would result in a Metrobús I bus at Sagrado Corazón every four minutes and would provide approximately 570 empty seats. In the event that additional capacity is needed during the peak periods or special events, the headways on the shorter portion could also be reduced to four-minutes as needed to accommodate demand, as this option provides an additional 300 seats. However, this option would require an additional seven vehicles, which is a 33 percent increase in vehicles over the first option and would result in many empty seats. Table 5-26 gives the peak-hour service capacity and vehicle requirements for the short-turning options for Metrobús I.

Table 5-26. Short-turn Metrobús I: Peak Hour Capacity at Sagrado Corazón

Route	Headway (min)	Vehicles / hour	Vehicles in Service	Capacity Available	
				Seated (pax/hr)	Standing/ Seated (pax/hr)
Current MI	6	10	17	276	536
Short-turn Metrobús I (1)	4/8 (short/long)	23	15/13 (total 28)	880	1478
Short-turn Metrobús I (2)	8/8 (short/long)	15	8/13 (total 21)	572	988

Short-turning half the Metrobús I service at the Sagrado Corazón station would not only retain service along the Río Piedras to Sagrado Corazón segment, but would also retain one-seat rides for passengers traveling from Río Piedras and Hato Rey to Minillas and Santurce. As discussed in the truncation strategy analysis, the truncation of Metrobús I

introduces a transfer that may deter some passengers from using transit. However, the service capacity increases that result from the truncation would help accommodate the forecast number of transferring passengers. Thus, either one of the Metrobús I short-turn options provides a good compromise in providing the needed capacity at Sagrado Corazón while also continuing to provide one-seats rides for a number of passengers.

Tables 5-27 and 5-28 list the options available with the short-turning strategy to the passengers in the two service markets of interest. In the Río Piedras to Minillas service market (Table 5-27), assuming that the transfer penalty has been minimized, a passenger riding Tren Urbano and then transferring onto the Metrobús I route at Sagrado Corazón would enjoy travel time savings of 9 minutes or 20 minutes compared to the longer one-seat Metrobús I and A9 routes, respectively. However, this passenger would also incur a higher fare and would sacrifice a one-seat ride. For those passengers who are not very sensitive to transfers or costs, this time savings of the bus and rail combination may be large enough to attract them onto Tren Urbano. If a free transfer policy is implemented, then the appeal of the Tren Urbano/short Metrobús I trip would increase. However, there is the likelihood that if a free transfer is not offered and the transfer environment is not effective in improving the passengers' transfer experience, then the transfer penalty will have a significant impact on the number of bus-rail trips. The long Metrobús I and A9 routes now become quite attractive to the passengers who are inconvenienced by transfers.

On the other hand, in the Hato Rey to Minillas service market (Table 5-28), with no transfer penalty, there are no time savings with the short-turned Metrobús I route and if a transfer penalty exists for the passengers, the Tren Urbano / Metrobús I option becomes even less attractive. Yet, since Metrobús II serves this market with a one-seat ride, even if Metrobús I is fully truncated, this market is likely to remain well-served with the current Metrobús II and the remaining Metrobus I services.

Table 5-27. Short-turn Metrobús I: Rio Piedras to Minillas Service Markets

Options	In-Vehicle Travel Time (min)	Total Wait Time (min)	Transfer Penalty (min)	Total Travel Time (min)	Fare (USD) *(free/no free xfer)*
Peak					
Current MI	24	3	0	27	0.50
Tren Urbano / MI(short) transfer	17	2	0 – 12	19 – 31	1.00/1.50
MI(long)	24	4	0	28 (-3 - +9)	0.50
A9	33	4	0	37 (+6-16)	0.25
Midday					
Current MI	24	3	0	27	0.50
Tren Urbano / MI(short) transfer	17	4	0 – 12	21 – 33	1.00/1.50
MI(long)	24	4	0	28 (-5 - +7)	0.50
A9	30	4	0 – 12	34 – 46 (+1-25)	0.25
Evening/weekend					
Current MI	19	5	0	24	0.50
Tren Urbano / MI(short) transfer	15	6	0 – 12	21 – 33	1.00/1.50
MI(long)	19	4	0	23 (-10 - +2)	0.50
A9	28	5	0	33 (-11 - +0)	0.25

Metrobús I (short) and Metrobús I (long) alternate at Sagrado Corazón.

Table 5-28. Short-turn Metrobús I: Hato Rey to Minillas Service Markets

Options	In-Vehicle Travel Time (min)	Total Wait Time (min)	Transfer Penalty (min)	Total Travel Time (min)	Fare (USD) *(free/no free xfer)*
Peak					
Current MI	10	3	0	13	0.50
Tren Urbano / MI(short) transfer	10	4	0 - 12	14 - 26	1.00/1.50
MI(long)	10	4	0	14 (-12 - +0)	0.50
MII	10	4	0	14 (-12 - +0)	0.50
Midday					
Current MI	10	3	0	13	0.50
Tren Urbano / MI(short) transfer	10	4	0 - 12	14 -26	1.00/1.50
MI(long)	10	4	0	14 (-12 - +0)	0.50
MII	10	4	0	14 (-12 - +0)	0.50
Evening/weekend					
Current MI	10	5	0	15	0.50
Tren Urbano / MI(short) transfer	9	6	0 - 12	15 - 27	1.00/1.50
MI(long)	9	5	0	14 (-1-13)	0.50
MII	9	5	0	14 (-1-13)	0.50

Metrobús I (short) and Metrobús I (long) alternate at Sagrado Corazón.

However, looking at the long-range operating environment, additional modifications to the Metrobús I route will be needed. Given the importance of maintaining the ridership on the very popular Metrobús I, adjustments will need to be made to circumvent the Minillas extension construction that will occur along Ponce de León between Sagrado Corazón and Minillas. Rerouting Metrobús I to Fernández Juncos Avenue is possible, but would require that Metrobús I operate without a contraflow lane, creating potential service delays. If Metrobús I is truncated at Sagrado Corazón by the time construction for the Minillas extension is started, some of the potential service disruption and passenger inconvenience can be mitigated with higher frequency service. In addition, truncating at Sagrado Corazón will provide the operator better means to control the scheduling and operation of the Metrobús I route. The adjustments to Metrobús I and the time required by the operator to keep the Metrobús I operating smoothly, effectively, and with high levels of service will require additional investments in the planning, implementation and operation of the service.

New Condado Route

Another service strategy is to implement a new route that serves Minillas and the Condado area, or other markets that may need additional service. Over time, when the developments planned for the Condado, Isleta, and Isla Grande are completed, demand for transit service to these areas as well as to other areas throughout the Santurce / Old San Juan corridor will increase. If the transit system is able to anticipate the demand shifts and provide high quality service to these areas, the transit system will be able to attract a portion of these new trips. In addition, implementing new or improved service will improve the accessibility of these areas to existing customers.

Such a new route would also complement the Metrobús I, Metrobús II and A9 routes in handling the demand for services through Santurce. This route could also complement the A5 route by providing added service to the Condado area as well as providing the Condado area a direct connection to Tren Urbano. There will be no travel time savings

on this route for travel to Minillas, since it will travel along the same corridor as Metrobús I and A9. However, it will help provide extra capacity at the station as well as provide improved service to Santurce. Table 5-29 lists the increases in capacity available at the Sagrado Corazón station with the implementation of the new Condado route at several alternative headways.

Table 5-29. AM Peak Capacity at Sagrado Corazón (New Condado Route)

Route	Headway (min)	Vehicles Required	Capacity at Sagrado Corazón	
			Seated (pax/hr)	Standing / Seated (pax/hr)
New Route	4	10	660	1050
New Route	8	5	330	525
New Route	12	3	220	350

The vehicle requirements for the new Condado route are reasonable. Even with 8 or 12-minute headways, the three to five vehicles that would be required would also provide empty seats that would be available to passengers transferring at Sagrado Corazón. And as the transfer volumes at the station and demand for connecting service to the Condado increase over time, the frequency of the new route could be increased to improve the level of service.

From the perspective of the communities in the Condado area, the new service would be a positive change for the area. The area is currently served by two low frequency bus routes (B21, C10) that do not provide a direct connection to Tren Urbano. Implementing a direct connection would improve the mobility of the local area residents as well as the accessibility of the Condado from other points in the SJMA. The improved transit accessibility could also potentially decrease vehicular traffic in the area, further increasing the benefits of the new service.

From the operator's perspective, this strategy is very attractive given the relatively low resource requirements at 8 and 12-minute headways and the ability to penetrate a new service market. The new service would also allow the operator to attract a number of the new passenger trips that are expected to be generated by the completion of the Golden Triangle development plan in the Condado area. Alternatively, a Condado service could

be combined with a strategy to short-turn A9 by rerouting A9 along Ponce de León, De Diego, Ashford, and RH Todd Avenues to Parada 18, essentially utilizing existing bus and driver resources.

Recommendations

Given the different operating conditions and service characteristics that exist during the peak, midday, and evening/weekend periods, different combinations of service strategies may be required. The analyses conducted in the previous sections have identified the characteristics of the various service strategies for each period of the day. Using the results of these analyses, different combinations of strategies can be formed to ensure that high levels of service and passenger convenience are maintained, an effective intermodal transfer environment is established, and service capacity and resource issues are effectively handled with minimal disruption to the existing transit system and passengers.

In determining which strategies should be implemented, the amount of funding available needs to be considered. Often, service providers view capital and operating budgets separately. Yet, given the huge capital investment that has been made, there also needs to be large investment in the complementary transit services to justify the overall investment in the transportation system. Hence, the service provider needs to ensure that a large capital-intensive project such as Tren Urbano also allocates an adequate portion of the operating budget for service provision. According to the AMA financial plan forecasts, in 2002 it will have over $70 million available in operating funding (Table 5-30). A projected peak in operating funding occurs in 2002 and includes arrangements for the acquisition of new vehicles. In the following years, the operating expenses are projected to increase, indicating that AMA anticipates service increases related to Tren Urbano. Allocating enough funds to cover the increased operating expenses will ensure that AMA can maintain and improve the bus service, ensuring that high levels of service can be provided and that multiyear strategies can be adopted and implemented. Similarly, adequate funding is required for Metrobús I and Metrobús Express services.

Table 5-30. AMA Financial Plan Summary

	Current	Recommended	Projected			
	FY99	FY00	FY01	FY02	FY03	FY04
Operating Funding	$43,395,584	$41,977,309	$66,054,781	$70,596,248	$65,416,257	$68,428,500
Operating Expenses	$39,275,134	$41,835,309	$51,212,722	$57,184,287	$65,416,256	$68,428,500
Debt Service / Contributions	$4,120,000	$142,000	$14,842,058	$13,411,960	$0	$0

Dollar estimates are for a fleet of 218 AMA and 19 Metrobús II buses
Source: Multisystems (2000)

- *Peak Period Services*

The combination of service strategies for the peak period must focus not only on providing sufficient capacity at the Sagrado Corazón station, but also on providing service that will smooth the passenger transition from the existing bus system to Tren Urbano. The selection of service strategies for this period is based on the findings of the bus route analyses conducted previously.

In the first analysis, it was shown that the A9 service should not be truncated. The A9 serves a unique market, and major modifications to the A9 service would severely inconvenience the residents along the route since they are not close to Tren Urbano. Though it is possible to short-turn A9 at Parada 18, the loss of one-seat ride service and increased cost could decrease the levels of service provided at these transfer points. However, the short-turning of A9 at Parada 18 should be a future consideration, once riders become accustomed to Tren Urbano and a region-wide feeder bus plan is implemented.

As for Metrobús Express, the analyses suggest that this service should be truncated at Sagrado Corazón on Opening Day in order to provide the extra vehicles and capacity necessary to accommodate the transferring passengers. Metrobús Express does not serve a significant number of passengers along the portion of its route south of Sagrado Corazón. Additionally, the travel time savings that are provided with truncation of Metrobús Express are quite large and can potentially justify any inconvenience caused by the rail-to-bus transfer. The fare increase inherent in the transfer needs to be mitigated by a free or discounted transfer.

As for the proposed new Condado route, it is desirable, but not critical that it be implemented in Time Period 1. With the modifications made to Metrobús I and Metrobús Express, enough capacity will be provided at the station on Opening Day without the Condado service, so no additional capacity will be needed initially. However, in the future, as transfer volumes at Sagrado Corazón and demand for transit service to new developments in the Condado area increase, a new Condado route will be needed. The new route would provide additional service capacity to accommodate the increased number of transfers. Moreover, the new Condado route would further improve the levels of service provided to Santurce and connect Condado to Tren Urbano. If the operating budget is adequate and vehicles are available, then this route can be added. If not, a diversion of A9 into this market with a termination at Parada 18 could be a reasonable Opening Day strategy. Once Metrobús I is truncated, vehicles will be available that can be reallocated to implement the new Condado service.

Finally, given that the benefits for the passengers of truncating Metrobús I may be offset by the inconvenience of the transfer and increased fare, the short-turning half of Metrobús I strategy is a conservative one that could provide the needed empty seats at Sagrado Corazón while also ensuring that the passengers are provided a smooth transition to Tren Urbano. With the short-turning of every-other Metrobús I bus and the truncation of Metrobús Express at the station, there will be enough service capacity at the station to accommodate the transferring passengers comfortably (Table 5-31) as the average loads of most of the bus routes upon leaving the station are below the 44 seat-capacity.

Table 5-31. AM Peak Hour Service Capacity at Sagrado Corazón (1)

Route	Headway (min)	Total Vehicles in Service	Avg. Load before station (pax/veh.)	Capacity Available		Avg. Load w/ Tren Urbano (pax/veh.)	Tren Urbano Transfers[2]
				Seated (pax/hr)	Standing / Seated (pax/hr)		
A9	8	18	31	104	312	31	0
MI (short)	8	8	0	352	560	44	352
MI (long)	8	13	16	224	432	35	148
MII	8	21	14	240	448	14	0
Truncated MX	4	10	0	660	1050	37	550
TOTAL		**49**		**1580**	**2802**		**1100**

[2] Transfer volumes are based on the assumption that half are to Metrobús Express. For the other half, it is assumed that passengers will first fill up all seats on the truncated Metrobús I service, with the remainder filling up the seats on the long Metrobús I. Any remaining passengers are then assigned to MII and A9.

Also, with the short-turning strategy, passengers traveling to Old San Juan or Minillas from Hato Rey or Río Piedras will have the choice of either taking the faster Tren Urbano / truncated Metrobús I and Metrobús Express combination or the one-seat Metrobús I or A9 route. Providing these options when Tren Urbano opens ensures that the transit system will still retain those passengers who are reluctant to change their travel patterns. However, once the initial adjustment period is complete and the majority of the passengers have adjusted to the improved Tren Urbano services, the longer-portion of the Metrobús I services should be short-turned so that all the passengers can be accommodated on Tren Urbano. Metrobús II would continue to provide one-seat Minillas to Hato Rey service. In addition, the elimination of the longer service can be timed to coincide with the introduction of new Condado service. Coordinating the two changes will help justify the elimination of Metrobús I and maintain the perception that continual improvements to the transit system are being made. Alternatively, if the Condado service has been introduced earlier, the ridership analyses of Metrobús I should be able to identify whether an increase in Metrobús II frequency can reasonably substitute for Metrobús I.

In addition to the bus system improvements, one option that should be strongly considered is the modification of the Tren Urbano operating schedule to address the issue of excess capacity between Río Piedras and Sagrado Corazón. This issue can be handled with a slight increase in service headways, from the planned 4-minute headways to 5-minutes. With this increase, the utilization of Tren Urbano will be improved from about 45% to over 50%, and the capacity of each train can be maintained. On the other hand, if two-car trains are used, the utilization would jump to 80 percent, but many passengers would be required to stand, sacrificing passenger comfort. The 5-minute headways appear to be a better solution to the excess capacity problem.

In addition, there are a number of other benefits with the use of 5-minute headways. Implementing these headways would provide better integration with most of the existing AMA routes which currently operate at 10,20, and 30-minute headways. The operating

costs and vehicle requirements for both Tren Urbano and the feeder services would also decrease, while still providing frequencies better than any existing services in San Juan. Moreover, strong consideration should be given to maintaining the 5-minute headway through the day, with two car trains, and 10-minute headways for the evening and weekend schedule, redeploying the Tren Urbano resources in a more customer friendly way.

With the strategies that introduce transfers at the Sagrado Corazón station, it is paramount that the transfer penalty be minimal, otherwise passengers may not be willing to take the Tren Urbano/Metrobús trips in the Santurce / Old San Juan corridor. The truncation of services will ensure that empty buses will be available, reducing the time spent transferring and reducing the transfer penalty. However, to ensure that the transfer penalty remains close to zero, the cost of transferring will need to be minimized. Hence, it is also highly recommended that a free transfer (or heavily discounted transfer) fare policy be implemented.

To implement these bus strategies discussed above, the operator will need to ensure that additional resources are allocated. The strategies described above, when implemented together, will require about 6 additional vehicles (Table 5-32). The vehicle requirements are not extreme and will help to maintain passenger convenience and interest in transit, while also providing the capacity necessary for excellent levels of service through the Sagrado Corazón station. If instead the Tren Urbano schedule is modified to 5-minute headways, the bus requirements drop to 55 vehicles, which is within the current fleet.

Table 5-32. Resource Requirements for Peak Period Service Strategies (1)

Service Strategies	Vehicles Required	Vehicle-Hours (per day-peak only)
Base Requirement *(Current A9, MI, MX, MII)*	60	360
Maintain A9 *(8-minute headways)*	18	108
Maintain MII *(8-minute headways)*	21	126
Truncate MX *(4-minute headways)*	10	60
Partial short-turn MI *(8-minute headways on both)*	21	126
TOTAL (4-minute Tren Urbano headway)	**70 (+10)**	**420 (+60)**
Maintain A9 *(10-minute headways)*	13	78
Maintain MII *(10-minute headways)*	17	102
Truncate MX *(5-minute headways)*	8	48
Partial short-turn MI *(10-minute headways on both)*	17	102
TOTAL (5-minute Tren Urbano headway)	**55 (-5)**	**330 (-30)**

With Tren Urbano operating at 5-minute headways and Metrobús II providing additional service capacity at the station, there will be just enough capacity at the station to provide seats for all the 1,100 transferring passengers (Table 5-33). However, any increases in transfer volume would need to be followed with increases in service frequency in order to minimize overcrowding.

Table 5-33. AM Peak Hour Service Capacity at Sagrado Corazón (5-min TU Headway)

Route	Headway (min)	Total Vehicles in Service	Avg. Load before station (pax/veh.)	Capacity Available		Avg. Load w/ Tren Urbano (pax/veh.)	Tren Urbano Transfers
				Seated (pax/hr)	Standing / Seated (pax/hr)		
A9	10	13	41	20	174	42	2
MI (short)	10	6	0	264	420	44	264
MI (long)	10	11	19	150	306	44	150
MII	10	17	18	156	312	44	156
Truncated MX	5	8	0	528	840	44	528
TOTAL		**38**		**1118**	**2052**		**1,100**
Transfer Vol. ~1,100 passengers / hour							

Once passengers are using Tren Urbano and Metrobús I is truncated, additional vehicles will be freed up that can be reallocated to increase the truncated Metrobús I service frequencies to match those of Tren Urbano. Though this configuration will result in a modest increase in service capacity at the station (Table 5-34), it will be necessary to accommodate the increased Tren Urbano ridership that will have occurred.

Table 5-34. AM Peak Hour Service Capacity at Sagrado Corazón (2)

Route	Headway (min)	Total Vehicles in Service	Avg. Load before station (pax/veh.)	Capacity Available		Avg. Load w/ Tren Urbano (pax/veh.)	Tren Urbano Transfers
				Seated (pax/hr)	Standing / Seated (pax/hr)		
A9	8	18	31	104	312	31	0
MII	8	21	14	208	448	14	0
Truncated MI	4	15	0	660	1050	35	550
Truncated MX	4	10	0	660	1050	35	550
TOTAL (4-min TU headway)		**64**		**1,632**	**2,860**		**1100**
A9	10	12	41	18	174	41	0
MII	10	17	18	156	312	21	18
Truncated MI	5	8	0	528	1050	44	528
Truncated MX	5	13	0	528	1050	44	528
TOTAL (5-min TU headway)		**50**		**1,230**	**2,586**		**1074**
Transfer Vol. ~1,100 passengers / hour							

In addition, if capacity at Sagrado Corazón is needed and the passengers' needs are not a concern, then the strategy of truncating Metrobus I on Opening Day should be considered. This strategy is more aggressive, is easier to implement and manage, and requires fewer resources than the partial short-turning strategy. However, the impacts of this strategy on existing Metrobus I riders is uncertain, and the threat of alienating riders is a concern, so it may be best to pursue a more conservative strategy to ensure that riders will not be discouraged from taking transit.

The resource requirements for peak-period service peak around Opening Day. On opening day, the bus service provider will need to allocate extra vehicles to maintain high levels of service and passenger convenience as they adjust to the new system. After this adjustment period, the operator can then restructure the system so that high quality services are provided without additional resources. Truncating and reinvesting the resources into a full short-turning of Metrobús I will not only results in a net savings of 6 vehicles over the previous configuration, but more importantly will not require any additional resources when compared to the present-day A9, Metrobús I and Metrobús Express peak-period vehicle or vehicle-hour requirements (Table 5-35). If the Tren Urbano schedule is modified to a 5-minute headway as recommended, the Opening Day vehicle requirement will be within the current fleet and full short-turning of Metrobús I will result in a net reduction of buses, which could be used to provide a new Metrobús service to Isla Grande.

Table 5-35. Resource Requirements for Peak Period Service Strategies (2)

Service Strategies	Vehicles Required	Vehicle-Hours (per day-peak only)
Base Requirement *(Current A9, MI,MII,MX)*	60	360
Maintain A9 *(8-minute headways)*	18	108
Maintain MII *(8-minute headways)*	21	126
Truncate MX *(4-minute headways)*	10	60
Truncate MI *(4-minute headways)*	15	90
TOTAL (4-minute Tren Urbano headway)	**64 (+4)**	**384 (+24)**
Maintain A9 *(10-minute headways)*	12	72
Maintain MII *(10-minute headways)*	17	102
Truncate MX *(5-minute headways)*	8	48
Truncate MI *(5-minute headways)*	12	72
TOTAL (5-minute Tren Urbano headway)	**49 (-11)**	**294 (-66)**

The service strategies analysis has primarily been from the passenger perspective, but the operator and community perspectives must also be considered. As discussed previously, truncating Metrobús Express and partially short-turning Metrobús I at the Sagrado Corazón station to ensure that waiting buses are available will increase the number of vehicles required and will require additional effort to maintain the intermodal coordination. However, ensuring that a high quality transfer environment is provided at the station will ensure that Tren Urbano and Metrobús can continue to attract new passengers as well as retain existing riders.

From the community perspective, the bus service strategies recommended for this period will promote activity in the Santurce / Old San Juan corridor as well as ensuring that the transit system remains cost-effective and well-utilized. The improved level of service resulting from the bus service strategies and the opening of Tren Urbano will promote activity that will not only transform the Sagrado Corazón area into a major activity center, but also improve the overall vitality of the Santurce / Old San Juan corridor during the peak and off-peak periods.

- *Midday Services*

In the midday period, the forecast transit ridership, as well as capacity and vehicle requirements, will decrease considerably from the peak period. Cambridge Systematics forecasts that there will be an average of 500 passengers per hour transferring at Sagrado Corazón during the midday period which is a decrease of almost 50 percent when compared to the peak period. If the peak period service is maintained during the midday periods, there will be significant excess capacity at the Sagrado Corazón station as well as on Tren Urbano.

Before selecting the bus service strategies for this period, the issue of excess capacity on Tren Urbano needs to be addressed. Tren Urbano will operate four-car trains during the peak and midday periods. However, given that on Opening Day, it is estimated that the trains will only be about 40 percent utilized during the peak period (as mentioned in the beginning of Section 5.3.3), there will be less utilization (25 percent) during the midday

periods. To reduce the excess capacity, 2-car trains could be used during these periods; the number of excess seats would be cut in half, but crowding on Opening Day could result during the peak. Since Tren Urbano needs to provide high levels of service to attract passengers onto the system, the use of 4-car trains during the peak periods should be maintained, but the use of two-car trains at off-peak periods, with a uniform five-minute (instead of 8-minute) headway throughout the day, and a ten-minute (instead of 12-minute) frequency at night and on weekends would result in a better deployment of train operating resources.

In addition to managing the excess capacity on Tren Urbano, it is also possible to eliminate one of the services provided to eliminate any wasted capacity provided at the Sagrado Corazón station. As with the peak-period strategy, the A9 route should maintain its current configuration. During the midday periods, the Metrobús Express route still maintains its considerable travel time savings and should still be truncated at the Sagrado Corazón station, but at an 8-minute headway.

Thus, the focus shifts toward selecting which Metrobús I service should be implemented in this period of the day. In the previous analysis, it was noted that the Tren Urbano / short Metrobús I combination provides some travel time savings, but that the transfer and higher fare may negate the convenience of the shorter travel times. Given that the maintenance of the longer Metrobús I route is recommended to maintain levels of service and passenger convenience and the fact that the midday transfer volumes have decreased, there will not be a need for the short-turned Metrobús I service. In addition, given the excess capacity that is available, the increasing of the bus headways for all the routes to 8 minutes will improve the utilization of the bus system during the midday while still having both Metrobús I and Metrobús Express meet every train at Sagrado Corazón. Table 5-36 gives the new service capacity provided at Sagrado Corazón. As the results show, even with the decreased headways, there is still enough capacity to provide comfortable connecting service to the transferring passengers. When Tren Urbano operates at 5-minute headways and the connecting bus service operates at 10-minute headways, there will be just enough seats available to accommodate all transferring

passengers. Yet, if frequencies are not improved in conjunction with transfer volume increases, there will not be enough seats available and passengers would be required to stand.

Table 5-36. Midday Hour Capacity at Sagrado Corazón

Route	Headway (min)	Total Vehicles in Service	Avg. Load before station (pax/veh.)	Capacity Available		Avg. Load w/ Tren Urbano (pax/veh.)	Tren Urbano Transfers
				Seated (pax/hr)	Standing / Seated (pax/hr)		
A9	8	18	23	165	373	23	0
MI (long)	8	13	14	240	448	44	240
Truncated MX	8	5	0	330	525	37	300
TOTAL (8-min TU headway)		**36**		**735**	**1,346**		**500**
A9	10	14	31	80	234	39	80
MI (long)	10	10	19	150	306	44	150
Truncated MX	10	4	0	270	525	37	270
TOTAL (5-min TU headway)		**28**		**500**	**1,065**		**500**
Transfer Vol. ~500 passengers / hour							

With the scaling back of services during the midday period, the operator will be able to reduce the amount of resources required to operate the service. As shown in Table 5-37, the service reductions during the eight-hour midday period result in four vehicles saved and a reduction of 32 vehicle-hours per day for services at 8-minute headways, and savings of 12 vehicles and 96vehicle-hours for services at 10-minute headways.

Table 5-37. Resource Requirements for Midday Period Service Strategies

Service Strategies	Vehicles Required	Vehicle-Hours (per day-midday)
Base Requirement *(Current A9, MI, MX)*	40	320
Maintain A9 *(8-minute headways)*	18	144
Truncate MX *(8-minute headways)*	5	40
MI (long) *(8-minute headways)*	13	104
TOTAL (8-min Tren Urbano headway)	**36 (-4)**	**288 (-32)**
Maintain A9 *(10-minute headways)*	14	112
Truncate MX *(10-minute headways)*	4	32
MI (long) *(10-minute headways)*	10	80
TOTAL (10-min Tren Urbano headway)	**28 (-12)**	**224 (-96)**

Focusing away from the station and toward the Río Piedras to Sagrado Corazón segment of Metrobús I, the service levels will decrease slightly, as the headways have increased from the current 6-minute headways. Nevertheless, given that Tren Urbano provides

high quality service along this corridor, the decreased bus service levels should not be a major issue for the passengers. Assuming that Metrobús II is continued at current scheduled frequencies, the Minillas to Hato Rey segment will be well covered and this problem will be minimized. Moreover, as with the peak-period strategies, the Metrobús I service will need to be reduced and eventually truncated at the Sagrado Corazón station to ensure that excess service capacity along the Río Piedras to Sagrado Corazón segment is eliminated and Tren Urbano is effectively utilized.

The service strategies recommended for this period benefit not only the passenger but also the operator. The resource requirements actually decrease over the current midday requirements, allowing the operator to reallocate the resources elsewhere or to reduce operating costs. In addition, with Tren Urbano operating with 2-car trains, the operating costs and train requirements will also decrease. Implementing the service strategies recommended for this period should also proceed smoothly, since aside from the Metrobús Express truncation and partial truncation of Metrobús I, no major changes to Metrobús I or A9 will be required on Opening Day. Not implementing any major changes will also allow the operator to focus on ensuring that the "waiting bus" intermodal coordination and service quality are at the highest levels.

The midday strategies do not have a significant impact on the local communities since no major changes to bus service have been implemented. Yet, the improved levels of service will no doubt improve the activity in the Sagrado Corazón area, further contributing to its transformation into a major activity center. The reduction of some bus service at the Sagrado Corazón station reduces the amount of excess bus capacity while also providing enough empty seats to satisfy both existing and new passengers. In addition, the recommendation to use 2-car trains during the midday period will result in considerable improvement in the utilization of Tren Urbano. Hence, the service strategies recommended for this period help satisfy the community and political pressures placed on the operator to ensure that Tren Urbano is successful and utilized effectively.

To improve the utilization of Tren Urbano further, the Tren Urbano could consider running the four-car trains at 10-minute, rather than 8-minute, headways. Operating at 10-minute headways would allow Tren Urbano to stay with clockface schedules and would provide easier coordination with the other feeder bus routes that operate at 10,20, and 30-minute headways. This however, would have the disadvantage of significantly worsening the current 6-minute Metrobús I frequency. A preferable alternative is likely to be the use of 5-minute headways with 2-car trains and the truncation of Metrobús I.

- *Evening / Weekend Services*

Providing high levels of service is very important in the evening and weekend periods. It is during these periods when the majority of the trips along the Santurce / Old San Juan corridor are for recreation. By establishing a convenient and high quality service, the transit system would be in a position to attract a number of these trips and improve evening and weekend ridership and utilization of the system. Moreover, establishing strong service during the evenings is important because many passengers will initially be wary of the safety and security of transit in the evening. Their fear would be compounded if they have to wait an extended period of time for Tren Urbano trains or connecting buses. Though the Sagrado Corazón station environment is designed to promote a sense of safety and security, it is still vital that there be a Tren Urbano train or connecting bus waiting or about to arrive as the passengers enter the station area.

Thus, the bus service strategies in this period need to focus on providing high quality service along the Santurce / Old San Juan corridor and at the station to ensure that passengers are not subject to lengthy wait times. There will be an estimated 200 passengers per hour transferring at Sagrado Corazón during the evening and weekend periods. Metrobús Express currently does not operate during the evening and weekend periods and maintaining the same operating policy will not be problematic. Given the low number of transferring passengers, the A9 and Metrobús I will be able to provide enough capacity to accommodate all the transferring passengers (Table 5-38).

Table 5-38. Evening Hour Capacity at Sagrado Corazón (1)

Route	Headway (min)	Total Vehicles in Service	Avg. Load before station (pax/veh.)	Capacity Available		Avg. Load w/ Tren Urbano (pax/veh.)	Tren Urbano Transfers
				Seated (pax/hr)	Standing / Seated (pax/hr)		
A9	12	10	26	90	220	38	60
MI (long)	12	9	16	140	270	44	140
TOTAL		**19**		**230**	**490**		**200**
Transfer Vol. ~200 passengers / hour							

Table 5-39. Resource Requirements for Evening Period Service Strategies (1)

Service Strategies	Vehicles Required	Vehicle-Hours (per day)
Base Requirement *(Existing service)*	18	108
Maintain A9 *(12 minute headway)*	10	60
Metrobús I (long) *(12 minute headway)*	9	54
TOTAL	**19 (+1)**	**114 (+6)**

Tren Urbano is planned to operate at 12-minute headways during the evening and weekend periods and coordinating headways to ensure that buses are waiting at the station is important in improving levels of service and reducing the transfer penalty perceived by passengers. Though it is possible to operate Metrobús I at 6-minute headways, there would be a significant amount of excess capacity. As a result, it is recommended that both the A9 and Metrobús I services operate at 12 minute headways to improve coordination with Tren Urbano as well as reduce excess capacity provided at the station. In addition, operating at 12-minute headways would only require one additional vehicle (Table 5-39).

Consideration could be also given to implementing 10-minute headways for the Metrobús I routes if it is decided that Tren Urbano should operate with 2-car trains and 10-minute headways during the evening and weekend periods. Though running buses at 10-minute headways would require additional vehicles, service capacity would increase and riders guaranteed empty seats. Moreover, as riders adjust to the Tren Urbano system and the new services that are provided, the short-turning of Metrobús I at Sagrado Corazón should be considered. Short-turning Metrobús I would free up vehicles that could be

used to maintain 10-minute headways while also creating large improvements in the service capacity provided at the station. The average bus load also drops considerably, improving the level of service provided by the bus system. In addition, truncating Metrobús I at the station would improve the quality of the intermodal transfer at Sagrado Corazón during the evening/weekend periods. Since a waiting bus will be available for the transferring passengers, their sense of safety and security would be improved along with their perceptions of taking transit and transferring in the evening periods, and reduce the excess capacity from Sagrado Corazón to Río Piedras inherent in the continuance of a longer Metrobús during the evening and weekends.

Table 5-40. Evening Hour Capacity at Sagrado Corazón (2)

Route	Headway (min)	Total Vehicles in Service	Avg. Load before station (pax/veh.)	Capacity Available		Avg. Load w/ Tren Urbano (pax/veh.)	Tren Urbano Transfers
				Seated (pax/hr)	Standing / Seated (pax/hr)		
A9	12	10	26	90	220	26	0
MI (short)	10	6	0	264	420	33	200
TOTAL		**16**		**354**	**640**		**200**
Transfer Vol. ~200 passengers / hour							

Table 5-41. Resource Requirements for Evening Period Service Strategies (2)

Service Strategies	Vehicles Required	Vehicle-Hours (per day)
Base Requirement *(Existing service)*	18	108
Maintain A9 *(12 minute headway)*	10	60
Truncate Metrobús I *(10 minute headway)*	6	54
TOTAL	**16 (-2)**	**96 (-16)**

For the operator, the additional resources required to improve coordination of the bus system and Tren Urbano are minimal (Tables 5-39 and 5-41). However, when additional capacity is needed, such as during special events or when new developments create new demand for transit services, the headways on Metrobús I could be reduced to 6-minutes or the route short-turned at Sagrado Corazón (Table 5-40). The benefits of the improved service levels would appear in the form of strong ridership growth and utilization of the transit system during the evening and weekend periods.

From the community perspective, the improved service levels in the evening and weekends will create significant benefits in the Santurce / Old San Juan corridor. As

mentioned previously, these two corridors experience a large amount of peak and off-peak traffic. Improving the accessibility of these corridors in the off-peak periods will help to attract additional residents into the area, improve the economic activity and vitality of the local area businesses and neighborhoods. In addition, improving the bus-rail coordination during the evening/weekend periods would also help ensure that Tren Urbano is successful in establishing strong evening/weekend ridership as well as continuing to attract new riders onto the transit system.

5.3.4 Timing of Implementation

The opening day of Tren Urbano will have significant impacts on both the service provider and the customer. If major modifications to the existing bus system were to be implemented in conjunction with the opening day of Tren Urbano, problems are likely to occur that would disrupt service as well as confuse passengers. Hence, as discussed in the previous section, it is better to take an incremental approach to the implementation of the bus service strategies. That is, to make a smooth transition to Tren Urbano, it makes sense simply to implement the bus service changes necessary to provide high levels of service on opening day, but to gradually implement major modifications to the bus system after observing ridership patterns. The incremental approach provides the SJMA residents time to become familiar with Tren Urbano and adjust their travel patterns accordingly. The gradual implementation of the Metrobús I truncation is such an example. Maintaining the Metrobús I route would preserve the existing service structure and provide passengers the option of taking either Tren Urbano or Metrobús I. Then, as use of Tren Urbano increases and ridership on the parallel segment of Metrobús I decreases, the service can be truncated. This would then be the time to implement the Condado service to maintain a sense of constant improvement.

The implementation of incremental service changes would also help the operator more effectively plan service. Any problems with intermodal coordination or the provision of service that arise can be identified and resolved before additional service modifications are implemented. The operator would also have time to evaluate changes in ridership and

demand levels and implement refinements to its implementation strategy to accommodate these changes. In addition, implementing service modifications over time will help ensure that bus drivers are properly trained on the new feeder routes and that service changes are marketed successfully to the public.

During the interim period after Tren Urbano opens when Metrobús I is partially short-turned, there will be two sets of riders utilizing Metrobús I. The longer portion of the Metrobús I route will cater toward those passengers that are transfer or fare averse. For those passengers that are more oriented toward travel time savings, they are likely to use the Tren Urbano/short-turned Metrobús I combination. By gathering ridership data on each route, the operator has a good opportunity to determine how the residents of the SJMA react to the presence of a transfer or increased fare. With a clearer understanding of the impacts of transfers on ridership, bus/rail integration strategies for future time periods can be better planned and analyzed.

5.4 Time Period 3: Tren Urbano Phase IA

This time period starts with the opening of Phase IA and continues until further extensions of Tren Urbano in the Santurce / Old San Juan corridor are completed. Given that this time period is in the medium-term future, much is unknown about what may occur in this time period. Because of this uncertainty, analyses at the tactical level, similar to those conducted for the previous time period, is less appropriate. Therefore, the focus of this time period analysis is on the long-range strategic issues that will need to be addressed when selecting service strategies.

The goal of the service strategies in this period is to ensure that the Tren Urbano system in the Santurce / Old San Juan corridor continues to be successful in providing high levels of service and attracting ridership. Phase IA of Tren Urbano marks the second major investment made in the public transportation system, and future extensions of Tren Urbano to Old San Juan are difficult to predict at this point. If the Minillas extension is

not utilized effectively, then approval of any future extensions in the Santurce / Old San Juan corridor may be jeopardized.

When this time period begins, Tren Urbano will have been providing service for several years and the residents of the SJMA will be familiar with the benefits of the Tren Urbano system. Thus, the service strategies in this period can focus less on ensuring that passengers become familiar with Tren Urbano and more on providing high quality service to accommodate the new Minillas extension passengers.

To ensure that high quality services are provided, it is vital that the integration and coordination of bus service at the Minillas and San Mateo stations be effective. As in the previous period, the service strategies in this period must also focus on establishing a high quality and effective transfer environment at both stations. Though passengers may have become accustomed to transferring at the Sagrado Corazón, the extension of Tren Urbano to San Mateo and the Minillas station should reduce the number of Santurce riders who require a transfer, as well as shorten the feeder buses to the remainder of Santurce, Condado, and Old San Juan. However, the Minillas station will not have the space to accommodate waiting and layover buses that Sagrado Corazón provides suggesting a greater role for San Mateo as a transfer station.

In addition to minimizing passenger inconvenience at the station, the service strategies must also address the key issue of providing enough capacity to accommodate transferring passengers. The Minillas station is located at a major activity center and will be a very popular destination for both work and recreational trips. Minillas could also become a popular and important transfer point. Table 5-42 gives the 2010 forecast boardings and alightings for the Minillas Extension. The service capacity required at each of these three stations is an important component that influences the analysis and selection of service strategies for this period. However, the limited space and capacity of the Minillas station may will allow it to accommodate the significant volume of transfers that are forecast. The close to 7,000 passengers that are expected to transfer at Minillas dwarfs the number of transfers expected for Sagrado Corazón, which is far better suited

to accommodate transfers. As a result, it may be unrealistic to expect Minillas to be the primary new bus/rail transfer point for Santurce.

Table 5-42. 2010 Phase IA Daily Boardings and Access Mode by Station

Station	Walk to Station	Drive to Station	Transfer at Station	Total for Station
Sagrado Corazón	3,740	76	1,272	5,088
San Mateo	2,947	22	1,530	4,499
Minillas	4,258	113	6,923	11,294
TOTAL	**10,945**	**211**	**9,725**	**20,881**
Sagrado Corazón (Phase I)	2,672	60	7,043	9,775

Source: FSEIS, Minillas Extension (1998)

Given the development that is now slated for the Sagrado Corazón area, adjustments also need to be made to the number of boardings at the Sagrado Corazón station. The new DTOP building will create an estimated 2,000 jobs that were not factored in the FSEIS estimates for this station. As a result, assuming that half of these 2,000 workers walk to/from the station, the number of passengers walking to the Sagrado Corazón station will then be close to 5,000, surpassing the close to 4,300 at the Minillas station. As developments in the Condado, Isleta, and Isla Grande occur, the number of transfer trips from these three stations is assumed to increase by at least 50 percent over existing FSEIS estimates (Table 5-43).

Table 5-43. 2010 Phase IA Daily Boardings and Access Mode by Station (Adjusted)

Station	Walk to Station	Drive to Station	Transfer at Station	Total for Station
Sagrado Corazón	~5,000	76	~1,900	~7,000
San Mateo	~3,000	22	2,200	~5,200
Minillas	~4,300	113	~10,000	~14,300
TOTAL	**~12,300**	**~211**	**~14,100**	**~26,500**
Percentage of total	46	1	53	100

Hence, the service strategies must also aim to continue the growth of the transit system to keep up with the developments and growth that will take place in the activity system of the Santurce / Old San Juan corridor. Service strategies should be implemented to take advantage of the improved accessibility that Phase IA provides to improve service to new markets and expand the reach of the transit system. By expanding the reach of the transit

system, high quality service can be provided to a larger customer base, resulting in potential ridership gains and continued success of the transit system.

5.4.1 Minillas Extension Station Analysis

Given that the Minillas station (Figure 5-7) is located in a densely developed area adjacent to Ponce de León Avenue, space will be at a premium, so an effective layout as an intermodal transfer point is not feasible. Therefore, until an extension of Tren Urbano to the RH Todd station, adjacent to Parada 18, becomes feasible, a primary intermodal transfer point should continue to be Sagrado Corazón. In addition, San Mateo can also serve as a major transfer facility given more available space and good street connections. Additionally, the A5, with its two-way service at the Minillas station on Ponce de León, could become an important distributor to Old San Juan and the rest of Santurce.

Passenger requirements

The Minillas Extension stations must satisfy the passenger requirements discussed in Chapter 3. The most important requirement that must be met is the comfort and convenience of the station environment. Aside from the station entrances, the station is located underground, so the passengers will not be exposed to changing weather conditions. However, upon exiting the station, the passengers may have to travel, unprotected, to the bus stops for connecting service. Once at the bus platforms, they will be located on the sidewalks of Ponce de León Avenue, with normal urban bus stops. Proper accommodations, such as bus shelters can ensure a comfortable environment for transferring passengers, but there is no capacity to accommodate the "waiting empty bus" strategy which is feasible at Sagrado Corazón.

The opening of the Minillas station can support the continuing revitalization of the area , which has already begun with the Plaza Europa and Performing Arts Center, to ensure that it provides a self-enforcing environment where passengers will not be concerned

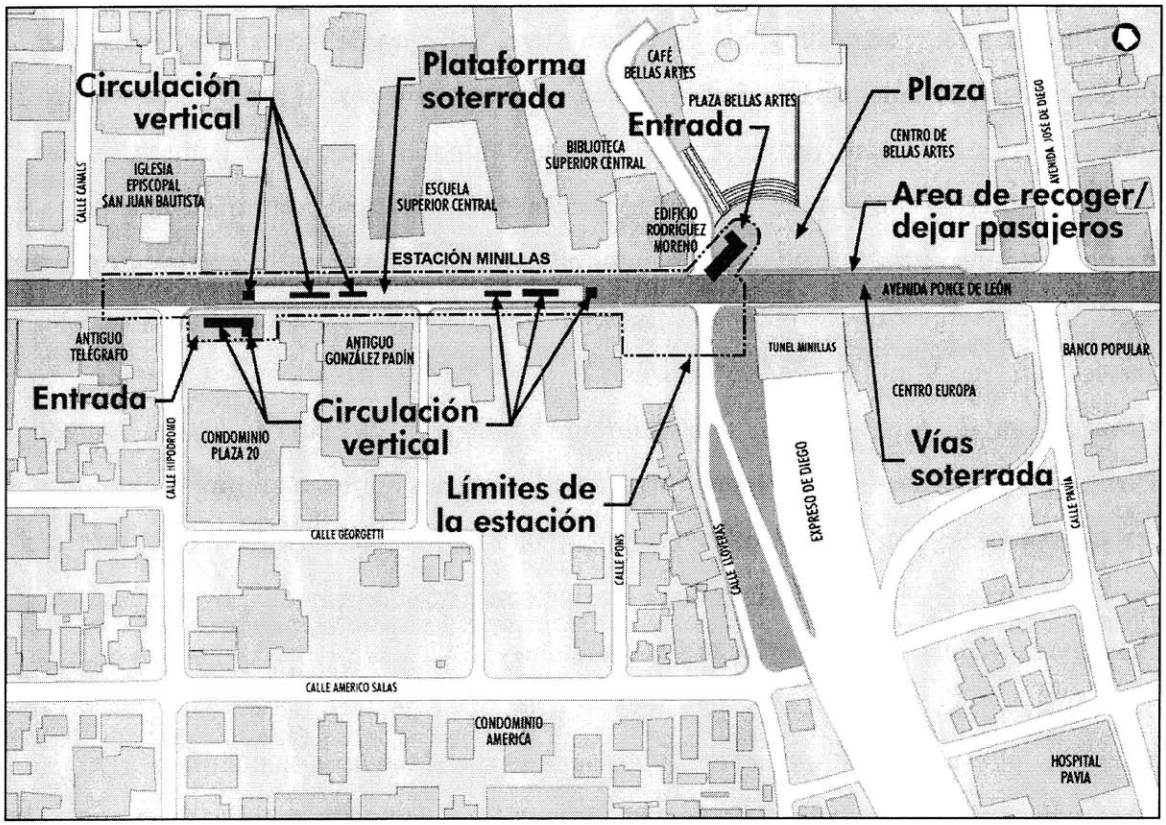
with safety and security. However, the station must also provide adequate capacity for very large volumes of transferring passengers which is not feasible on a city sidewalk.

Operator requirements

Several operator requirements also need to be met by the Minillas Extension stations. First, the Minillas station needs to be able to accommodate the buses that are stopping or terminating at the station. The operator can also improve service reliability by truncating routes at this station, since the buses will no longer have to face vehicular congestion south of Minillas along Ponce de León and Fernández Juncos Avenues. However, though the layout of the station provides curb space for the pickup and drop-off of passengers (Area de recoger / dejar pasajeros in Figure 5-7) close to the station entrance and plaza, the curb space will not be able to accommodate the routes that stop or terminate at the station. Moreover, unlike the Sagrado Corazón station, there are no parking areas available to accommodate the layover of buses, should routes be terminated at the station. Due to the lack of curb space and the busy contraflow lanes, the provision of buses that wait at the station for connecting passengers is not possible.

On the other hand, the San Mateo station may be more suitable as a major bus/rail transfer point. Compared to the Minillas station, there is space available around the San Mateo station that could be used to accommodate bus/rail transfers. The San Mateo station is located on Ponce de León Avenue, but compared to the Minillas station, provides better access to other major roadways in Santurce, namely Fernandez Juncos Avenue and Muñoz Rivera and Baldorioty expressways.

Figure 5-7. Minillas Station Layout



Transit access to Ponce de León Avenue is easy since either station is located directly below this major arterial. The southbound buses that operate on the contraflow lanes will have easy access to the station. On the other hand, the northbound buses may be subject to some service disruptions. The planned location of the Minillas station is not close to the Fernández Juncos Avenue, so bus routes on running along this avenue would have to undergo major restructuring in order to stop at the station. The buses heading northbound to/from the Minillas station will be subject to the traffic congestion that may be present in the Minillas area. The northbound buses can travel either on Ponce de León Avenue or on the contraflow lanes on Fernández Juncos Avenue. However, if these buses were to travel on Ponce de León Avenue, they would be required to operate with other vehicles and be exposed to congestion. In order to access the northbound contraflow lane on Fernandez Juncos, the buses would be required to navigate through the narrow, congested cross streets, subjecting the buses to delays. In short, the bus circulation for a Condado service can feed Minillas, but the Metrobús Express is better off staying at Sagrado Corazón, and the Metrobús I short-turned route would provide better service at Sagrado Corazón or San Mateo. If the longer Metrobús I route has not been eliminated at this point, it should be, as the bulk of the Santurce-Hato Rey market now have one seat rides on Tren Urbano. Moreover, Metrobús I service could be supplemented by an increase in A3 service frequency and service to the Condado.

Given the physical constraints of the Minillas station and the need to maintain high quality bus-rail transfers, there are several options for the transit system at this point. The intermodal transfers can remain at the Sagrado Corazón station, where the facilities are designed to accommodate waiting buses. Another option is to shift a portion of the intermodal transfers to the San Mateo station so that buses will have improved access to Minillas and other destinations in Santurce. A third option is to improve the frequency of A5 and Condado service, not ahead of "waiting buses" at Minillas, and count on high service frequency to keep travel times low and service levels high. This problem provides incentive to push for an extension of Tren Urbano to the RH Todd station, which is adjacent to Parada 18. Extending to this transit center would allow waiting bus

strategies to be implemented at the RH Todd Tren Urbano station as well as improve the mobility of passengers traveling to the Old San Juan corridor and the rest of the Santurce corridor, and substantially transfer much of the bus distribution interaction from Sagrado Corazón, economizing on bus operating resources.

Community requirements

For the Minillas community, the new extension will also introduce many benefits. First, the new Minillas station will provide increased accessibility in the peak and off-peak that will help revitalize the area. The station provides a great opportunity to redevelop the surrounding area with shops, restaurants, and other attractions to make it popular during peak and off-peak periods.

Yet, for the Sagrado Corazón community, the transformation of the Minillas station into the new transfer point for the Santurce / Old San Juan corridor may also pose some problems. The Minillas area is already a popular activity center and focusing transit service around this station will further increase the activity in the area. The forecast number of boardings at Sagrado Corazón decreases dramatically with Phase IA; only 5,088 passengers are forecast to board at the station in 2010, compared to the 12,146 forecast for Phase I. As a result, the activity in the Sagrado Corazón area may decrease, resulting in negative impacts on the local businesses, economy and community. However, if the developments around the Sagrado Corazón station, such as the DTOP building, are effective in transforming the area into a popular activity center, the impacts of decreased Tren Urbano activity on the Sagrado Corazón area can be mitigated. Additionally, if Metrobús Express and potentially Metrobús I stay at Sagrado Corazón, the community will benefit considerably until extension of Tren Urbano to Parada 18 is complete.

5.4.2 Infrastructure

Given the uncertainty that exists in this period, it is difficult to identify specific changes to the road network. However, as in the previous period, the service strategies should be developed to ensure that any remaining transit rights of way are protected, especially in light of potential Tren Urbano extensions further into Santurce and to the Isleta. For example, current plans call for the Old San Juan extension to be built along the Calle del Tren, so by maintaining transit use on this right of way, it can be acquired easily for the Tren Urbano extension without requiring the operator to pay high acquisition costs.

The contraflow lanes along Muñoz Rivera and Ponce de León Avenues should also be preserved. This will ensure that bus service into the Isleta will still retain some competitive advantage over the automobile. In addition, these contraflow lanes will also be useful when construction of future extensions into the Santurce / Old San Juan corridor begins. The construction of the extension will interfere with access to the Isleta and Calle del Tren and bus service can be rerouted onto the contraflow lanes to minimize service disruptions and passenger inconvenience. As a result, the traffic problems that may result from the construction provides a good opportunity for transit to attract residents onto the system and away from the automobile. Eventually it may also be possible to allow taxicabs to also use the contraflow lanes.

In addition, the construction that will take place at the entrance to the Isleta provides a good opportunity to make accommodations for transit. The renovation of the bridges and the construction of the new vehicular tunnel will increase the number of lanes that enter and exit the Isleta. If one or two of these lanes were preserved for transit use, then the bus system would have a competitive advantage. Moreover, with the possibility of further extensions onto the Isleta, the construction of the vehicular tunnel should be coordinated with Tren Urbano. Any extension of Tren Urbano onto the Isleta is likely to occur underground and underwater. If the design and construction of the Tren Urbano extension is not coordinated with the highway tunnel project, problems may arise that could inhibit construction of a further Tren Urbano extension. As a result, it is

recommended that both tunnel projects, if possible, be executed at the same time to avoid multiple disruptions to the transportation system in the Isleta and Santurce as well as to ensure that extension into the Isleta will be possible in the future.

5.4.3 Network structure

The approach taken to select the service strategies that should be implemented to ensure that high quality service is provided from the Minillas station is similar to the one used in the previous time period. However, given the uncertainty that exists in this time period, the application of the analysis framework can not provide the same level of detail. Rather, the approach used in the previous period will be applied to identify what information will be needed as well as how the analysis of service strategies for this period should be conducted.

The first step in selecting the service strategies for this period is to identify the routes and service markets that will be affected by the Minillas extension. Given the current location of the Minillas and San Mateo stations, the major trunk routes that will be affected are: A5, A9, Metrobús I and Metrobús II. For each of these routes, the current service characteristics, such as ridership, cost-effectiveness, service reliability, resources required, and levels of service (average bus loads, transfers required, travel times), need to be identified. The characterization of each route will help identify whether the route provides such key elements as high levels of service or sufficient capacity to accommodate increased passenger demand, which will lead to the identification of the service modifications that are available to accommodate the Minillas extension.

In the previous time period, all of the service strategies were centered on providing high quality service at the Sagrado Corazón as well as the effective use of the Tren Urbano system. Likewise, when identifying the service alternatives for each bus route in this time period, the focus needs to be on providing high quality service from the Minillas and San Mateo station. The service strategies in this period should build upon the strategies

considered and implemented in the previous time period. Some of the service strategies that may be applicable for the A5, A9, Metrobús I and Metrobús II routes are identified below; additional information will help to identify additional strategies that may also apply.

1. Maintain the existing structure (applicable to all routes)
2. Truncation (A5, A9, Metrobús I)
3. Partial short-turning (A5, A9, Metrobús I, Metrobús Express)
4. New route (to Condado, Isla Grande)

Each of the strategies identified above, must be analyzed using a number of key service criteria. For each route, service capacity at the stations and along the route needs to be determined, as well as the levels of service provided on each route and the amount of resources required to implement each strategy. The impacts of transfers on the bus system, ridership and passenger satisfaction will also need to be considered in the service strategy analysis. Although this analysis could be conducted now, it is much more appropriate to conduct it in the future when more accurate and reliable data is available.

In order to conduct an accurate analysis, detailed, up to date information for each criterion needs to be obtained at the time of the analysis. The operator needs to develop a detailed data collection strategy to ensure that the information for the evaluation criteria are obtained. A survey can be implemented in the earlier time period to gather passengers' options, perceptions, and reactions to service changes to accommodate the opening of Phase I. Once information is obtained on all these elements, a better assessment can be made on which combinations of bus service strategies are best able to improve the service provided to the Santurce / Old San Juan corridor by the bus system and Tren Urbano.

The strategies listed above will now be briefly discussed to point out the key issues with each strategy that will need to be addressed (either with additional information or more detailed analyses) before selecting the appropriate strategies for implementation when Phase IA opens.

- *Maintain existing service*

Maintaining existing services will result in minimal inconvenience for the passengers, and will ensure that service will not be disrupted when the Minillas extension is completed. This strategy is appropriate for the bus routes that currently provide high quality service to unique markets, and provide enough capacity to accommodate forecast demand. However, overlaps in service between the bus route and Tren Urbano, specifically along the Sagrado Corazón to Minillas corridor, caused by maintaining the existing bus route may lead to service redundancy, excess capacity, decreased cost-effectiveness, and potential competition for ridership. When more detailed information is gathered on each of the bus routes that are operating in this period, the benefits and costs of maintaining the existing route can be better assessed and a decision on whether to implement a service modification can be made with confidence.

- *Truncation at the Minillas Extension stations*

The truncation of routes at the Minillas or San Mateo station could help to ensure sufficient capacity is provided to accommodate the transferring passengers as well as those who are walking to the station. Terminating bus routes at either station would help ensure that buses will be waiting at the station for Tren Urbano passengers, which will reduce the amount of time passengers spend waiting along Ponce de León Avenue for their connecting vehicles and as a result, will improve the convenience and attractiveness of the transfer.

However, several issues must be addressed when considering this strategy for the Minillas station. First, information on the service capacity along the Sagrado Corazón to Minillas segment needs to be obtained in order to determine the impacts of the truncation on the passengers traveling between these two areas. It is probably better to consider truncating services at San Mateo and accommodating larger transfer volumes there. The impacts of transfers on the levels of service need to be evaluated. Gathering information on the impacts of transfers on passengers will help in the evaluation of the route truncation options.

Finally, unlike Sagrado Corazón, the Minillas station's ability to accommodate the truncated buses needs to be further analyzed. As mentioned earlier, there is limited curb and parking space available to accommodate vehicles, so it may be impossible to terminate routes at this station.

Parada 18 has long been a major transfer center and plays a very important role in providing high quality service throughout the Santurce / Old San Juan corridor. Plans for the Old San Juan extension of Tren Urbano indicate that the R.H. Todd station is tentatively located adjacent to Parada 18. Thus if, by the time the Minillas extension is operational, the plans for an extension closer to the Isleta are approved, the completion of the R.H. Todd station could provide a very good transfer location. Moreover, the importance of the roles Parada 18 and the R.H. Todd station play in providing high quality intermodal connections can also help put pressure on planners and government officials to speed up the planning and approval process for further extension of Tren Urbano toward Old San Juan, at least to reach R.H. Todd.

In summary, given the constraints of the Minillas station and the importance of Parada 18, the truncation of routes at the Minillas station is a proposal that cannot be implemented successfully. On the other hand, the termination of routes at both San Mateo and Sagrado Corazón is still a potentially successful alternative. Ultimately, as Tren Urbano ridership increases, the inability of the Minillas station to accommodate transfers and increasing transfer volumes at San Mateo and Sagrado Corazón would require that a better bus/rail transfer point be created, providing an impetus to extend Tren Urbano to RH Todd.

- *Partial short-turning at Minillas*

The decision on whether or not to implement a short-turned route is dependent first on the service capacity currently available and the ability of the Minillas station to facilitate effective transfers. If enough service capacity is provided with the existing route and other services are available to provide high quality connections at the station, then the

short-turning strategy may not be needed. Moreover, if the Minillas station is determined not to be an effective transfer point, then the short-turning of a bus route at the station may result in decreased levels of service.

Since the short-turning strategy is geared toward minimizing passenger inconvenience and providing time for the passengers to adjust to the new Minillas extension, the impacts of transfers on the passengers needs to be determined to see if it is helpful. The use of historical data from the opening of Tren Urbano Phase I will help the operator understand how the presence of transfers affected ridership and passenger satisfaction as well as help predict the impacts of the rail-to-bus transfer. As stated earlier, the residents may then be accustomed to the rail-to-bus transfers since Tren Urbano will have been in operation for several years. So, the passengers may not mind that a route is truncated at Minillas and an intermodal transfer is required, so long as high levels of service are provided. Yet, if the information obtained from Phase I shows that the presence of transfers has significant impact on the passengers' willingness to take transit, the service provider can consider implementing this strategy to ensure that passengers will not be severely inconvenienced.

- *New route*

In addition to modifying existing routes, new routes can be implemented from Minillas or San Mateo. Since these stations provide improved accessibility to the northern section of Santurce, new routes to previously underserved areas could improve service in these areas as well as expand the reach of Tren Urbano to attract additional residents onto the transit system.

Areas experiencing new developments, such as the Isla Grande area, are prime candidates to receive new or improved bus service. The Golden Triangle and Waterfront development plans will substantially increase residential, recreational and commercial activities in the area. These developments provide a great opportunity for the transit system, as a new market of potential riders will be created. Given that the Isla Grande area is currently underserved by transit, establishing strong service to area would help to attract the residents that will be making work or recreational trips to this area.

Benefits are also attainable with improved service to the Condado. With the changes stemming from the Golden Triangle plan, the Condado can further improve its status as a major activity center and recreational destination. The operator would benefit from the increased demand for peak and off-peak transit services to the area. Passengers would benefit from improved accessibility and service levels to the Condado from Tren Urbano and points along the Santurce / Old San Juan corridor and the SJMA. Finally, improved service to the Condado would promote increased activity during all periods of the day, benefiting the hotels, casinos, and restaurants in the area.

It must be noted that the Metrobús Express route is excluded from most of the analyses that will be conducted in this time period. Given the current route configuration and location of the Minillas station, the relocation of Metrobús Express to the Minillas station would not be prudent. As mentioned previously, given the station's location and physical constraints, access to either the Muñoz Rivera (south of the station) or Baldorioty de Castro (north of the station) expressways would not be convenient or efficient. If Metrobús Express were to terminate at Minillas, the buses would need to navigate through congestion on local roads to get to the expressways. As a result, any travel time savings from traveling on the expressway would likely be negated. Unless a more direct route to the expressway or improvements in the right of way are made, the truncation of Metrobús Express at Minillas would provide no added benefit.

In fact, the Metrobús Express service may not be needed once the Minillas extension is completed. Currently Metrobús Express provides travel time savings of close to ten minutes from Sagrado Corazón to Old San Juan. However, when the Minillas extension is opened, buses from the Minillas station will travel a shorter distance to Old San Juan, resulting in travel time savings. Combining the shorter bus trips with the faster Tren Urbano trips could negate any travel time savings provided by the current Metrobús Express service, however station problems at Minillas make Parada 18 and the RH Todd station better candidates for this change. As a result, once additional information on the

performance and characteristics of the service is available, a more accurate assessment of whether or when the service should be eliminated can be conducted.

5.4.4 Timing of Implementation

Once the Minillas extension is completed, the service changes should be implemented without severely disrupting existing Tren Urbano service and inconveniencing the passengers. Hence, an incremental approach similar to that used in Time Period 2 should be used. This approach would provide both the operator and customer enough time to adjust to the new extension and to utilize opportunities for the improved service it provides. Yet, the operator also needs to ensure that throughout the entire implementation process, aggressive marketing campaigns are carried out so that passengers are informed of the changes and disruptions will be kept to a minimum.

Since specific service strategies have yet to be identified in this period, the lessons learned from the implementation of similar service strategies for Phase I will provide much needed information that will help transit service planners better assess when it would be appropriate to implement different service strategies as well as better predict the potential outcomes of the implementation process. Information on a number of elements can be obtained from the observations of previous implementation processes. Information on the time required to train drivers as well as to procure and allocate vehicles to bus routes will help ensure that service changes are implemented with minimal disruption to the existing transit system. In addition, insight can also be gained on the adjustment period of passengers to service changes. This information can be used to formulate an implementation strategy that minimizes passenger inconvenience and ensures that passengers will have enough time to adjust their travel patterns.

Finally, the time required to implement and market service changes, as well as their effectiveness, in previous periods can be very useful in the determination of a strategic implementation plan for Phase IA. The operator needs to ensure that throughout the

entire implementation process, customer surveys, and marketing campaigns are carried out to keep passengers informed of service changes and avoid inconvenience.

In order to coordinate and integrate bus service modifications with long-term developments in the urban infrastructure and local activity system, information will need to be obtained on when these developments are expected to be completed and their potential impacts on the transit system. If these developments require major service changes, the incremental approach used in the previous time period should be used. Information can be gathered from the incremental implementation of services in previous periods that will be useful in coordinating future service changes with any developments that may occur.

5.5 Summary

There is a need to reflect on the recommendations made for the bus services in each period (Table 5-44) to ensure that they contribute to the long-term success of the transit system in the Santurce / Old San Juan corridor. In Time Period 1, it was recommended that service hours of the bus system be extended to generate additional ridership and interest in evening services, as well as to prepare the residents for Tren Urbano. The strategies suggested in the second time period focus on providing high quality off-peak services and their success in attracting additional off-peak ridership will depend strongly on the success of the service hour extension implemented in the first time period. Hence, the service changes recommended for the pre-Tren Urbano opening period are in-line with the strategies employed in the following time periods.

The changes recommended in the second period are much more substantial than those in the first period and their long-term impacts on the transit system are also more significant. Terminating most of the routes at the Sagrado Corazón station will ensure that high levels of coordination and high quality transfers are provided at the station. In addition, the short-turning and possible eventual elimination of the Metrobús I route between Río Piedras and Sagrado Corazón will provide a smooth transition to the new

Tren Urbano system for many residents and existing passengers. The addition of new routes as developments or shifts in demand occur will help in establishing sufficient service capacity at the station as well as attracting new transit riders. All the strategies in this period are focused on establishing a high quality intermodal connection at Sagrado Corazón, which will improve the use of Tren Urbano and make the transit system appealing to both existing and new passengers. Looking at the longer-term, by making a conscious effort to improve the system to attract additional riders, the future success of Tren Urbano within the Santurce / Old San Juan corridor can be ensured. The success of the strategies employed for Phase I will help to justify further extensions toward Old San Juan.

Finally, the third period strategies are focused on integrating the bus system with the Minillas Extension stations. Unfortunately, the Minillas station itself is unlikely to be nearly as effective as Sagrado Corazón in facilitating high quality intermodal transfers. In addition to Sagrado Corazón, the San Mateo station is also a likely candidate as a major bus/rail transfer point. The further extension of Tren Urbano to Parada 18 should be pursued to ensure that the transfers forecast for the Minillas station can be accommodated effectively. However, in the event that the extension of Tren Urbano to Parada 18 will not occur for a while, Sagrado Corazón, and potentially San Mateo, could become the major intermodal transfer point(s), and the strategies implemented in the second period for Phase I will become very important in maintaining the high levels of service and coordination at the stations.

Table 5-44. Recommendations for Transit Service in the Santurce/Old San Juan corridor

	Time Period		
	1. Pre-Tren Urbano Opening	**2. Tren Urbano Phase I**	**3. Tren Urbano Phase IA**
Bus Service Recommendations	• Extend AMA/Metrobús service hours later into the evening	• Match Tren Urbano headways during peak, midday and evening/weekend periods; • Maintain A9 service • Truncate Metrobús Express at Sagrado Corazón on Opening Day • Partial short-turn of Metrobús I at Sagrado Corazón on Opening day • Elimination of longer Metrobús I portion in the future • Introduce service to Condado	• Evaluate truncation/ short-turning of some bus routes at Minillas strategies as more information is made available • Consider elimination of all Metrobús Express service • Introduce service to Isla Grande
Tren Urbano Recommendations	• Implement aggressive marketing/promotion plan for new Tren Urbano service and modified bus system	• 2-car trains during midday/base periods • Operate trains at 5-minute headways during peak and midday, and 10-minute headways during evening/ weekend periods	• Establish Sagrado Corazón and/or San Mateo as the transfer points due to Minillas station limitations • Strongly pursue the extension of Tren Urbano to RH Todd (Parada 18)
Other Recommendations	• Potential fare increase with service hour extension	• Implement free transfer fare policy, monthly pass system, discounted senior/student fares	

Chapter 6. Summary and Conclusions

This chapter summarizes the research approach used in the planning and analysis of integrated rail/bus service strategies, the findings and recommendations for the bus system and the importance of the bus system in the Santurce / Old San Juan corridor, and concludes with recommendations for future research.

6.1 Strategic Planning Process

The selection of short-term bus service strategies must account for the future needs and expectations of the transit system. In the context of the future Tren Urbano service, the bus service strategies need to be focused on providing high levels of service to help create a high quality intermodal transit system in the Santurce / Old San Juan corridor. To do this, the service strategies that are selected must be designed around the phasing of Tren Urbano to ensure that the rail system will be supported effectively by the bus system and used by the residents of the SJMA.

In order to focus the strategic planning of bus services around Tren Urbano, several time periods were established based on the Tren Urbano phases. The first time period extends from now to the opening of Tren Urbano Phase I. The second time period runs from Phase I Opening Day up to the opening day of the Minillas extension. Finally, the third time period starts from this point and continues until future extensions of Tren Urbano into the Santurce / Old San Juan corridor are completed. The purpose of considering a long-range view in bus service planning is to ensure that short-run service strategies do not conflict with the long-range objectives of the transit system, but rather support them.

Any changes in the operating environment that are anticipated to occur in each time period were then classified into three main activity systems. Changes classified as affecting the *local activity system* focused on changes in demand, ridership, demographic

shifts, socio-economic trends, and other similar issues. Another category, the *urban infrastructure* dealt primarily with developments to existing infrastructure, roadway structure and network. The final category is the *public transportation system* and focused on developments directly related to the bus or rail system.

To further assist the decision-making process of selecting the appropriate bus service strategies for a given time period, each category was then evaluated using three perspectives- customer, operator, and community. The customers are impacted the most by changes in the transit system, and their perception of the transit system must remain positive. The second perspective is that of the operator, who seeks to minimize the negative impacts of changes in the operating environment on the transit system as well as to expand the reach of the system to new or underserved markets and needs to focus on the adequacy of resources. Lastly, the community perspective must be considered since changes in the transit system need to contribute to positive changes and growth in the surrounding communities.

6.2 Recommendations for Transit Service in the Santurce / Old San Juan Corridor

The Old San Juan area currently attracts a large volume of peak and off-peak trips, due to its rich mix of commercial and recreational areas. Old San Juan's popularity as a recreational destination will continue to generate a large number of recreational trips, many of which will take place in the off-peak, evenings and weekends. The government and commercial centers will remain important attractors of peak period work trips. Moreover, as plans to develop and improve the Isleta, Isla Grande, and Condado areas move ahead, the demand for service in the Santurce / Old San Juan corridor will only increase. However, since the popularity of the automobile in Puerto Rican culture is very high, a large portion of the trips in the Santurce / Old San Juan corridor will continue to be via automobile.

Yet, the Old San Juan and Isleta is facing increasing levels of vehicular congestion. Daily traffic levels are forecast to increase by almost 50 percent in the next five years and more than double in the next decade. Moreover, there will be road construction in the future that will hinder automobile access to the Isleta. As a result, the transit system's role in providing a high quality alternative to driving becomes vital in the reduction of the vehicular congestion in the Old San Juan area. With the reserved rights of way available, and the first phase of the new Tren Urbano system near completion, the bus system has an opportunity to attract potential riders onto transit by showcasing the benefits of using transit in the Santurce / Old San Juan corridor.

Even though the bus routes in the Santurce / Old San Juan corridor have the highest ridership in the SJMA, the automobile is still dominant. The introduction of Tren Urbano provides a real opportunity to improve the quality of transit service, to establish credibility among the residents of the SJMA, and to increase overall transit ridership. Ridership is key to the success of both the bus system and Tren Urbano and they need to complement each other in order to become competitive with the automobile and attract new riders. In order for this to occur, the bus service needs to effectively utilize the services offered by Tren Urbano as well as ensure that high levels of service are provided throughout the Santurce / Old San Juan corridor. By establishing a strong presence in this corridor, the transit system will be able to attract and maintain a large ridership base and promote the creation of a transit-oriented culture.

Planning bus service strategically provides the operator the ability to anticipate and accommodate future developments in the operating environment and their potential impacts on the transit system. The primary focus of the service strategies analyzed in this thesis is to support Tren Urbano Phases I and IA. The bus system needs to maintain high levels of service not only to continue serving existing passengers, but also to ensure the success of the new rail system by attracting new riders. With a strategic focus, the future expectations of Tren Urbano, such as high levels of service, ridership and mode share, are taken into account in the selection of short-term bus service strategies. These strategies are designed to implement short-term changes that will at each step maintain service

quality for existing riders and provide a mix of services to attract new riders. This approach, consistently applied, will over time meet these expectations and ensure the long-term success of Tren Urbano and the transit system in the Santurce / Old San Juan corridor.

Time Period 1: Pre-Tren Urbano Opening

The objectives for this period are to establish high quality transit service at all times to ensure that once Tren Urbano is open, it will be well utilized during all periods of the day. Hence, changes in the service levels of the bus system in the Santurce / Old San Juan corridor will need to be implemented in order to assure that Tren Urbano will be successful upon its debut. As discussed previously, the Santurce / Old San Juan corridor generates large volumes of both peak and off-peak trips, and in order for transit to be able to attract a portion of these trips, the peak and off-peak service needs to be credible in the minds of the customers. Currently, though the peak-period service is good, the off-peak evening and weekend service needs much improvement. By improving the service levels of evening and weekend service as well as extending AMA and Metrobús service hours, the transit system will become a more attractive option for residents. Increasing the off-peak use of transit will help to ensure that when Tren Urbano debuts, it will be successful in attracting riders during all periods of the day. In addition, AMA fare increases, if implemented, should be accompanied with prepaid passes and fares or discounted transfers to get the public accustomed to dealing with prepaid fare media.

Time Period 2: Tren Urbano Phase I

The service strategies selected for the opening day of Tren Urbano Phase I are designed to meet several key objectives for this period. The first objective is to establish and maintain a high quality transfer experience at Sagrado Corazón, the northern terminus of Phase I. The second objective is to provide high levels of service to maximize passenger convenience on transit as they adjust to Tren Urbano. A third objective is to ensure that

sufficient capacity is provided at the Sagrado Corazón station to accommodate transferring passengers. Finally, a fourth objective is to avoid providing excess capacity along the bus routes and on Tren Urbano to improve the cost-effectiveness of the transit system as long as the three effectiveness criteria are met.

Issues related to the intermodal transfer and transfer environment are major factors that influence what service should be provided at the Sagrado Corazón station. A convenient and comfortable intermodal transfer environment is key to providing a high quality interchange for passengers transferring between bus and rail. A review of transfer penalty studies revealed that the presence of transfers can have a profound impact on the passengers' willingness to take transit. As a result, the transfer environment must be designed to make transfers as convenient as possible by decreasing transfer and wait time, improving intermodal connectivity, and creating a user-friendly and safe environment. An analysis of the Sagrado Corazón station revealed that it is a well-designed transfer facility.

A key recommendation is that current fare policies be revised to reduce the penalties associated with transferring. Free or discounted fares can reduce the cost impacts on riders and improve their willingness to accept transfers. The anticipated fare of $1.00 to use Tren Urbano is double the current Metrobús fares and quadruple the AMA fare. Much of the cost increase can be justified by the higher quality service that Tren Urbano will provide. However, if passengers are also required to pay an additional fare to transfer onto lower quality buses to complete their trips to points in the Santurce / Old San Juan corridor, passengers may be discouraged from taking transit altogether. Discounted or free transfers would provide an incentive for price-sensitive riders as well as rewarding those who frequently use transit. In addition, the maintenance of some redundant bus service to retain one-seat rides would help retain price sensitive riders while also attracting new riders with high quality, but higher cost, multimodal transit services.

The availability of operating funds constrains the operators' ability not only to implement bus service strategies but also to provide high levels of service. Without sufficient operating funds, the operator cannot procure buses or implement changes to the bus system to improve service quality and integration with Tren Urbano. Hence, the operator's strategic concern here is the securing of adequate funds for any future improvements in the transit system (prioritization of actions in the event of inadequate funding needs to be considered as well).

Service capacity along the bus route and at the Sagrado Corazón station is another major factor in the service strategy development process. Through an analysis of the number of peak, midday, evening and weekend period passengers transferring at the Sagrado Corazón station and the capacity of the three major trunk routes in the area (Metrobús I, Metrobús Express, A9), it was determined that to establish high levels of service and provide empty seats for the transferring passengers, empty buses need to be provided at the station. Ensuring that buses are waiting and that empty seats are provided, the passengers' transfer experience will also be greatly improved, resulting in increased willingness to ride transit.

To ensure that empty buses are available at the station, Metrobús Express needs to be terminated at the Sagrado Corazón station. The partial truncation of the Metrobús route provides the capacity and service levels required to serve the forecast number of passengers transferring during the peak and midday periods. This service strategy will displace some passengers, but they will still have other transit options available to them. More importantly, the truncation of Metrobús Express would free up a number of vehicles that could be used to match its headways with those of Tren Urbano, ensuring that an empty bus would be available to greet the transferring passengers.

Though it is possible to provide high quality service at the station by terminating only the Metrobús Express, it may also be desirable to terminate Metrobús I at Sagrado Corazón. However, the termination of Metrobús I would eliminate the Río Piedras to Sagrado Corazón segment of the route. Despite the introduction of Tren Urbano service in this

part of the corridor, many existing passengers, particularly those that have a one-seat ride from Santurce to Hato Rey, will be inconvenienced. So on opening day, rather than truncating Metrobús I immediately, it could be partially short-turned. With the partial short-turning, a Metrobús I route that runs along the entire Río Piedras to Santurce / Old San Juan corridor is alternated with a shorter Metrobús I route that serves the Old San Juan to Sagrado Corazón segment. The implementation of the short-turning strategy would retain provide one-seat rides for passengers that may be slow to adapt their travel patterns to Tren Urbano or who are severely inconvenienced by transfers (Metrobus II also service this sub-market and can mitigate this potential problem).

Once passengers have become accustomed to Tren Urbano and ridership decreases on the longer Metrobús I route, it would then be truncated at Sagrado Corazón. This would reduce the excess capacity that would otherwise exist along the Río Piedras to Sagrado Corazón segment while improving the utilization of Tren Urbano, as direct competition between Metrobús I and Tren Urbano would be eliminated. In addition, the buses freed by the truncation could simultaneously be redeployed to provide a new Sagrado Corazón to Condado service, so the customer will perceive the changes as an improvement, rather than a decrease, of service. Additionally, Metrobús II, which provides a one seat ride for the Hato Ray - Santurce market could be improved.

In conjunction with the termination of routes at Sagrado Corazón, the peak-period headways on these routes should also be increased to match the peak period headways of Tren Urbano. This will help improve the coordination with Tren Urbano during the peak periods as well as decreasing the passengers' transfer and wait times for connecting vehicles.

Time Period 3: Tren Urbano Phase IA

To determine the service strategies in Phase IA, the process of analyzing individual bus routes and the service strategies available to each of them used in the Time Period 2 analysis should also be used in this period. However, given the uncertainty that exists as

to the state of the transit system in this period, a detailed analysis cannot be conducted now. Instead, the key issues influencing the selection of service strategies, as well as the information needed to make an educated decision, are identified.

In this period, the main goal of the service strategies is to ensure that the transit system in the Santurce / Old San Juan corridor remains successful. One key objective of the strategies is to provide high quality bus services that are integrated effectively with the Minillas extension. As with the previous time period, another key objective is to introduce a high quality and convenient transfer environment this time at the Minillas extension stations. The service strategies must be designed to provide sufficient capacity at the Minillas and San Mateo stations to accommodate transferring passengers. The service strategies must also focus on providing service to new or underserved markets, such as the Isleta and Isla Grande, to make Tren Urbano more accessible to a larger base of potential riders. Maintaining high quality services to these new markets will attract potential riders onto transit, resulting in ridership growth and improved utilization of the transit system.

A preliminary analysis of the Minillas station was conducted to assess its effectiveness in accommodating transfers. From this assessment, it was found that Minillas would not be able to handle the large number of routes that might otherwise logically terminate at the station. The location of the Minillas station along the very busy Ponce de León Avenue does not provide enough space to implement many major layout changes or to accommodate a large number of connecting and layover vehicles. As a result, it would be preferable if the Minillas extension could reach R.H. Todd, with Parada 18 available nearby. Otherwise, it is probably necessary to continue to use Sagrado Corazón as well as San Mateo for many of the bus/rail transfers.

The service strategies in this and previous periods must also aim to preserve any available rights of way that are currently reserved for transit services. Calle del Tren, which is currently reserved as a bus-only lane, is a very important and valuable right of way that needs to be reserved for future transit use. Many improvements in the bus system, such

as new routes along the Isleta or bus rapid transit between Tren Urbano and Old San Juan, might benefit from use of the reserved bus lane. Developing exclusive lanes in the rebuilt bridge connecting to the Isleta can improve bus service quality and reduce cost. Furthermore, the preservation of Calle del Tren would also facilitate the potential extension of Tren Urbano to Old San Juan by providing a logical new right of way.

The first step in selecting the service strategies for this period is to identify the routes and service markets that would be affected by the Minillas extension. Given the planned location of the Minillas station, the major trunk routes that would be affected are: A5, A9, Metrobús I and Metrobús II. For each of these bus routes, the (future) service characteristics (ridership, cost-effectiveness, service reliability, resources required, and levels of service) would need to be identified.

Because of the limitations of the Minillas station, it is important that the extension of Tren Urbano to the R.H. Todd station, adjacent to Parada 18, be pursued. This extension would provide the intermodal facilities necessary for the integration of bus service in the northern Santurce corridor. If the further extension of Tren Urbano is not anticipated in the immediate future, bus service modifications will still be needed at the Minillas and San Mateo stations and some service will still need to be maintained at Sagrado Corazón.

However, it is suggested that the operator develop a detailed data gathering strategy and process to ensure that the information required for the analysis is obtained. Other information, such as customer attitudes and reactions to service changes, will also provide insight on the effects of implementing various service strategies. Obtaining as much information as possible will be helpful later when the analysis and selection of the best bus service strategies to further public transport in the Santurce / Old San Juan corridor with a combination of the bus system and Tren Urbano.

6.3 Areas for Further Research

This thesis has touched upon a number of issues related to the planning of bus service in the Santurce / Old San Juan corridor. There clearly exists a need to explore many of these issues in greater depth. The following list highlights potential areas for further research:

- Transfers will be a key component of the intermodal transit system in the Santurce / Old San Juan corridor. To improve the development and analysis of alternative service strategies for future phases of Tren Urbano, further research is needed to quantify the impacts of transfers. The penalty perceived by the passengers needs to be better understood so that strategies to improve passenger satisfaction with the transit system can be developed. Specifically, transfer impedance includes the perceived penalty of the act of transferring, the time spent during the transfer, and the penalty associated with the monetary cost of transferring. This thesis has attempted to develop service strategies to minimize the potential impacts of each of these components. Further research on the relationships among these three elements and their impacts on passenger behavior will help to plan service strategies that minimize the transfer penalty.

- Using San Juan specific data, develop a passenger utility function that is representative of the San Juan environment. As discussed in Chapter 2, a utility function is a useful step in defining the likelihood a passenger will use transit. The studies reviewed in Appendix A indicated that there are varying weights associated with different aspects of a passengers' trip on transit. However, of the studies reviewed, none are specific to the San Juan case. In San Juan, the inconvenience of the transfer may be exacerbated by climate and culture. Improved understanding of the penalties associated with each aspect of a passenger's trip (i.e. waiting time, transfer time, in-vehicle travel time, travel cost) will help in the formulation of service strategies to improve the passengers' convenience and increase the transit system ridership. There are opportunities to

perform surveys and analyses of the behavior of existing riders, new riders, and those who will not switch to transit to determine what drivers influence their decision to take or refuse to take transit. More importantly, understanding user behavior will help to determine the impacts of transfers and the severity of the transfer penalty on the residents of the SJMA.

- The period after the opening of Tren Urbano to Sagrado Corazón, if some Metrobús I service continues to Río Piedras, presents a good opportunity to estimate the transfer penalties by observing passenger behavior and distinguishing between: transfer averse customers, who continue to use the bus service, and transfer insensitive, who will shift to Tren Urbano. This opportunity to observe passenger behavior and estimate the transfer penalty will be very useful when future planning transit service strategies.

- An analysis of the costs and benefits of the implementation of AVL technology on bus and rail systems and their impacts on the successful integration and coordination of intermodal service in the SJMA is another area where further work will benefit the service providers. AVL systems can help anticipate and overcome any delays or problems in service to maintain service reliability and schedule adherence. AVL technology can allow the operator to better control operations and execute intermodal transfers, resulting in increased passenger level of service (i.e. decreased transfer and wait times). Additionally, the real-time information provided by AVL systems can improve the transfer experience by helping to reduce the uncertainties associated with the act of transferring.

- Further research on the San Juan institutional environment in terms of influences on decision-making for Tren Urbano and bus services will help to determine the obstacles that must be overcome in order to implement high quality service strategies. In addition, a better understanding of the institutional drivers and influences will help to identify approaches to deal with conflicts that may arise

when attempting to coordinate the AMA, Metrobús, jitney and Tren Urbano services.

- After Phases I and IA of Tren Urbano are complete, there are proposals to extend rail service to other parts of the SJMA, including Carolina, the Airport, and Caguas, as well as to Old San Juan. Improvements in the bus services from these areas to Tren Urbano can begin to develop stronger ridership in these areas, and to help determine priorities for future extensions. Further research is needed to determine the impacts of these extensions on bus service in the respective areas as well as what service strategies should be implemented to maximize the use of these extensions and ensure that they will be successful in serving and attracting riders.

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Appendix A. Transfer Penalty Review

The transfer penalty to transit riders has long been recognized as an important consideration in service design and the performance of a transit system. The use of transfers in the design of transit services provides more options for the transit operator in terms of area coverage, resource allocation, and flexibility, resulting in better overall service. The existence of a transfer penalty has broad implications for transit route planning, specifically, and for transportation system evaluation, more generally (Horowitz, 1981). That is, the design of transit services and transfer facilities is important in helping to reduce any negative impacts on the passenger that are associated with the transfer. Hence, in order to identify the combination of transit services that provides the most effective service to customers, it is necessary to obtain an accurate assessment and understanding of the perceived penalties associated with intermodal transfers.

Little is known about the characteristics of transfers, intermodal transfers, or travel impediments caused by transfers. One reason behind this is that the perceived transfer penalty varies by the individual user and transit system (Liu, 1996). Yet, there are some factors known to affect the severity of the transfer penalty. These factors include the ease of transfer, comfort, convenience, safety, seat availability, trip length, group size, fare technology, luggage issues, and protected versus unprotected transfer environment.

There have been a number of studies on the transfers and their associated penalties. There is a consensus that transfers are necessary to provide more service options to the passenger, and can result in better service overall. In addition, all the studies identify that when transfers are planned correctly, the resistance for transferring passengers can be easily outweighed by the benefits transfers bring with respect to routes, schedules, and in better services offered.

Alger, Hansen, and Tegner (1975) studied the role of waiting time, travel comfort, and convenience on commuters' modal choices. Unlike previous studies that focused

primarily on the impacts of travel time and costs, this study also emphasized the impacts of changes in comfort and convenience variables- such as waiting time, the number of transfers and the ability to get a seat- on user behavior. In calibrating their model, Alger, et. al. used survey data for commuter trips obtained in the Stockholm metropolitan area in 1968 and 1971.

The results of the Alger, et. al. study was value of time equivalents for the inconveniences of various types of transfers (Table A-1). According to the authors, the transfer penalty associated with the combinations of bus plus several rail modes or underground plus several bus routes was the most reliable transfer penalty. The comfort value associated with these transfers should be interpreted as reflecting either feeder bus or rail transfers in suburban areas, or city bus or rail transfers in the inner city.

Table A-1. Transfer Comfort Values

Type of Transit Transfer	Cost per Transfer (Swedish Kr) 1 Kr=0.116 USD	Line-Haul Time Equivalent per Transfer (min.)
Subway-to-subway	0.31	4.4
Rail-to-rail	1.03	14.8
Bus-to-rail	1.60	23.0
Bus-to-bus	3.44	49.5
Other transit combinations	2.14	30.8

Source: Alger, Hansen, and Tegner (1975)

Alger, et. al. also identified that the range of waiting time during transfers depends on the level of service of the transit system in terms of transit headway. Higher frequency services would result in a lower variation of transfer waiting times, and lower frequency services result in larger ranges of waiting time. Hence, a higher frequency service will decrease waiting times, resulting in a decreased transfer penalty. However, the waiting time used in the calculations of transfer penalties was based on a hypothetical situation rather than real data, which weakens the results of the study (Horowitz, 1984, Liu, 1996). In addition, since the authors did not identify an independent transfer penalty when calculating the transfer waiting times, the weights of the wait times may be overestimated.

Alger, et. al. (1975) noted that the distance and difference in the physical convenience level between rail station platforms and feeder bus stops are considerable. The convenience level of transfers between different underground lines is very high compared to the other transfers they reviewed. In Stockholm, transfers between rail modes always take place in a sheltered location where passengers can transfer by walking across a platform or by using elevators or escalators. In addition, passenger convenience is also enhanced since they are protected from the weather and can use other conveniences such as kiosks and shops.

However, the feeder bus transfers are valued to a lesser extent. Alger, et. al. found that transfers between different bus lines take place at bus stops that have fewer conveniences compared with commuter train and underground stations that are equipped with shelters and other convenience facilities. Also, the values of transfer discomfort also reflected the time spent walking to and waiting for transit. Since the buses generally operate less frequently than the subway, the time spent waiting for a transfer is, on average, higher for the bus than for the subway.

Yet, Alger, et. al. remain unclear about other reasons behind the high discomfort associated with the non-subway-to-subway transfers. One of the most important factors is the cost of the transfer. Subway-to-subway transfers are typically free, but the study did not identify whether the intermodal transfers were free and the results do not consider this. In addition, other transfer station characteristics such as safety, security and the presence of sheltered waiting areas were not evaluated.

A study of bus riders in Taipei, Taiwan conducted by Han (1987) identified the presence and impacts of an independent transfer penalty. This study was conducted in the context of path choice rather than mode choice, and strictly focused on the transfer penalty associated with bus-to-bus transfers. At that time, the bus system in Taipei was the most important mode of public transportation, carrying forty percent of the total daily passenger trips generated in the metropolitan area.

Han's study collected actual time data on the walking, waiting, and in-vehicle times of a random sample of 1850 bus riders. Of these riders, 327 responded with complete surveys, and the results were used to calibrate the demand model. Travel time, costs, and transfer dummy variables used in the model represented the disutility associated with travel on a given path. Han evaluated the transfer penalty that represented the bus-to-bus transfer inconvenience independently of the overall waiting time, which also included transfer waiting time.

From the results of the model calibration (Table A-2), the relative importance of the transfer penalty and other related factors were determined. Han found that the disutility of one bus-to-bus transfer perceived by a transit user in Taipei was equivalent to 30 minutes of in-vehicle travel time, or 10 minutes of waiting at a bus stop, or 5 minutes of walk time. Han suggests that the values determined from the model indicate that transit planners often underestimate the transfer penalty to bus riders. Thus, an optimal transit network structure requires much more coordination and planning than planners have traditionally provided.

Table A-2. Assessment Results for Taipei Bus Riders

Attribute / Value	In-Vehicle Time (min.)	Wait Time (min.)	Walk Time (min.)	Bus Fare (N.T. Dollar)	Transfer Penalty (util)
Estimate of Coefficient (util)	-0.020	-0.059	-0.121	-0.134	-0.600
Money Equivalency (N.T. Dollar)	0.15	0.44	0.90	1.00	4.48
In-Bus Travel Time Equivalent (min.)	1.00	2.95	6.05	6.70	30.00
Wait Time Equivalent (min.)	0.34	1.00	2.05	2.27	10.17
Walk time Equivalent (min.)	0.16	0.49	1.00	1.11	4.96

Source: Han (1987)

From the table, one can see that the values of walk time and wait time are six and three times the value of in-vehicle travel time, respectively. Han suggests that the overestimated value of walk time implies that pedestrians in Taipei are experiencing significant inconvenience or unpleasantness when walking on the streets due to the lack of adequate walking space and the physical obstructions caused by merchants and

motorcycles. In addition, the design of the traffic signals and signs emphasize vehicular traffic but ignore pedestrian traffic.

Han identifies a preference for passengers to board the first available bus, even if that would require a subsequent transfer en route. This result implies that when the capacity of a system is insufficient to handle the demand, bus riders are more concerned about getting on a bus than about minimizing the number of transfers. Hence, in this scenario, comfort is sacrificed in order to ride the bus. However, according to Han, the results and implications of his assessment may not apply to transit systems in North America due to their relatively low volume to capacity ratios. In North America, though the general volume to capacity ratio may be low, increased crowding on buses is a significant detractor for those transferring to another route, and it decreases the attractiveness of transit.

Han does not make clear the characteristics of the major transfer centers within the city. He does speculate that the high penalties that he observed were partly due to passenger inconvenience while on the streets. The various obstacles that line the typically narrow sidewalk make it difficult for pedestrians to move about. In addition, the congestion levels of the roadways make it unpleasant for pedestrians standing at bus stops.

However, Han fails to address other aspects of the facility, such as its location, the appearance and design of the waiting areas, whether the passengers are sheltered, and if the riders perceive the facility as safe and secure. In addition, Han does not address the fact that Taipei's lack of free transfers contributes to the high transfer penalty. His study, however, shows that bus fare has a negative influence on the utility of a chosen path.

Hunt (1990) performed a study centered on the estimation of a logit model of public transportation route choice behavior using data from commuters in Edmonton, Canada. 1,702 individuals employed by 80 different employers located in the CBD of Edmonton were interviewed to identify various aspects of their morning journey to work. Of these individuals, 834 used public transportation. Using the data from the interviews, Hunt

formulated a route choice model that included such variables as the walking distance to a stop, the wait time for a transfer, and the number of transfers along a given route.

The results of his "best" model estimation are shown in Table A-3. From these results, we can see that among bus riders in Edmonton, Canada, the impact of a transfer is equal to 17.9 minutes of in-vehicle time, independent of the time spent waiting for the transfer. The fit of the model was better when the influence of transfers was represented using the number of transfers rather than the total time spent waiting when making transfers. One reason behind this is the imprecision of waiting time estimates, while the number of transfers is easily measured. Other than this issue, the results show that the act of transferring accounts for most of the transfer penalty, while waiting time does not play a large role.

Table A-3. Model Estimation Results for Edmonton Transit Riders

Variable	Coefficients	Significance (w.r.t IVT)
Constant	-0.00634	0.0401
Walking distance to the Stop	1.00	7.33
Number of transfers	-2.83	17.9
Total in-vehicle riding time	-0.158	1.00
Time between successive opportunities for making the trip	-0.600	3.80
Walking distance to the Alighting Stop	-0.00335	0.0212

Source: Hunt (1990)

Though Hunt identifies the presence of a transfer penalty, he does not go into any detail about the transfer environment. One important component that Hunt left out of his model estimation was the monetary cost of transferring. He states that the influence of fare could not be considered because the fare structure was such that alternatives with different fares were never included together in an observation. At present, Edmonton provides free transfers, using a receipt, within ninety minutes of paying a fare. However, Hunt is not clear as to whether this policy was in place at the time of his study.

Hunt also neglects to discuss the other components of the transfer environment. It is unknown whether passengers transferring between the buses and Metro had to endure

lengthy walks and waits. Also unclear is whether the passengers perceive the station to be safe or comfortable.

Liu (1996) also recognized that the presence of the transfer and the transfer wait time are independent. She studied the impacts of the disutility of intermodal transfers on passenger mode choice decisions in different transfer situations. A major component of her study focused on the following three hypotheses:

1. The transfer penalty has two components; one is associated with transfer time and the other is independent of transfer time.
2. The value of the transfer penalty is different from the transit headway (when transfer penalty is equal to the headway, it implies that when the waiting time is assumed to be half the headway, the penalty weighting factor is close to two).
3. The values of transfer penalties vary depending on different modal combinations.

The results of Liu's model showed that in general, one transfer was equivalent to approximately eight minutes of in-vehicle travel time or 4.75 minutes of out of vehicle travel time (which includes wait and walking time). The results also showed that transfer penalties varied depending on the type of transfer. The intermodal transfer has a more negative impact on the utility of a mode when compared to an intramodal transfer. Table A-4 shows the transfer penalties associated with two types of transfers: intermodal (auto-to-rail) and intramodal (rail-to-rail).

Table A-4. Intermodal and Intramodal Transfer Penalties

Penalty	General Transit	Auto-to-Rail	Rail-to-rail
IVTT per transfer	8.00	14.97	1.41
OVTT per transfer	4.75	8.85	0.835

Source: Liu (1997)

The results of Liu's study found that the transfer penalty associated with auto-to-rail transfers is higher than with rail-to rail transfers. This is believable since auto-to-rail transfers can be quite inconvenient, as passengers are required to find a parking space, walk from the lot to the station, purchase a ticket, and wait for the train to arrive. In addition, the convenience of the automobile is greater than that of transit, and users may

be reluctant to abandon it, adding to the transfer penalty. In contrast, rail-to-rail transfers occur within a connected rail network, so no new tickets need to be purchased (and transfers are typically free), the waiting areas are often protected from bad weather, and walking distances between platforms is relatively short.

In her thesis, Liu (1996) did not specifically describe the transfer environments that users experienced. However, many of those surveyed did express concern about security and safety, in terms of lighting and patrolling, at the stations. In addition, the overall impression of the results of those surveyed was that the security of the transfer environment and the reliability of connections seemed more important than the length of walk between vehicles, so long as the walk was reasonably short. Yet, the other characteristics of the transfer environment, particularly for bus-rail transfers, remain unclear. From the results of the study, it appears that most of the intermodal transfers were not free, but the impacts on the transfer penalty were not addressed. The levels of service of the feeder routes were also unknown, so the issues of coordination of services were not addressed. The comfort and convenience of the station areas were also ignored.

Liu does suggest some improvements to the transfer experience. In a pure transfer station or a bus stop, riders have a very small tolerance for waiting since they cannot find productive uses of the waiting time. However, if shopping, entertainment, or business activities are added to transfer stations, transfers may be utilized more productively and the perceived waiting time may be shortened. In addition, if transfer stations are built as multi-function centers, more people can make intermediate stops on their way to and from work. Hence, transfer penalties may be lowered through the more enjoyable and efficient use of transfer time.

With all these models, it is assumed that the values of in-vehicle times for all modes of transportation are considered equal. According to Horowitz (1981), the value of time spent riding in a bus is not significantly different from that spent in an automobile, as long as the vehicle remains in motion. To come to this conclusion, Horowitz examined transfer penalties associated with different service alternatives in the Chicago area.

Eighty-four Chicago residents were asked to rate the time spent on a series of common urban trips. Among these trips were several transit trips that varied in time, length, number of transfers, transfer time, waiting time, need to wait, and seat availability.

This study found that under normal conditions, passengers were indifferent between automobile and buses for trips of equal time when waiting was not required. The results demonstrated that each minute of travel time was valued the same, and that different travel time values were not the reason for poor transit usage. Rather, other factors such as transfers, waiting time, and security, may be important in the commuter mode choice.

The results of Horowitz's study show the enormous impact that transfers have on a rider's perception of transit. Yet, the numerical results of Horowitz's survey may not be completely accurate. The surveys used in Horowitz's study were structured only around bus and automobile trips, so no intermodal transfers were evaluated. There are notable differences in the utility of a bus trip versus an automobile trip, and many studies have shown that the utility provided by an automobile is much greater than that of a bus, and that it can be difficult to lure a potential rider from their automobile. As a result, in an intermodal transit system where the transfers are from one transit mode to another, there is the likelihood that the perceived disutility of an intermodal transfer will be less than what Horowitz calculated. In addition, Horowitz does not address the characteristics of the transfer environment, which also can have a large impact on the disutility of transfers.

A recent study was conducted by the Central Transportation Planning Staff (1997) to estimate the impacts of transfers on urban mode choice in the Boston region. This study looked specifically at the impacts of intermodal transfers between bus and rail systems on riders in the Boston area, and is the only study reviewed that assesses the significance of various characteristics of the transfer environment.

The results (Table A-5) from the model estimation show that there is a detectable transfer penalty for work trips in Boston. The act of transferring was equivalent to 12-15 minutes of in-vehicle riding time. There are also a number of additional findings:

1. The transfer penalty exists above the disutility associated with transfer waiting time.
2. Transfer penalties for one versus two-plus transfers are not different, indicating that regardless of the number of transfers, a user experiences a single level of disutility.
3. Transfer waiting time is more onerous that initial waiting time.
4. Transfer waiting time is over twice as onerous as in-vehicle time.

Table A-5. CTPS Model Results

Variable	Transit	Relative Importance (w.r.t. IVT)
Transfer Dummy	-0.545[a]	13
In-vehicle time	-0.042	1.0
Walk time to transit	-0.033	0.8
Initial wait time for transit	-0.055	1.3
Transfer wait time for transit	-0.100	2.2
Auto access time to transit	-0.139	3.3
Out-of-vehicle time	-	-
Transit cash fare/income	-0.828[a]	19.7
Constant	-	-
[a] Significance at 0.85 level All others significant at 0.95 level		ρ^2 w.r.t. zero = 0.6063 ρ^2 w.r.t. constants = 0.3198

Source: Modified from CTPS (1997)

Though the transfer penalty presented in the CTPS study is specific to Boston, it may also be indicative of the results that would be formed in other cities. CTPS notes that these results would be most relevant to cities with mature transit systems, congested roadways, and high downtown parking costs. In cities without a competitive transit system, the transfer penalty may be even higher.

The CTPS study also addresses the role of some characteristics of the transfer environment on transfers. Detailed descriptions of the data gathering process is provided, as well as analyses of the impacts of selected environment characteristics on transfers. However, it was found that much of the data did not provide enough information to adequately assess the impacts of many characteristics of the transfer environment on transfers, as they were found to be statistically insignificant.

CTPS tackled the issue of transfer costs by using the cash fare amount required for an entire one-way transit trip without discounts. By doing so, the impact of discounts as a confounding factor was eliminated. In the Boston area, there are no transfer costs for most rail-to-rail transfers. However, those transferring between bus and heavy rail must pay the applicable full fare. The study made no differentiation between free and paid transfers and focused strictly on the full cost of taking transit, which averaged $1.10.

Looking at transfer costs, the study did not find any penalty associated with the extra cost of transferring, nor did it provide information on whether a penalty should be associated with the cost of transferring. However, it was not clear from the data whether the results were due to no penalties associated with extra costs or whether the complexities of the transit pricing policies hid the true transfer costs. According to the study, the existence and frequent (but not universal) use of discount fares made it impossible to estimate the true cost of transferring in Boston.

The authors did identify the fact that the results were based on a transportation system with transfers that mostly occurred in sheltered locations. From the surveys, 31 percent of transit rider transfers occurred in unsheltered areas. Additionally, 73 percent of these transfers required users to traverse stairs. However, this data did not provide any information on the differences between transfer penalties associated with different types of transfers – such as sheltered vs. unsheltered areas, transfers requiring stairs, and transfers between different sub-mode pairs (bus-to-bus vs. bus-to-rail) – since the results were found to be statistically insignificant.

The effect of one-way trips versus round-trips on transfer penalties was another issue that was addressed by CTPS. In the research, only trips from home-to-work and from work-to-home were used. In separating the two directions, the effects of the frequency of the service transferred to can be evaluated. There is a tendency for trips from home-to-work be from lower frequency feeder buses to higher frequency services, such as heavy rail, and this was thought to have a possible impact on the transfer penalty. The results of one model estimate showed that the transfer dummy coefficient in the attraction-to-

production (work-to-home) direction is significant and is of much greater magnitude than in any of the other models that were estimated. In addition, the total average transfer wait time was 44 percent greater in the attraction-to-production direction. The results do show that transferring to lower frequency services has an impact on the transfer penalty. Despite the results, the authors concluded that the estimation of mode choice models should not be based on one-way trips unless the reverse trip is also included, hence averaging the total passenger impedance.

The CTPS study identified the impacts of the costs of transfers as well as the frequency of the connecting services on transfers, but does not make clear the impacts of other characteristics of the transfer environment. The issue of a sheltered transfer area was discussed, but the impacts were not significant. The safety and security of the transfer areas was not taken into account. The comfort and convenience characteristics of the station areas were not detailed, neither were the distances between modes in intermodal transfer facilities.

In summary, all of these studies identify that the presence of a transfer imposes a penalty on the passengers that negatively impacts their willingness to take transit. Table A-6 summarizes the estimated transfer penalties from a number of studies that have attempted to quantify the act of transferring. Yet, the transfer, however inconvenient to the user, is a necessity in order for transit operators to effectively serve a large metropolitan region. However, there is also pressure on transit operators to maintain or increase ridership numbers, which may not be possible with a system whose users experience high transfer penalties.

Table A-6. Independent Transfer Penalty Equivalency

Study / City	Author	Type of Transfers	Equivalent Minutes of:	
			IVTT	OVTT
Honolulu	CTS	Bus-Bus	--	2.3
Chicago	Horowitz	Bus-Bus	18-37	--
Ottawa	Kain	Bus-Bus	--	8-12
Edmonton	Vaga & Shortreed	Bus-Rail	--	5-10
Edmonton	Hunt	Bus-Rail	18	--
Taipei	Han	Bus-Bus	30	5-10
Boston	CRA	Bus-rail	--	6-11
Boston	CTPS	All Trips	12-15	--
Houston	Brand	All Trips	15-20	--
Attica, Greece	Spanos, et.al.	All Trips	10	--
NY-NJ	Liu	All Trips	8	4.75

Source: Modified from Liu (1996)

There are two approaches to reduce transfer penalties: reduce the number of transfers or minimize penalties associated with each transfer. The first approach implies the elimination of transfers, which in an intermodal transportation system may limit the extent of the services provided. In a transit agency introducing a rail system with service structured around transfer centers, which is the case in San Juan, the elimination of transfers is not feasible. Rather, in the case of San Juan, since transfers are a necessity, the focus of the transit agency should be on the second approach- reducing the penalties associated with the transfer process. One method of reducing the penalties is to ensure that high quality services are provided. Another method is to ensure that the environment within which the transfer takes place is friendly and convenient. Changes to improve the transfer environment may reduce the penalty, making the system much easier to use and possibly resulting in an increase in overall ridership.

Few of the studies reviewed above mention, let alone measure, various characteristics of the transfer environment. From the studies that do, a number of characteristics have been identified as having some impact on the disutility of transfers. Long walking distances between modes, as well as wait times due to lower frequency connections have a role in influencing the disutility of transfers. Safety and security of a station is also important in determining the attractiveness of a transfer and transfer station. The use of free or discounted transfers is also a factor in determining the transfer penalty. Also, station

amenities that increase the comfort and convenience of transferring passengers also has an impact on willingness to transfer, though specific impacts have not been quantified. However, some issues, including crowding in waiting and platform areas, level changes, sheltered areas, and station design, were not discussed and the impacts remain unclear.