# Procurement of Backup Energy Supplies for Mass Transit: Tren Urbano, A Case Study

by

Dhaya Lakshminarayanan

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

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# Abstract

This thesis embodies the results of extensive research and analysis on options and strategies for procuring backup energy supplies for the Tren Urbano, an urban heavy rail transit system under construction in San Juan, Puerto Rico. The Tren Urbano is designated as a Federal Transit Administration demonstration project because of the unique private role of the private sector in the design, construction, operations, and maintenance. The Tren Urbano is seen as a solution to the increasing traffic congestion and current lack of reliable public transportation in San Juan. The success of Tren Urbano will depend on a high degree of acceptance and usage by riders. Historically, Puerto Rico has suffered prolonged and frequent power outages due to extreme weather, a large demand on the island's isolated power grid, and reliance on a single power producing authority. Power disruptions will jeopardize public safety if passengers are stranded; loss of service and delays will compromise the public image of the train system. Therefore, reliable and adequate power supply is essential in ensuring Tren Urbano's reliability, safety, and positive public perception. This study addresses the critical need for backup power for TU, using as its starting point earlier engineering requirements which recommends 20 MW backup power split between two key locations.

The thesis discusses procurement options in general and then presents case studies of organizations from which the Tren Urbano Organization can draw valuable lessons about procuring backup power. A decision tree is derived by carefully analyzing and critically assessing various options open to Tren Urbano. A time line is developed for evaluating these options. From this study, two options emerge: 1) to go out and solicit bids for a backup power system using one of the following delivery methods: Design-Build/Turnkey or Design-Build-Operate/Design-Build-Operate-Maintain 2) to provide the backup power through a Siemens change order. Option 1 has the potential of saving 10 million dollars for the Tren Urbano Organization.

This study takes into account legal, political, and technical issues. It is applicable even under possible departure from current engineering requirements, and as such provides the Tren Urbano Organization with an extremely useful and flexible decision-making template.

Thesis supervisor: Paul F. Levy
Title: Adjunct Professor of Environmental Policy

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# Chapter 1: Introduction

The main objective of this work is to recommend viable options and effective strategies for the procurement of backup energy supplies for mass transit. These options and strategies are presented in the context of the Tren Urbano, a heavy rail transit project under construction in San Juan, Puerto Rico. The specific objectives of this work are to:

1. Review the need for backup power for the Tren Urbano system.
2. Study other relevant organizations and analyze their strategies in procuring main or auxiliary power.
3. Identify key lessons learned from these organizations.
4. Propose options for the procurement of a backup energy supplies for Tren Urbano.
5. Critically assess the viability of these options.
6. Develop a timeline for evaluating various procurement options.
7. Examine options that comply with time constraints and schedule requirements.
8. Recommend a negotiation strategy for the most viable procurement options.

Although the above topics are specific to the Tren Urbano, this study is expected to be useful to a broad audience. This study is relevant for those who wish to understand the market for backup power and how backup power may be important in infrastructure projects such as transit and wastewater, or even in commercial plants. It is also intended to stimulate a thought process for those wishing to explore the legal, political, and engineering issues associated with procuring power in the current competitive and technologically advanced marketplace.

This chapter provides background on Puerto Rico and the Tren Urbano project and outlines the goals of this study. Section 1.1 describes the current transportation situation in Puerto Rico, the need for Tren Urbano, the procurement of the Tren Urbano project, and Phase I of the project. Section 1.2 discuses the reliability of the Puerto Rican electric power supply while section 1.3 brings out the compelling need for a reliable backup power supply for Tren Urbano. Section 1.4 states the problem studied and methodology used to solve the problem and also presents an outline of the rest of the thesis. Section 1.5 summarizes key points of the chapter.

## 1.1 Background

### *1.1.1 Urbanization and Traffic in Puerto Rico*

Puerto Rico lies 1,600 kilometers southeast of Miami, Florida (Figure 1.1). It is a self-governing commonwealth of the United States, influenced by Spanish models (commercial codes and language). It has been under U.S. law for the most part since becoming the Commonwealth of Puerto Rico in 1952. The island has a population of 3.6 million in a land area of 8,959 square kilometers (less than half the size of Massachusetts). Because Puerto Rico is surrounded by water, (precluding any possible expansion) and its population is growing, the island becomes more densely populated each year. The capital, San Juan, and its surrounding area make up the San Juan Metropolitan Area (SJMA). SJMA boasts the most densely populated region of Puerto Rico with a population of 1.3 million in an area of 1,020 square kilometers.[1] "San Juan has some of the highest population densities in the United States. The regional average of 3,230 persons per square mile places it within the top 15 most densely-populated regions in the nation."[2]

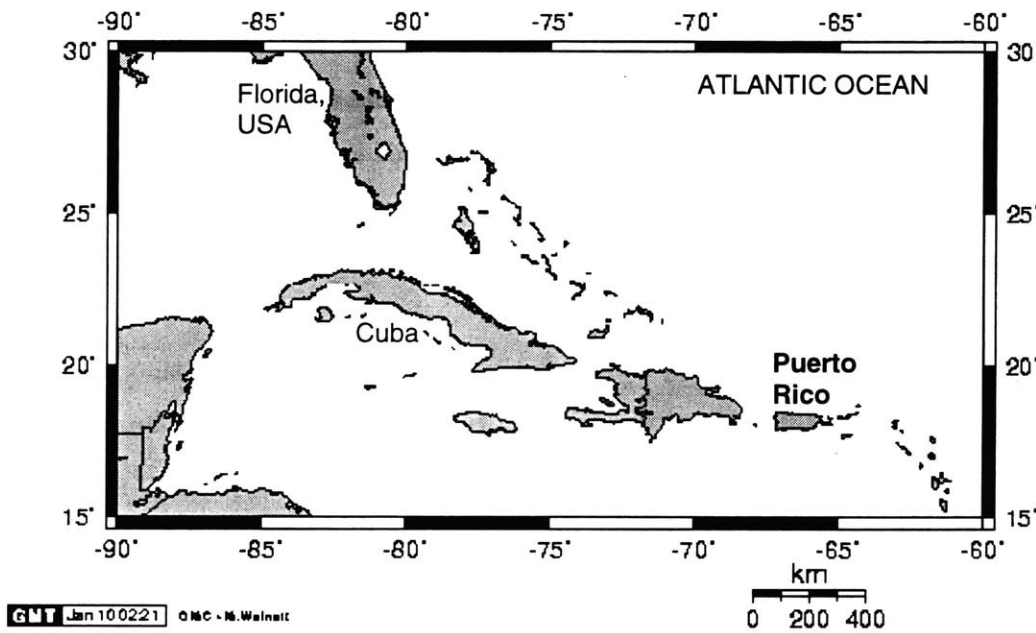


**Figure 1.1: Location of Puerto Rico[3]**

Since World War II, San Juan's population as well as economy have grown. San Juan is an economic center for the pharmaceutical, textile, manufacturing, and electronics industries. The job opportunities concentrated in San Juan represent 63% of the employment in the region.[4] Puerto Rican residents commute into San Juan to work in these industries, stressing the limits of the urban area. Economic growth since World War II has placed an enormous burden on the highway and transit infrastructure, particularly in the San Juan metropolitan area.[5] Due to this economic growth (and a lack of an effective alternative to commuting by car), there are now 4,286 vehicles per square mile in SJMA.[6] There are 4.65 million daily trips in the San Juan metropolitan area alone.[7] The average daily trip rate per capita for San Juan has risen from 1.62 in 1964 to 2.47 in 1990, and it is projected to increase to 3.0 trips per person per day by 2010.[8] With the total regional travel expected to grow by 45% between 1990 and 2010, the city will become more congested and roads and highways will be further stressed unless major transportation investments are made.[9]

### *1.1.2 Public Transportation in San Juan*

To date, numerous public transit systems have been largely ineffective at providing effective public transportation, creating the dependence on the automobile. The Department of Transportation and Public Works has overseen the operation of the Autoridad Metropolitana de Autobuses (AMA) bus system and the ferry system.[10] Metrobus is a privately operated bus transit system and Publicos are private van services.

> However, Publicos and local bus services have suffered from declining patronage in the past decade largely because these vehicles operate in mixed-traffic lanes and, therefore, are constrained by the same congestion bottlenecks as private automobiles. Even Metrobus service, a privately-operated system under contract to the metropolitan bus authority (MBA), which offers significantly higher quality service to the use of exclusive contraflow lanes, suffers from the large number of congested intersections and cannot offer a level of service superior to the private automobile for longer trips... Therefore, simply increasing the levels of at-grade bus service is not expected to improve travel times and reliability in high demand travel corridors.[11]

A history of a lack of effective alternatives available to travelers in SJMA has kept hopes and plans for a heavy rail transit system alive in Puerto Rico for the past 30 years. The idea of a heavy rail system was first mentioned in the San Juan Metropolitan plan in the late 1960's and continued to be an ambitious idea in planning studies until the San Juan Regional Plan in 1993, from which plans for the Tren Urbano were developed.[12]

Until recently, political divisions have kept a heavy rail transit system from being realized. Puerto Rico has a non-voting member of Congress and thus has limited political power to acquire federal funding and support. Puerto Rico does have a governor, but in the past, governors who were interested in such a project have left office before generating political capital for the project. Typically, any progress that had been made was then undone by the new administration.

### *1.1.3 Creation of the Tren Urbano Project: Hybrid Turnkey Procurement*

Finally, in the early 1990's, Governor Pedro Rosello put together a team of people to write an environmental impact statement (EIS) and apply for federal funding for an urban transit system, the Tren Urbano. The Puerto Rico Highway Authority (PRHTA) then created the Tren Urbano Organization (TUO). As the "owner", PRHTA hired the General Management Architecture and Engineer Consultants (GMAEC) to serve as a conglomerate of consulting companies to the TUO. GMAEC consists of many consultants, but four major consulting companies: Frederic R. Harris Inc. (a Boston-based internationally recognized firm with expertise in transportation infrastructure); Daniel, Mann, Johnson, and Mendenhall (a Los Angeles-based firm specializing in project management of large rail transit projects); Eduardo Molinari and Associates (a San Juan based architectural firm); and Barrett and Hale (a San Juan based engineering firm).[13] The final EIS and record of decision in mid 1996 cleared the path for the start of construction.[14]

Although the Department of Transportation and Public Works had demonstrated the capacity to manage "large-scale civil works projects", including toll roads, bridges and tunnels, through "privatization", there was no existing expertise in designing or building rail transit. In addition, the necessary experience for operation and management of a rail system in Puerto Rico was not available.[15] Rosello's administration also sought to "bid out" a majority of the construction contracts before the next election, in case an upset would undo the work of the Rosello administration. The contractual agreements would then bind the next governor to proceed with construction.

Thus, TUO in collaboration with its consultants developed a plan to incorporate private sector involvement as a crucial part of the Tren Urbano project. The proposed 17.2

km alignment of the train (Phase I) was divided into 7 sections. One segment (the test track) was awarded to Siemens as a Design-Build contract, along with the contract for design, construction, operations, and maintenance of the entire project (vehicles, tracks, control center, power).[16] The Notice to Proceed was given in August of 1996.[17] This contract is called the Siemens Systems Test Track Turnkey (STTT) contract and covers system design, construction, and operation and maintenance for 5 years with an option of 5 additional years for operation and maintenance. Siemens is responsible for the test track and also for the systems of the entire project. The Siemens Transit Team (STT) also assists in the management of the other six sections.

The remaining 6 sections of the alignment were awarded to 4 local contractors on a Design-Build (DB) basis. The Notices to Proceed were given between September 1996 and June 1997.[18] The local private contractors would perform the functions of both designer and construction contractor for the alignment sections. Although the systems contract was awarded to a multinational with significant transit construction, operation, and maintenance experience, local contractors were chosen to complete the actual alignment sections. The purpose of choosing local Design-Build alignment contractors was to develop a cadre of experienced native companies, professionals, and technicians. These experts would remain on the island and share the technological, administrative, financial, environmental, legal, and procedural expertise within Puerto Rico and throughout Latin America after the project was completed. It was important that the experts would remain in Puerto Rico to be able to continue designing, constructing, operating, and maintaining parts of the Tren Urbano. The alternative would be to choose non-native companies that would take the expertise away from the island.[19]

Tren Urbano is unique since federal construction projects have traditionally been procured through the Design-Bid-Build (DBB) process, which forces a separate bidding process for both design and build. This strategy was legislated by the Brooks Act of 1972[20] and is now the most common procurement method in the United States. In DBB, one contractor is responsible for design, and after the completion of design, the owner conducts a bidding process to select the lowest cost construction contractor. However, Puerto Rico is not a U.S. state, and has used alternate methods in delivering infrastructure. (The Tedoro

Moscoso Bridge was procured using a Build-Operate-Transfer delivery method.)[21] In awarding alignment sections the PRHTA chose a DB over DBB as DB would allow for faster completion of the alignment sections as well as integration of design and construction. This would ensure contractors took more care in design and more responsibility for the construction to actually meet the design.

The procurement strategy chosen for the systems was a hybrid: partially a Design-Build-Operate-Maintain (DBOM) and partially a turnkey procurement. Turnkey is unique in the United States where Design-Bid-Build is the norm. Turnkey is much like a Design-Build except that the contractor holds full title until the "keys" are turned over to the owner. The owner in this case is the Puerto Rican government.

The PRHTA chose this approach because federal funding was available to several federal turnkey demonstration projects. In 1993 the federal transit administration designated Tren Urbano as one of four turnkey demonstration projects in the United States. [22] Tren Urbano was able to use federal funds in this non-traditional procurement as part of a federal study on alternative procurement options. As mentioned earlier, the systems procurement is partially a DBOM. The PRHTA wanted a private sector involvement in operations and maintenance as well as a design and construction, at least for five years after the opening of phase 1. This DBOM approach would not divert staff or funds from the PRHTA. This approach would also allow experienced private sector firms to make Tren Urbano success. Thus, the overall procurement strategy is a hybrid.

The Procurement strategy for the Tren Urbano is thus a mix between Turnkey, DBOM, and DB. The rationale was laid out in a procurement strategy paper during the initial conception of the project.

> For the hybrid approach, there may be better opportunity to accelerate the schedule for starting construction by dividing the procurement into separate design-build turnkey packages... Hybrid turnkey with multiple packages may be a better way to reach the policy objectives for technology transfer and provides better arrangement for owner control of community and politically sensitive decisions.[23]

The local DB contractors have the chance to develop expertise and can benefit the island with this expertise in the future. The private systems contractor would be able to deliver operation and maintenance in addition to the system itself. The project would be able to be delivered at a fast-paced schedule because of the unique approaches. Lastly, the owner does not have to devote its own staff or funds to an expensive and human capital intensive project.

### *1.1.4 Tren Urbano Phase I Operation*

The 1.5 billion dollar Phase I of this uniquely procured project is scheduled to open in November of 2001 with 17.2 kilometers of track running from Santurce southward and west to Bayamon in a backward "L" formation, connecting 15 stations (Figure 1.2). For Phase I, 60% of the train is elevated; 30% is at grade; and 10% is below grade.


**Figure 1.2: Alignment of Phase I of Tren Urbano**

The goals and features of Phase I can be summarized as:

- Trains operating 20 hours per day
- Headway ranging from 4 to 12 minutes with maximum speed to 55 mph
- Capacity from 72 to 181 passengers per car
- 64-74 total cars
- Service to an estimated 115,000 travelers daily by 2010

Once Tren Urbano begins operating, the GMAEC contract estimated that there will be between 50,000 and 90,000 fewer cars on San Juan metropolitan region roads and highways and an estimated 6.5 million hours of travel saved annually.[24]

## 1.2 Reliability of Puerto Rico's Power Supply

The opening of the Tren Urbano in November 2001 will be a success if there is a strong and sustained ridership as well as a positive public perception. Ridership will be high and public perception will be positive if Tren Urbano meets its goals of reliability and consistent service.

The PRHTA and TUO face a unique challenge in maintaining a reliable transit system because of inherent problems in power distribution and supply. As a small landmass surrounded by water, Puerto Rico is isolated in terms of power production and distribution. The island is located in an area particularly susceptible to hurricanes and heavy rains which compounds the problem of delivering reliable power to businesses and residences. Puerto Rico is frequently hit with storms that leave its residents without power for hours or days at a time. The island's power reliability problems are also due in part to the monopoly of the Puerto Rico Electric Power Authority (PREPA) on the island. PREPA has very little competition on the island because it is not subject to Federal Energy Regulatory Commission (FERC) wheeling laws.[25] PREPA has invited private companies such as Enron and Kenetech to help it to provide additional power to the island. However, the companies sell power directly to PREPA and not to the customers of Puerto Rico.[26] Therefore PREPA has no competition.

Many businesses and residences have adapted to this uncertainty of power availability by installing their own personal power generators. For example, the island's major newspaper, *El Nuevo Dia*, has installed a backup generator to protect against power outages.[27]

A few companies, like Abbott pharmaceuticals, provide their own power through cogeneration plants. However, these companies must satisfy strict conditions regarding use of excess heat or steam and, even then, they can only supply power for their own facilities. Puerto Rico's constitution and its statutes make it very difficult for independent power producers or private companies interested competing against PREPA to enter the market.[28]

Figures 1.3-1.5 graphically show the history of power outages and service interruptions suffered by the PREPA system from 1992 to 1997. The information for Figures 1.3 –1.5 was obtained from the San Juan Star.[29]

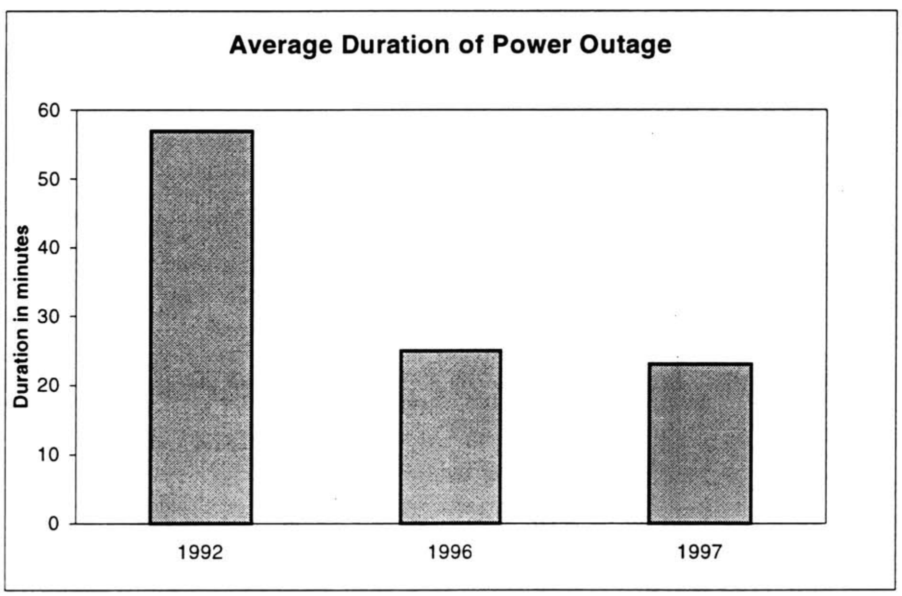


**Figure 1.3: Average Duration of Power Outages in the PREPA System, 1992-97.**

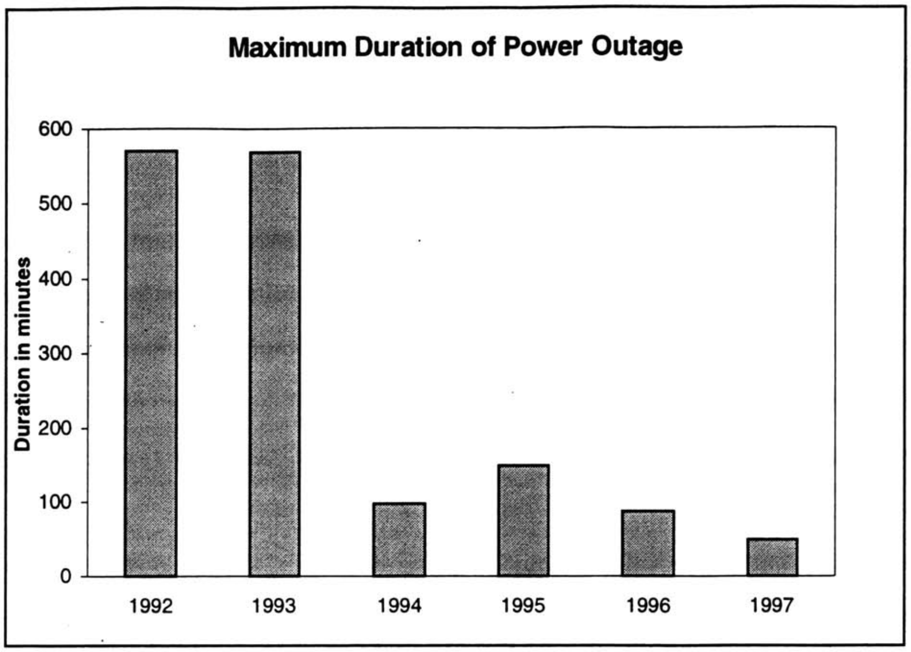


Figure 1.4: Maximum Duration of power outages in PREPA System, 1992-1997

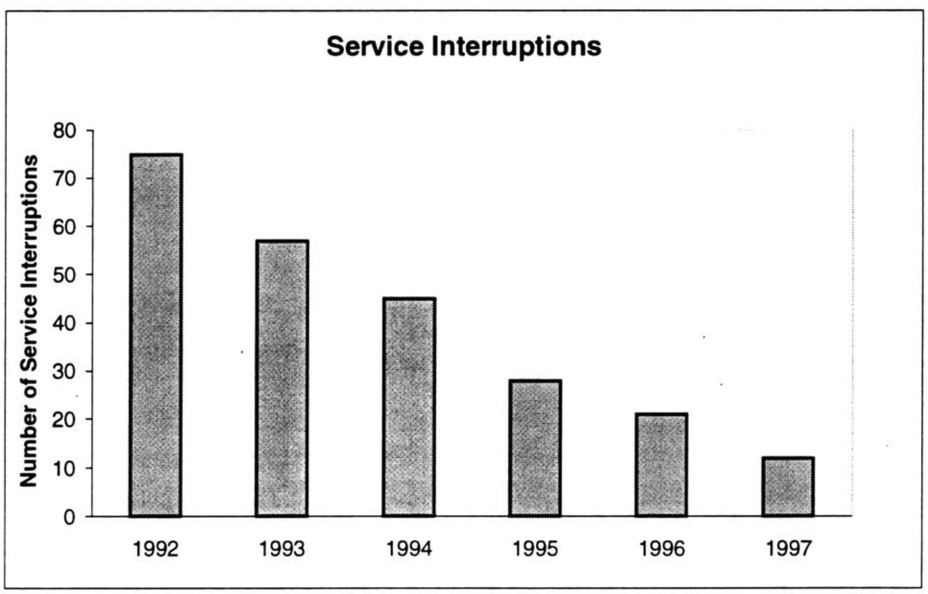


Figure 1.5: Number of Interruptions of Service in the PREPA System, 1992-1997

Figures 1.3-1.5 illustrate that PREPA has improved substantially over the past five years in terms of duration and occurrences of power outages. However, Figure 1.4 shows that an average outage could last over twenty minutes, enough to pose a health and safety threat to passengers in stalled cars. Though power interruptions are decreasing, there are still power failures that are not categorized as *interruptions*. The shorter (but still damaging) power outages are *brownouts*. "Because of growth in the San Juan area, PREPA's electric service is becoming progressively less reliable, as evidenced through frequent brownouts. PREPA is expected to have capacity shortfall problems by the opening of Tren Urbano."[30] The San Juan Star reported on this issue in January of 1998 on its front page, "PREPA May Be Unable To Meet Projected Need For Electricity In 2001."[31] It is therefore imperative that a backup power scheme is worked into the TU system before the problem manifests itself once the train is running.

## 1.3 F. R. Harris Report on Tren Urbano Power Supply

This thesis represents a second stage of a process. Frederic R. Harris Inc., consultant to the TUO , has worked on the problem of Puerto Rico's power reliability as linked to Tren Urbano's service reliability. When this thesis was conceived, it was intended to analyze Puerto Rico's overall power infrastructure and its deficiencies, possibly resulting in recommendations of an engineering solution or solutions to problems that were identified. During the initial stages of this research, however, the consulting firm F. R. Harris conducted a study covering essentially the same ground. This thesis therefore turned to implementing the Harris study's central finding: that the solution to Tren Urbano's power needs is to provide 20 Megawatts of backup power in two separate locations. However, a note of caution is essential. The Harris study has serious drawbacks as a source of objective and rigorous analysis. The report does not analyze the sources of power unreliability in Puerto Rico. The report's assumption of lack of backup power goes largely unsupported by economic or engineering analysis. Also, the Harris report does not represent a definitive policy decision: ultimately the decision rests in the context of negotiations between the government, Siemens, and the Tren Urbano Organization. There is some evidence that a different course than that recommended in the Harris study will ultimately be chosen by the Tren Urbano Organization. Thus it is important to recognize that the findings of this study, while based on the assumption of a need for 20 Megawatts of backup power, may be used regardless of whether the Harris study is followed. Nonetheless, this section will review the arguments presented by F. R. Harris for acquiring 20 MW, as this thesis assumes that the 20MW recommendation is the backup supply to be procured.

The executive summary of the Frederic R. Harris report states:

> The reliability, safety and comfort of the Tren Urbano system are paramount to its success in meeting the project goals as set forth by the Puerto Rico Highway Transportation Authority. Achieving these elements, especially during emergency situations, sets positive impressions in commuters' minds that encourages them to use Tren Urbano over alternate forms of transportation, such as automobiles. Energy is a vital component in the delivery of these elements. Energy capacity shortfalls are currently being experienced in Puerto Rico. Proper availability and management of energy resources will allow Tren Urbano to overcome potential problems and take advantage of substantial opportunities. Therefore the development of an energy strategy that addresses these issues is critical.[32]

F. R. Harris recognizes the energy problems even in light of PREPA's improvements in recent years. F. R. Harris also realizes that safety, comfort, and liability are tied to energy supply for the Tren Urbano. The Siemens Systems and Test Track Turnkey (STTT) contract with the government of Puerto Rico assumes that Tren Urbano will rely on PREPA, the Puerto Rico Power Authority, for its main power supply. The contract specifies that 4 substations will connect Tren Urbano to PREPA. The contract does not specify plans for any emergency backup systems. Since Tren Urbano must have power even during an unexpected power loss from the main supply, procuring a backup system is essential.

According to F.R. Harris, "the current design does not include an emergency backup power strategy for either short or long term power outages."[33] The contract does provide for an uninterruptible power supply (UPS) for lights, controls, and ventilation. The operation/maintenance facility at Torrimar and Las Lomas will have a small emergency backup generator to provide power to the main operation control center and for restoration activities. The Harris report even goes so far as to say that under the current plan power outages will cause trains to stop, forcing stranded passengers to walk along the guideways to the nearest stations.[34] This scenario would be a public safety and public relations disaster that could turn riders away from using Tren Urbano and render it ineffective in reaching its goal of reducing traffic congestion.

The backup power needs, siting, and distribution recommended in the Harris Energy Strategy Report are 20 MW of backup power split between two sites: Sagrado Corazon and Bayamon, each containing two 5 MW generator sets. The Harris solution of 20 MW of backup energy supplies will be used in the rest of this thesis when discussing procurement options or the process of procuring. Although the 20MW recommendation is subject to change, and probably will, this thesis allows room for flexibility in the engineering solution. Thus the options and processes laid out in this thesis can be implemented regardless of whether the engineering solution is 20 MW, 50 MW, or a future stand-alone power plant.

## 1.4 Problem Statement and Thesis Outline

This study presents an in-depth analysis of a variety of options available for procuring a backup power system for the Tren Urbano. Detailing these options is the first step in enabling TUO to critically evaluate them and select the one that best serves the needs and requirements of the project. This study recommends options directly to the TUO although they apply as well to its umbrella organization, the PRHTA. It is likely that TUO will become a separate entity within the government of Puerto Rico. Thus, this study anticipates TUO as the decision-maker.

This thesis assumes that the backup power needs, siting, and distribution are as recommended in the Harris Energy Strategy Report – namely, 20 MW of backup power split between two sites: Sagrado Corazon and Bayamon, each containing two 5 MW generator sets. The thesis will focus on the procurement aspects, constraints, and practicality of various procurement options and possible negotiation strategies for implementing viable options. The analysis process will be graphically represented in a decision tree diagram, which will be used to develop a suggested schedule and time line for incorporating procurement of backup power. The methodology adopted is independent of the specific amount of power needed or the placement of the sources. In other words, *the same decision process and the same rigorous analysis can be used by the Tren Urbano Organization for backup power procurement in the event future studies result in revision of the backup power requirements.*

In particular, Chapter 2 describes the various procurement options or delivery methods that a public or private entity (i.e. "owner") has in acquiring a new facility or structure. It covers the history of procurement options, the process of choosing delivery methods, and the advantages/disadvantages of various options: Design-Bid-Build, Design-Build, Design-Build-Operate/Design-Build-Operate-Maintain, and Build-Operate-Transfer. Chapter 3 presents mini case studies of a few selected organizations in North America, which have their own main or backup facilities. The organizations are Disney World, Harvard University, Massachusetts Bay Transportation Authority (MBTA), Massachusetts Institute of Technology (MIT) and Massachusetts Water Resources Authority (MWRA), and Medical Area Total Energy Program (MATEP). This is done with a goal of creating a foundation of experiences and useful lessons that can be used in the analysis. Chapter 4 applies the principles described in procurement literature (Chapter 2) and of the case studies (Chapter 3) to the Tren Urbano case to provide Puerto Rico with a thorough decision-making process/tool to procure backup power. It presents the viable procurement options, analyzes them, outlines a suggested timeline based on the viable options, and outlines negotiation strategies for the Puerto Rico Highway and Transportation Authority to employ. Chapter 5 presents the conclusions of this study.

### 1.5 Summary of Chapter 1

The Tren Urbano heavy rail transit system was born out of the need to alleviate automobile congestion in the densely populated (and growing) economic center of San Juan, Puerto Rico. A hybrid turnkey procurement approach was employed in its implementation, involving multinational and local private sector contractors to design, build, construct, operate, and maintain various portions of the train. Because of the unique private involvement, it is a Federal Transit administration demonstration project. In November 2001, Tren Urbano will open to the public. It must operate reliably to attract commuters away from using cars, thereby meeting its goal of service to an estimated 115,000 travelers daily by 2010, with between 50,000 and 90,000 fewer cars on San Juan metropolitan region roads and highways.

The reliability issue is tightly tied to the availability of dependable power supply. The power supply in Puerto Rico has suffered frequent blackouts and brownouts owing to excessive demand on the power grid and power authority and also calamities caused by numerous hurricanes and storms. Therefore, a backup power supply is of paramount importance to ensure safe, reliable and uninterrupted service and project a positive public image. This thesis analyzes several options for procuring backup power and recommends the most viable for Tren Urbano.

# Chapter 2: Procurement Options

## 2.1 Introduction

This chapter describes the various procurement options or delivery methods available to a public or private entity (i.e. "owner") in acquiring a new facility or structure. Since each procurement option has advantages and disadvantages, there is no definitive best procurement solution for a given situation. Different options have advantages and disadvantages with regards to money, time, legal backing, market availability, relationship between owner and contractor, relationship between contractors, and management of changes. The owner must decide which delivery method best fits their needs and which are most viable. The literature regarding procurement options is a growing body of work with many viewpoints. Resources such as the Design Build Institute strongly advocate the use of one approach, "Design-Build" while some interest groups advocate other processes, even the traditional "Design-Bid-Build" method. However, this chapter draws primarily upon the pioneering work of John B. Miller, professor at MIT, and Christopher Gordon, P.E., of Bechtel Corp., lecturer at MIT who have researched and published extensively in this field.

Section 2.2 describes the history of procurement options. Section 2.3 examines the process of choosing delivery methods while section 2.4 examines the advantages and disadvantages of various options: Design-Bid-Build, Design-Build, Design-Build-Operate/Design-Build-Operate-Maintain, and Build-Operate-Transfer. Section 2.5 summarizes the chapter.

## 2.2 History of Procurement Options in U.S. Infrastructure

Miller writes extensively regarding the role of the private sector in U.S. infrastructure development. In 19th-century United States, "significant technological advances in infrastructure were developed without substantial government participation. Examples include the telegraph, the telephone, electric power, and natural gas, all of which became key element of the nation's infrastructure. The systems were developed, installed, and operated privately..."[35] The government was not directly involved and no formal rules applied to infrastructure development.

Federal Acts like the Federal Property and Administrative Services Act (FPSA) of 1949 and the Armed Services Procurement Act (ASPA) of 1947 specified the need for prior advertising of a project, full and free competition, and fairer procurement procedures for federal project. However these acts did not define how agencies should provide this competition in the procurement system.

> For example there was no statutory requirement that competition in construction be based on price alone. There was no statutory requirement that there would be price competition only among general contractors proposing to build a particular piece of infrastructure. There was no statutory requirement that competition can only occur once a single design had been produced by an architect or engineer, independently hired by the government.[36]

Thus there was still considerable flexibility and competition within U.S. procurement. This began to change in 1972 with the passage of the Brooks Act, separating the procurement of design from the procurement of construction.

> [The Brooks Act] established a specific statutory selection procedure for architects and engineers on all federal construction and related projects.... [It also specified that] whenever architecture or engineering services are required in connection with federal construction and related projects, a separate procurement must be conducted by the government... The Brooks Act has been interpreted to preclude competition among proposers to finance, design, construct, maintain, and operate infrastructure facilities for the federal government.[37]

The Brooks Act is subpart 36.6 of the Federal Acquisition Regulation (FAR) which pins down procurement policy. FAR limits procurement to essentially segmented, government funded options. For construction, the FAR requires submittal of sealed, firm fixed price bids (or in limited situations, lump sum unit prices). Contract clauses are set forth in the FAR and required to be included in invitations for bids.[38]

## 2.3 Choosing the Delivery Method: The Process

Regardless of the current U.S. legal entrenchment of the separated design and construction procurement processes, known as Design-Build or the "traditional method", there are indeed many different project delivery methods available. "An owner must understand both the advantages and disadvantages of each strategy to properly match the project objectives and resources with the best delivery methods."[39] In fact, during the last decade, wastewater projects, power plants, roads and bridges have been procured through privatization or "alternate delivery methods" throughout the United States.

The traditional method can be used quite well in projects that are clearly defined, well designed, or completely designed. It can also be used for project having well-known requirements that are unlikely to change during construction or are not bound by time constraints that cannot be supported by the traditional method. Many modern projects, however, do not meet these criteria and owners should look at other procurement methods.[40]

Owners may be reluctant to try alternative procurement options because newer methods have less legal precedent or merely because Design-Build is most familiar to the owner.[41] "In many cases, there is not one single best method but several that are appropriate. The selection process often takes a 'process of elimination' approach, paring away obviously inappropriate methods until reasonable alternatives remain."[42]

Gordon identifies project, owner, and market drivers in the process for choosing appropriate delivery methods:[43]

- *Project drivers* may include time constraints, financial constraints, or flexibility needs (design flexibility as the project moves forward, or owner is "locked in" because of permit requirements, specified ahead of time).
- *Owner drivers* may include construction sophistication, how knowledgeable the owner is about construction, how much advice he/she will need, current capabilities, size of staff the owner can commit to monitor the project, restriction on methods, and laws on bidding.
- *Market drivers* may include the availability of appropriate contractors, the state of the market, and whether the project size is such that adequate competition can be attracted in the current market.

Gordon also outlines the checklist of what needs to be defined before selecting the procurement process:[44]

- How will the scope of the project be divided between owner and contractor (i.e. design, construction, and finance)?
- What will the organization of the entity be (i.e. general contractor or construction

manager)?

- How will the contract be structured (i.e. fixed price or reimbursable contract)?
- How will the contract be awarded (i.e. competitive bidding toward negotiation)?

## 2.4 Various Procurement Options: Advantages and Disadvantages

Figure 2.1 summarizes how the common project delivery methods fit into the "quadrants" operational framework developed by Miller.[45]

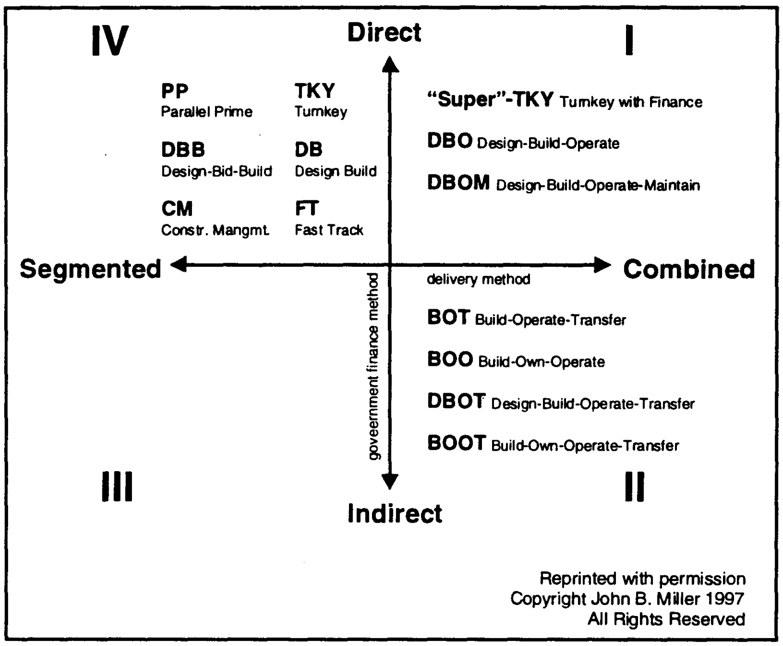


**Figure 2.1: Quadrant Framework of Project Delivery Methods**[46]

The various procurement options can be placed on this grid based on how they are funded and how the procurement subprocesses are distributed between different entities (for example, when the design is separate from construction). The vertical axis varies from direct financing by the owner to indirect financing (private financing). The horizontal axis varies from a segmented delivery method to a combined one, such as the design, construction, operation, and maintenance of the Tren Urbano project by Siemens Corporation. Sections 2.4.1 to 2.4.4 describe the four procurement options from Figure 2.1 that Chapter 4 examines in the context of Tren Urbano.

*2.4.1 Design-Bid-Build (DBB)*

Design-Bid-Build (DBB) is also known as the traditional method or even sometimes as general contracting because it is the most widespread and common delivery method employed in the United States.[47] DBB is sequential, i.e. each activity (and its financing) is completed prior to execution of the next activity.[48] After the need for the project is identified, the owner selects the designer based on qualifications and the designer is solely responsible for completely developing the plans.[49] The owner supplies the financing package and the funding (usually up-front) before each stage and reaps the benefits of any revenue. Once the design is complete, the owner awards the contract for construction to the lowest bidder. In this process, there is a "wall" between the designer and construction contractor. Often, a consultant is hired by the owner to oversee and ensure the designer and contractor fulfill their respective roles, although the consultant has no contractual authority over the designer and contractor. DBB lies in quadrant IV because the design and construction are separate (i.e. segmented) and the funding is direct (i.e. provided by the owner). Figure 2.2 shows how Miller represents the division of responsibilities amongst the owner, designer (architect/engineer), and contractor for DBB procurement.

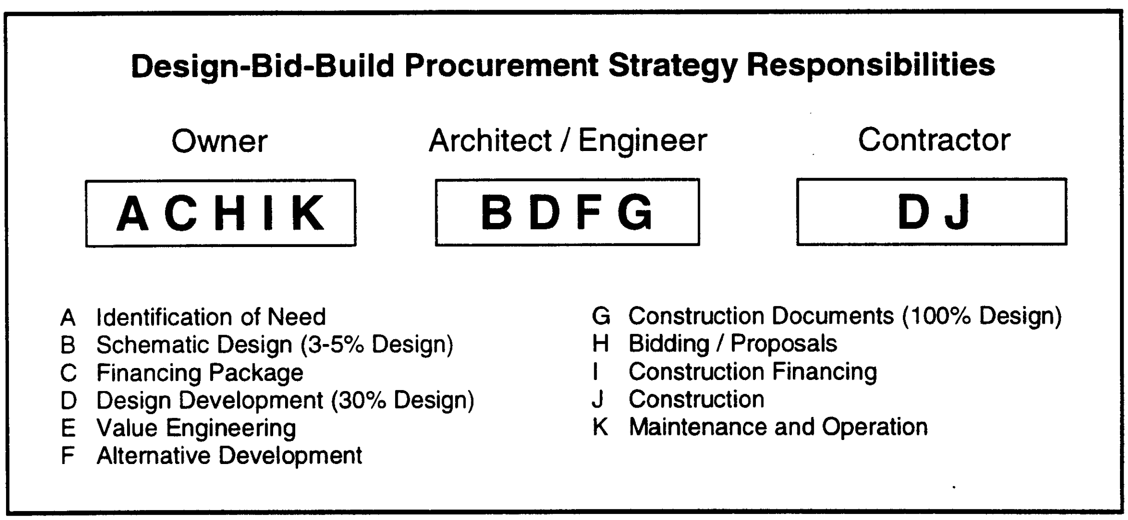


**Figure 2.2: Design-Bid-Build Procurement Strategy Responsibilities[50]**

The following are the advantages and disadvantages of DBB:[51]

Advantages:

- Historically, it is supported, with legal and contractual precedents.
- "How to" resources and documentation are widely available.
- Dependency on only one contractor for both design and construction is avoided.
- Construction is selected based on one criteria: lowest bid.
- The process is straightforward.
- In some cases DBB is the most cost-effective approach.
- The designer can be selected on the base of qualifications.

Disadvantages:

- Because the process is sequential, it is usually time-consuming. Often, the time between the announcement of the bid to the actual time of the bid is regulated.
- The relationship between designer, construction contractor, and owner is often adversarial.
- Historically, DBB is a source of costly litigation, slowing down the project and increasing costs.
- Selecting a contractor based on the sole criteria of low bid may not yield the best results.
- Changes in design are difficult to make once the builder begins construction.

### *2.4.2 Design-Build (DB) and Turnkey*

In Design-Build (DB) projects, one contractor is responsible for a combined design and construction contract. The owner screens potential contractors by issuing a Request for Qualifications (RFQ). The owner provides the financing upfront and prepares a design between 5 and 10% before calling for bids. Then the owner issues a Request for Proposals (RFP) to those bidders who are pre-qualified. The RFP must be very specific, as there is little time for changes. The contract is awarded based on specific criteria, which can even include "low bid." After completion, the owner is responsible for operations and maintenance.[52] DB can include "value-engineering, completion of design, commissioning, and warranty repair, including risks associated with design, construction, and start-up of the facility."[53] Although more "combined" than DBB, DB is still classified in quadrant IV because other aspects of project management (financing, operation, ownership, maintenance) are separate. Figure 2.3 shows how Miller represents the division of responsibilities amongst the owner, and designer/contractor for DB procurement.

**Design-Build Procurement Strategy Responsibilities**

| Owner | Designer / Contractor |
|---|---|
| **A B C H I K** | **D E F G J** |

A Identification of Need
B Schematic Design (3-5% Design)
C Financing Package
D Design Development (30% Design)
E Value Engineering
F Alternative Development
G Construction Documents (100% Design)
H Bidding / Proposals
I Construction Financing
J Construction
K Maintenance and Operation

**Figure 2.3: Design Build Procurement Strategy Responsibilities[54]**

*Turnkey* is a very similar to DB, often considered a more sophisticated version of DB. The main difference is that in Turnkey, "payment is made at the completion when the contractor turns over the *key*."[55] In Turnkey the owner provides the necessary funds *after* the project is finished, thus the design-construction contractor must be able to finance the project until they are paid. "Full title to a Turnkey project is essentially held by the Turnkey contractor until the *keys* to the fully-operating facility are turned over to the permanent owner."[56] Turnkey may include payment, title ownership, and some optional added services. Turnkey can also include site selection, real estate planning, and start-up services. Figure 2.4 shows Miller's representation of the division of responsibilities amongst the owner and Turnkey builder for Turnkey procurement. The only difference between DB and Turnkey in Miller's diagram is the construction financing. Miller would consider construction financing as the Turnkey builder's responsibility, as payment would not be available until after the project is completed.

**Turnkey Procurement Strategy Responsibilities**

| Owner | Turnkey Builder |
|---|---|
| **A B C H K** | **D E F G I J** |

A Identification of Need
B Schematic Design (3-5% Design)
C Financing Package
D Design Development (30% Design)
E Value Engineering
F Alternative Development
G Construction Documents (100% Design)
H Bidding / Proposals
I Construction Financing
J Construction
K Maintenance and Operation

**Figure 2.4: Design Build Procurement Strategy Responsibilities**[57]

Both DB and Turnkey have been used in power procurement. "In the power sector, design-build has been used on cogeneration and other small to mid-sized fossil projects. Design-Build has also been used on many small hydroelectric projects and on major hydroelectric projects."[58] Turnkey projects in power generation offer many advantages including single-source responsibility, fixed price, schedule control, and less demand on the operating utility's staff.[59]

The following are the advantages and disadvantages of DB and Turnkey:[60]

Advantages:

- The process is less segmented/sequential thus resulting in significant time savings.
- Cost and schedule are less variable than in DBB.
- Government or owner can benefit from capital and operating savings.
- DB/Turnkey integrates many elements of the design and construction process.
- Relationships between the owner and design-builder are usually enhanced in DB/Turnkey.
- The changes in design and construction can be easily managed by one

pointperson.

- Financing does not have to be presented upfront in Turnkey,
- In Turnkey, the private contractor may be able to borrow money at interest rates lower than those at which government organizations may be able to borrow.

Disadvantages:

- The owner must choose one best design-builder and cannot separately choose the best designer and the best construction contractor.
- The owner may not be included in discrepancies or problems between design and actual construction. The contractor only may be privy to this information.
- Depending on the project, the market may not be competitive enough to yield one experienced designer/builder of the particular facility.
- There is little time for changes, as most DB/Turnkey projects are on a fast-track schedule.

### *2.4.3 Design-Build-Operate or Design-Build-Operate-Maintain (DBO/DBOM)*

Design-Build-Operate (DBO) or Design-Build-Operate-Maintain (DBOM) projects are derivatives or variants of the previously described Design-Build. The operations and maintenance components are added to the contractor's responsibility. The owner finances projects upfront and provides a 5 to 10% complete design prior to the bidding process.[61] Often municipalities encourage DBO projects by guaranteeing minimum quantities of waste to waste treatment facilities, water to water treatment facilities, or other such materials on which the facility depends.[62] The contractor is thereby guaranteed an income to cover operation costs. DBO/DBOM lies in Quadrant I because one contract is awarded for the design, construction, operations, and maintenance (combined) and the owner usually provides the financing (direct). Figure 2.5 shows how Miller represents the division of responsibilities amongst the owner, and designer/contractor/operator for DBO (which also applies to DBOM) procurement.

**Design-Build-Operate Procurement Strategy Responsibilities**

| Owner | Designer / Contractor / Operator |
|---|---|
| **A B C H I** | **D E F G J K** |

A Identification of Need
B Schematic Design (3-5% Design)
C Financing Package
D Design Development (30% Design)
E Value Engineering
F Alternative Development
G Construction Documents (100% Design)
H Bidding / Proposals
I Construction Financing
J Construction
K Maintenance and Operation

**Figure 2.5: Design Build Procurement Strategy Responsibilities**[63]

The following are the advantages and disadvantages of DBO/DBOM:[64]

Advantages:

- Cost and schedule are less variable than in DBB.
- The process is less segmented/sequential thus resulting in significant time savings.
- Relationships between the owner and design-builder are usually enhanced in DB/Turnkey.
- The changes in design and construction can be easily managed by one pointperson.
- The owner does not have to engage in the operations or the maintenance of the facility.
- The government or owner can benefit from capital and operating savings.
- DBO/DBOM integrates many more elements of design and construction than even DB/Turnkey.
- Design/Builder may have better expertise in operation and maintenance than the owner may and thus the project may be more successful.
- Because the contractor is responsible for the operations and maintenance as well as the design and construction, the contractor will be sure to design and

construct the facility so it is easier and more cost-effective to maintain in the long-term.

Disadvantages:

- The same disadvantages of Design-Build apply to DBO/DBOM.
- The owner has less control in the DBO/DBOM project than in a DB/Turnkey project as operation and maintenance are often beyond the owner's control.

As mentioned in Chapter 1, Siemens will be performing design, construction, operations, and maintenance for the Tren Urbano systems and test track (DBOM). The Siemens Transit Team has an option of operating and maintaining the system for five years after the end of construction with an option of another five more.

### *2.4.4 Build-Operate-Transfer (BOT)*

Build-Operate-Transfer or "BOT" projects are very much like DBO/DBOM except the contractor is responsible for financing. Here, financing is indirect and not provided by the owner. The various components (design, construction, operation, and maintenance) are combined into one contract. BOT can also be called DBOT (Design-Build-Operate-Transfer) or BOOT (Build-Own-Operate-Transfer). Thus BOT is located in Quadrant II of Figure 2.1. Figure 2.6 shows how Professor Miller represents the division of responsibilities amongst the owner, and franchisee for BOT procurement.

**Build-Operate Transfer Procurement Strategy Responsibilities**

| Owner | Franchisee |
| --- | --- |
| **A B** | **C D E F G I J K** |

A Identification of Need
B Schematic Design (3-5% Design)
C Financing Package
D Design Development (30% Design)
E Value Engineering
F Alternative Development
G Construction Documents (100% Design)
H Bidding / Proposals
I Construction Financing
J Construction
K Maintenance and Operation

**Figure 2.6: Design Build Procurement Strategy Responsibilities**[65]

The advantages and disadvantages are also much like DBO/DBOM except for the following:[66]

Advantages:

- The private sector provides funding and collects revenue.
- If owner is a government entity, private financing may alleviate pressure on limited government budgets.
- The government saves more money in capital and operating expenses.
- BOT integrates more elements than DBO/DBOM (financing).
- The owner assumes very little risk as the private entity has enormous responsibility for the project success.
- The contractor is responsible for the project over a longer period of time than in the other methods.
- BOT projects typically employ new or emerging technologies that government entities may not be able to access.

Disadvantages:

- The private sector expertise will not be available unless the private sector contractor has an opportunity to turn a profit.

- The owner may not have as much control as desired and any mistake by the BOT contractor may be politically perceived as the error of the government entity.
- Political or legal barriers may exist to allow private financing or profit sharing.

## 2.5 Summary of Chapter 2

The United States government has a history of using different procurement options, but over time the options have become limited. Some of the common delivery methods employed are Design-Bid-Build, Design-Build, Design-Build-Operate/Design-Build-Operate-Maintain, and Build-Operate-Transfer. Design-Bid-Build is the most commonly used option in the United States. The tasks of design, construction, operations, maintenance, and project financing may be divided between the owner and the private sector contractor in numerous ways. In each of the delivery methods, the private sector contractor performs anywhere from one to all of these tasks. There is no single best delivery method, rather all options have their advantages and disadvantages and they may work well or poorly depending on the situation. It is therefore important to identify the owner drivers, market drivers, and project drivers, as well as the scope, organization, contract structure, and type of bidding process before selecting the delivery method. The process of choosing a procurement option a process of elimination. The owner must consider the advantages/disadvantages including legal backing, time to complete project (scheduling), market availability, relationship between owner and contractor, relationship between contractors, and management of changes. Studying the literature on procurement provides Tren Urbano with information on the options available to it. Chapter 4 will detail specifically which procurement options best fit Tren Urbano's needs. The next chapter will explore case studies of organizations and institutions that have dealt with resolving and solving issues of reliable power, including procurement of power through different approaches.

# Chapter 3: Mini Case Studies of Power Management

## 3.1 Introduction

This chapter presents mini case studies of various organizations in North America, which have procured their own main or backup power facilities. A general overview of these organizations will assist in providing a foundation of experiences and useful lessons regarding procurement strategies for reliable backup or main power. The study of power management by these organizations provides a look beyond the engineering questions and an understanding of the political, legal, and economic context and constraints. Tren Urbano and the government of Puerto Rico can then use the experiences of these other institutions to build a strategy for procuring power.

Sections 3.2-3.6 describe the organizations: Disney World, Harvard, Massachusetts Bay Transportation Authority, Massachusetts Institute of Technology, Massachusetts Water Resources Authority, and Medical Area Total Energy Program. Section 3.7 draws out key lessons learned from the case studies about power procurement and analyzes the lessons in the Tren Urbano context. Section 3.8 summarizes the chapter.

## 3.2 Disney World in Florida (Amusement Park)

Disney World in Florida is in an area susceptible to hurricanes, storms, and inclement weather, much like Puerto Rico. In fact, Florida has the highest number of lightning strikes in the United States. Disney World's backup system allows a small part of its operation (rides) to operate in severe weather conditions. This is due to Disney's highly advanced weather forecasting systems, which predict when lightning storms may affect the area and will allow Disney to disconnect from the main power grid and rely on their backup power during these times.[67]

## 3.3 Harvard University (Educational Institution)

Harvard power comes from a continuously operating cogeneration plant. Economic reasons motivated the decision to use cogeneration. In the late 1970s Harvard, in its move towards self-sufficiency, overcame many legal hurdles because the Cambridge Electric Co. (CELCO) refused to run electric lines to Harvard's plants as Harvard was opting out of Cambridge power. Harvard's problems with CELCO are similar to the problems between MIT and CELCO, except in this case Harvard was CELCO's *largest* customer. Although Harvard's decision to use cogeneration was mainly economic, with environmental benefits, the ramifications of Harvard's decision were political and legal.[68]

### 3.4 Massachusetts Bay Transportation Authority (Transit Agency)

The MBTA lobbied for legislation to approve it as a wholesaler of power. With its gas turbine engines, the MBTA is the only transit authority to generate its own power. The federal government provided a large percentage of the funding for the MBTA's power. The MBTA also receives income from Boston Edison who pays the MBTA to run its generators in case of a shortage of supply for other customers. This strategy has proved very cost-effective for the MBTA. The MBTA has benefited from its unique power procurement strategy in terms of reliability is well. During the Northeast blackout of 1965, the MBTA power system was operating and kept trains running while all of New England in New York was without power. This took place when the MBTA operated its own 25 Hz power system. The steam electric power plant that was in use then operated through about 1982.[69]

### 3.5 Massachusetts Institute of Technology (Educational Institution)

The Massachusetts Institute of Technology operates a 21 MW cogeneration plant. MIT found that using cogeneration was cheaper than relying on the Cambridge Electric Company (CELCO) for its power. In fact between 1981 and 1991 Cambridge was experiencing outages and rate hikes that greatly affected MIT's power. MIT wanted direct control of its power supply. Although it was cost-effective and possibly more reliable for MIT to generate its own power, MIT was penalized. The Department of Public Utilities imposed an exit fee, or a 4.5 million dollar "customer transition fine," because CELCO had acquired additional generating capacity mainly to address the MIT demand as MIT was CELCO's second largest customer. When MIT backed out of the Cambridge distribution system, CELCO was left with excess capacity.[70]

## 3.6 Massachusetts Water Resources Authority: (Water/Wastewater Utility)

The Massachusetts Water Resources Authority not only has the responsibility for providing safe drinking water to its ratepayers, but it has the enormous responsibility of treating wastewater for the municipalities. Wastewater for the MWRA municipalities is treated on Deer Island, a peninsula jutting off from the town of Winthrop into the Boston Harbor. During inclement weather, flow into Deer Island increases dramatically. Storms are also known to interfere with power supply, causing brown-outs or black-outs. However, the MWRA, in accordance with The Clean Water Act, cannot allow interruptions to the sewage treatment process, lest raw sewage flow into the Boston Harbor. Boston Edison built a cable under the Harbor and a substation on Deer Island. Notwithstanding, the MWRA is responsible for procuring any backup power it needs. The MWRA has several backup mechanisms: two 26 MW combustion turbine diesel which run in parallel with the main power supply; two 6 MW diesel engines which are inefficient and rarely used (this was leftover from a previous sewage treatment facility on Deer Island); one 17-18 MW steam turbine which usually runs between 3.5-4; cogeneration; one 2 MW Hydro facilities; and one 200 kW fuel cell. The MWRA is legally allowed only 1000 hours of operation of its diesel backup per year. According to the MWRA, environmental and Massachusetts procurement laws heavily influenced the procurement of secondary power sources for facility operations. In fact the MWRA's lengthy procurement process was a reason it preferred that Boston Edison to build the cable and the substation. For the other levels of backup, the MWRA contracted out using Design-Bid-Build because of existing procurement laws.[71]

## 3.7 Medical Area Total Energy Program (Hospitals)

Located in the 200-acre Longwood medical area of Boston, MATEP serves steam, chilled water, and electricity to over nine million square feet of space in facilities throughout the area including six hospitals, medical research centers, and teaching institutions. Harvard University originally built a power station in this area to provide steam and electricity for the Harvard Medical School. Harvard eventually subsidized MATEP because the market shifted and MATEP experienced significant economic losses. MATEP is capable of producing 62 megawatts of electricity in addition to steam and chilled water. In terms of reliability, each of MATEP's major customers is connected to two steam lines and two electrical feeders (one from MATEP and one from Boston Edison). MATEP's electrical network is operated in parallel with Boston Edison. If needed, MATEP can supply approximately 95% of the total electrical needs of the hospitals. These generators run continuously.[72]

## 3.8 Lessons Learned

This section identifies and analyzes the key lessons learned, the cases in which these lessons played a central role, and the ramifications for the Tren Urbano project.

**Lesson 1**: It is not sufficient to consider power procurement as an engineering issue. Important political, legal, and planning factors must be considered as well.

- MIT constructed its cogeneration plant without adequately considering its potential legal ramifications. The result was an extensive legal fight whose outcome proved costly to MIT.
- As with MIT, Harvard's cogeneration facility ran afoul of the local utility, which tried to cut Harvard out of the system in retaliation.
- The engineering solution to the MWRA's issues may have been to build a plant that would have caused emissions in excess of those allowed in the Clean Air Act. The ultimate solution with a variety of backups represented an innovative way to comply with all relevant laws.

**Implications for TU:** Although the F. R. Harris study focused exclusively on the functional power needs of the Tren Urbano project, legal, political, and planning issues will inevitably play a major role in determining whether and how backup power will be delivered to the system. These issues are discussed in detail in Chapter 4.

**Lesson 2**: The energy plan should be flexible enough to accommodate changes in technical and/or economic requirements.

- The variety of generators included in the MWRA's backup facilities allows it to alter its power output and emissions depending on the weather conditions and power needs.
- In MATEP's case, changing economic circumstances resulted in unnecessary losses that could have been forestalled had the backup power facility been designed with more flexibility.

**Implications for TU:** Tren Urbano will require flexibility in the design of its backup power system because of the planned construction of additional lines. The economic and regulatory situation could also change dramatically over the long run - for example, if the local power market was deregulated.

**Lesson 3**: The organization should make an extensive search of financing options before deciding which is optimal.

- The MBTA was able to find funding sources from the federal government and Boston Edison, an innovative financing solution that may not have been readily apparent.
- Like the MBTA, the MWRA sought and received special funding by partnering with Boston Edison, which constructed a cable and substation for the MWRA.
- MATEP's initial financing scheme did not work out as planned, and had to be subsidized by Harvard when losses resulted.

**Implications for TU:** As will be discussed in Chapter 4, currently direct financing appears to be the only option. However, exploring other options now could result in innovation down the road if the regulatory environment in Puerto Rico changes.

**Lesson 4:** The institution must prioritize its concerns and interests. Key interests might include finishing a project (1) on time, (2) at the least cost, (3) at the greatest political reward, which may be linked to other priorities, (4) or at the highest level of reliability.

- Disney's made reliability and safety its priorities, and proved willing to expend additional resources to bring about a solution that maximized these factors rather than adopt cheaper, more conventional alternatives.
- MIT and Harvard sought to be self-sufficient without examining other potential priorities, such as reducing the costs of litigation, avoiding causing "stranded excess capacity," and avoiding being cut out of the local power grid.

**Implications for TU:** Tren Urbano's priorities are discussed in greater detail in Chapter 4. However, reliability and quick construction are priorities, while other considerations might also play a role.

## 3.9 Summary of Chapter 3

The organizations studied in this chapter, viz. Disney World, Massachusetts Institute of Technology, Harvard, Medical Area Total Energy Program, Massachusetts Bay Transportation Authority, and Massachusetts Water Resources Authority, incorporated redundancy and have improved reliability within their organization's power system. It will be highly advantageous for Tren Urbano is to use these organizations as examples, analyzing both the useful lessons and pitfalls and applying specifics to San Juan. This strategy will allow the government of Puerto Rico to develop a decision process by which to procure 20 MW of emergency backup power at a low-cost, expedient, and politically viable method.

# Chapter 4: Analysis and Findings

## 4.1 Introduction

The goal of the chapter is to present a thorough decision-making process for procuring backup power for Tren Urbano. This chapter seeks to answer three questions of central concern to the Tren Urbano project: First, how should Tren Urbano acquire 20 MW of backup power? Second, which procurement methods are sub-optimal? Finally, which procurement options are the most viable? To answer these questions, this thesis draws upon the existing literature in this area (summarized in Chapter 2) and some relevant case studies (Chapter 3). In order to meaningfully analyze the options and select a delivery method, it is first necessary to determine the factors affecting the procurement process. This is accomplished by identifying the relevant procurement drivers in Section 4.2. This knowledge is utilized to derive the details of the decision-making process in Section 4.3, which presents and analyzes the viable procurement options. Section 4.4 develops a timeline based on the viable options consistent with schedule requirements and section 4.5 outlines possible negotiation strategies for TUO to employ. A summary of the chapter follows in Section 4.6.

## 4.2 The Relationship of the Existing Literature to TU

Each project is unique, and hence Miller, Gordon, and other experts in the field have shied away from prescribing specific procurement options for given types of project. It is rare to find objective authors who are willing to make a definitive judgment about which procurement methods should be employed for a specific type of project. Some lobbying organizations, contractors, and other political actors have recommended various procurement options in general, apparently in their own self-interest. (One example of this predilection is the case of the Design-Build Institute, touched on in Chapter 2.) Yet project managers must inevitably make judgments about procurement methods, despite the lack of objective prescriptions. In the case of Tren Urbano, a close examination of the academic literature on procurement can lead to a better understanding of which procurement options are viable and which are not. Although this thesis was written as a practical tool for application in only one specific case, it represents a departure from the past because it recommends some options and proscribes others.

Gordon's literature on procurement drivers[73] is an appropriate starting point. Given what has already been described about the current power situation in general, and of Puerto Rico and Tren Urbano in particular, it is relatively simple to identify a handful of project drivers, owner drivers, and market drivers. To do this, a little reiteration of the lessons and concepts of Chapter 2 will be necessary.

#### *4.2.1 Project Drivers: Time Constraints, Reliability, and Flexibility of Design*

Regarding project drivers, the issue of backup power must be examined in light of the fact that the Tren Urbano project is already under construction, with a completion deadline of November 2001. The project has already cost $1.5 billion and the political leadership is ostensibly anxious to avoid unnecessary cost-overruns. In addition, reliable power will be needed at the time of the project's completion. The safety and reliability of TU at the opening is crucial to ensuring that the system is well received by the public. Lesson 4 of Chapter 3 may be useful to Tren Urbano in that identifying and prioritizing objectives will make the procurement of power more efficient; in this case reliability is driving the need for backup power and is therefore a high priority. Finally, the project will continue to expand after the first line opens and there are certain uncertainties associated with the planned expansions. Thus, the power requirements must be flexible enough to grow and change with the system and the needs of the community as indicated in lesson 2 of 3.8.

#### *4.2.2 Owner Drivers: Staff Limitations and Desire to Contract Out*

The next category of drivers outlined by Gordon are the "owner drivers," the concerns held mainly by the project "owner," in this case the government of Puerto Rico. A critical issue in this area is the government's limited ability and/or desire to address the need for backup power on its own. For whatever reason, the backup power problem was not addressed in the Siemens Test Track and Turnkey contract, and thus responsibility for backup power does not rest with Siemens. This contractual omission represents an obstacle for the project. The PRHTA lacks the expertise and manpower to address the problem on its own. Although PREPA could conceivably provide a solution, at present this appears unlikely. Based on discussions with Tren Urbano contacts who serve as intermediaries between Tren Urbano and PREPA, PREPA currently has no interest in addressing potential needs for backup power. Doing so would represent a de facto admission that PREPA as it is now constituted is not a reliable provider of power to Puerto Rico. The issue is a particularly sensitive one at this point because PREPA is currently negotiating with the EPA over emissions that might result from its plans to construct new power plants in the southern part of the island.[74] PREPA also claims to have made great strides in improving its reliability, at least in the short run.

#### *4.2.3 Market Drivers: Private Sector Expertise, Deregulation, Low Cost Options*

Market drivers comprise a more general category about which only a few concrete statements can be made. First, a number of private firms already possess much of the expertise needed to carry such a backup power project to completion, including Raytheon, Caterpillar, Siemens, GE, and Onan (a division of Cummings). Therefore, it should be feasible to locate a private sector company that can provide backup power. As mentioned in section 1.1.3, Puerto Rico is not bound by federal procurement rules and PREPA is free to involve as much private sector involvement as it decides will best meet its needs. Second, municipalities, regions, and organizations in the private sector in the United States have recently begun to acquire the expertise needed to undertake projects of this nature owing to the deregulation of the United States power market. Success abroad may provide the source of additional contractors who could enter the Puerto Rican power market if it were similarly deregulated. Third, Tren Urbano may choose to explore a variety of power options including some unconventional, low cost alternatives such as use of decommissioned "standby" diesel generators previously used by nuclear power plants. Though Puerto Rico is not presently availing itself of some of these opportunities, they represent notable examples, practices, and trends that Puerto Rico would do well to examine closely and borrow from where possible.

#### *4.2.4 Quadrant Analysis*

The classification of procurement methods originated by Miller can help bring the above "drivers" to bear on the central problem. The salient point in the context of the quadrant framework (Section 2.4) is that the backup power project must be financed directly. The current regulatory setting on the island, in which PREPA is the sole power utility, mandates this requirement. Indirect finance generally relies on some kind of market-driven cost recovery by the entity that finances its construction, such as through a surcharge or direct sale of power or excess power. These options are not available; rather, whatever entity operates the backup power facility will be expected to supply power to Tren Urbano based on direct contractual obligations rather than as an independent utility. Thus all options must fall in quadrants I or IV.

## 4.3 The Decision Tree and the Viable Options

With the knowledge of the factors that play an important role for procuring the 20 MW of backup power, the decision-making process can now proceed. The process is elucidated here step-by-step utilizing a graphical representation in order to make the steps clear and easy to understand. Figures 4.1a-e describe the decision making steps while the full decision process is represented by combining the steps of Figures 4.1a-e into Figure 4.2.

Figure 4.1a shows that in order to obtain 20 MW, Puerto Rico has two initial paths: first, initiating a procurement process from within Tren Urbano and, second, relying on PREPA to meet the power supply and reliability needs of Tren Urbano.

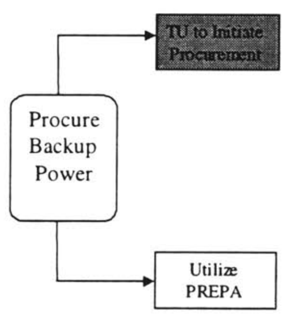


**Figure 4.1a: TU Can Initiate a Procurement or Utilize PREPA**

There are two possible scenarios if PREPA is utilized in acquiring reliable power. These are shown in Fig 4.1b. Tren Urbano can either depend on current PREPA systems to provide reliable power or contract with PREPA to build a backup system specifically for Tren Urbano.

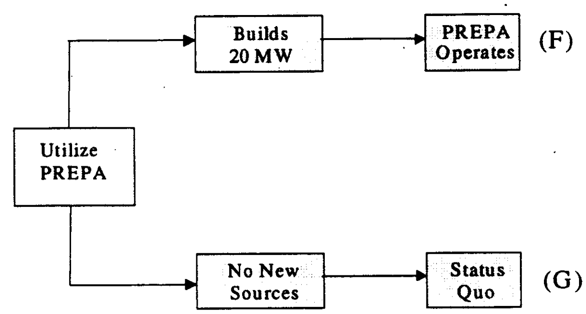


**Figure 4.1b: TU Can Rely on PREPA Systems or Contract with PREPA for 20 MW**

The following considerations apply in evaluating the scenario of Figure 4.1b. The PREPA power supply has improved in the last few years and especially in the last year as shown earlier in Figures 1.3-1.5. However, utilizing PREPA's current power grid may increase Tren Urbano's risk and therefore option (G) is unacceptable since reliability is a priority for Tren Urbano. An alternative is to initiate negotiations with PREPA to design, supply, and build two 10 MW backup power generators in Sagrado Corazon and Bayamon, possibly partially financed by Tren Urbano. PREPA would have the option of taking over these two sites at a future date. This would allow a great deal of flexibility as recommended from the case studies of Chapter 3 (lesson 2). However, based on discussions with Tren Urbano contacts who serve as intermediaries between Tren Urbano and PREPA, PREPA currently has no interest in this partnership. PREPA is currently working to build new power plants in the southern part of the islands and fighting battles with EPA over emissions from these plants.[75] Additionally, PREPA has made great strides in improving reliability of its power supply throughout Puerto Rico. Building extra capacity specifically for Tren Urbano would be an indication that PREPA is unable to meet the increased demand from Tren Urbano in 2001. Politically, PREPA may fear a loss of prestige or an admission of failure if it builds a backup system for Tren Urbano. Although the best engineering solution may be for PREPA to address reliability issues, political factors prevent

Tren Urbano from doing so, just as has occured in other cases (lesson 1 of 3.8). Thus, relying on PREPA to build 20 MW of emergency backup power specifically for Tren Urbano option (F) is not a viable option.

We have now eliminated the lower branch shown in Fig. 4.1a and are left with the option of Tren Urbano initiating procurement. Here, TUO has two choices as shown in Fig 4.1c.

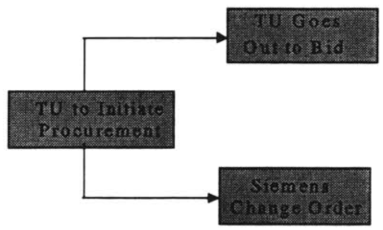


**Figure 4.1c: TU Options for Initiating Procurement of Backup Power**

These two options are to 1) provide the emergency backup power through a Siemens change order or 2) issue a request for proposals on which private firms could bid. Both of these are viable options. Issuing a change order to Siemens would essentially update the contract to include backup power for an additional cost. This would be relatively fast and it could be used if time pressures leave no other options, but an open bidding process could have advantages. A bidding process could occur in two different ways as shown in Fig 4.1d (options I and II).

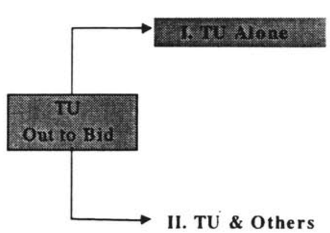


**Figure 4.1d: TU Options for Going out to Bid to Procure Backup Power**

As suggested in option II, Tren Urbano could possibly form a consortium with others in the San Juan area in need of reliable backup power. The consortium could jointly issue an RFP and solicit bids. At this stage, the consortium does not appear possible for several reasons. First, the negotiations with potential consortium members will be difficult and would take longer than the time Tren Urbano has available to make decisions on backup power. Second, even if the consortium were possible, a separate engineering study would have to be undertaken since F. R. Harris has only studied the demands and potential solutions for Tren Urbano acting alone. Third, the prior behavior of potential consortium members including the University of Puerto Rico at Rio Piedras has presented some difficulty in terms of timely payments. Therefore, future conflicts may arise between Tren Urbano and potential consortium members on finances, priority, and siting. Finally, research indicates that it is currently illegal under Puerto Rican law to form a consortium to produce, sell, and buy power in competition with PREPA. Puerto Rico is not subject to FERC wheeling rules and has a very large unionized lobby that opposes massive deregulation in Puerto Rico, despite the deregulation that has swept through energy markets in North America.[76] Therefore, forming a consortium (option II) is not viable at this time.

If Tren Urbano goes out to bid alone, four possible delivery methods exist, as shown in Fig 4.1e.

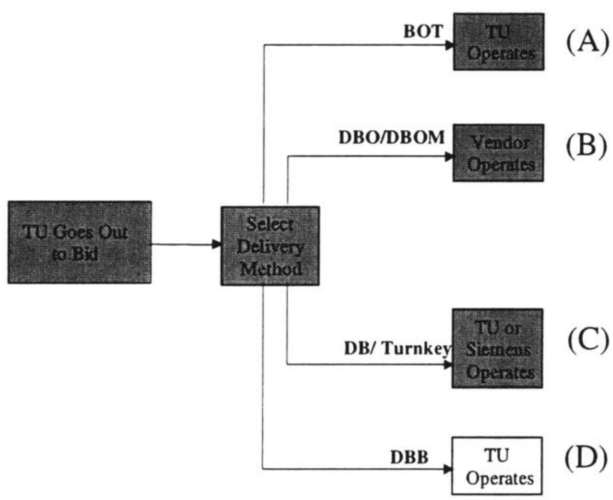


**Figure 4.1e: Options for TU Going out to Bid**

The first delivery method is BOT in which the vendor will design, build, and operate, but Tren Urbano will own (A in Fig 4.1e). The second is DBO/DBOM in which the vendor will undertake operations (B). Third is a combined Design-Build in which a vendor will design and build the facility and hand it over to either Tren Urbano or Siemens to own and operate (C). The last option (D) is separate Design-Bid-Build, which is most common in federal procurements. Chapter 2 offers a more in-depth description of all these options.

The entire procurement process can now be conveniently presented as decision tree by combining the pieces 4.1a to 4.1e as shown in Fig. 4.2.

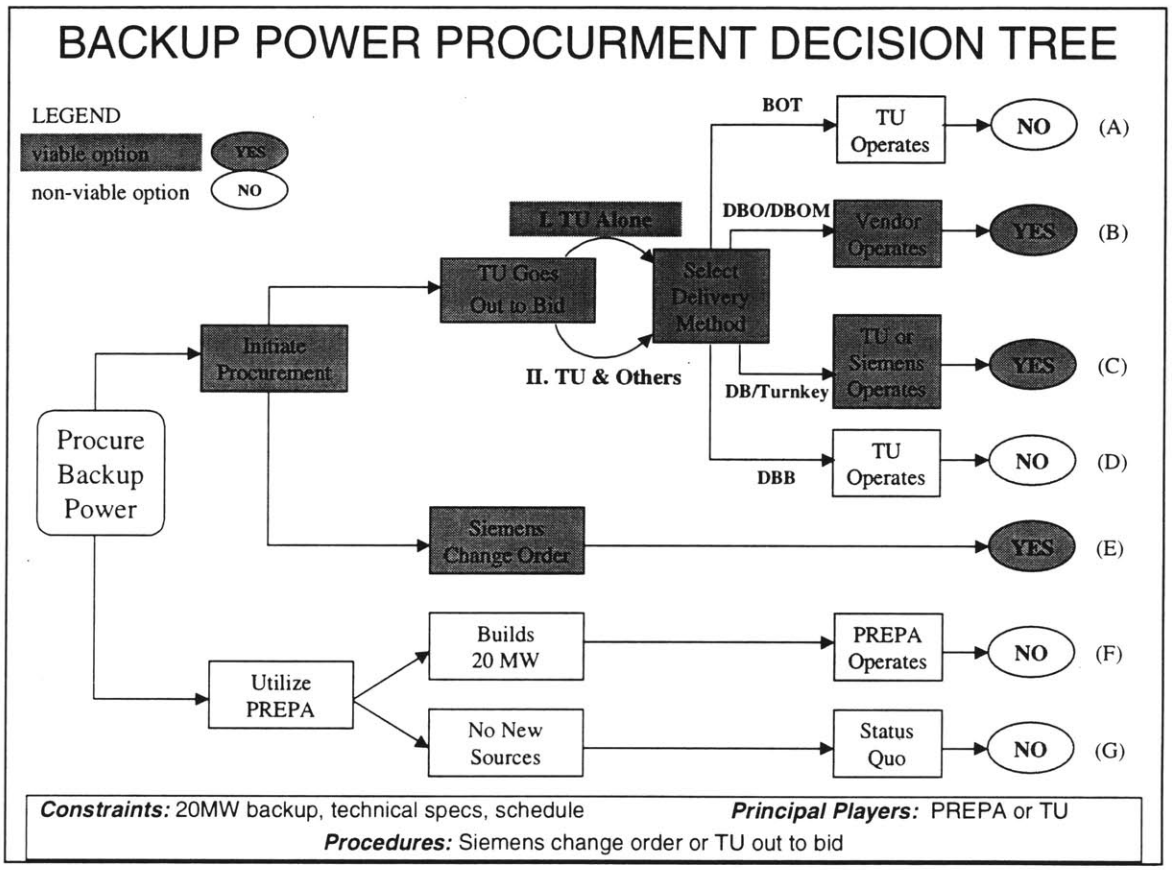


**Figure 4.2: Decision Tree**

A detailed discussion of the options A-D follows. In the delivery methods represented by these options it is expected that Tren Urbano will cover all the cost associated with financing the project. There is very little opportunity for a private company to own an emergency backup power plant because of PREPA's monopoly on the Island and existing regulations. However, there are many private entities nationwide that have the design and construction expertise to participate in any of the other delivery processes. The energy industry is growing, especially in North America because of deregulation, and Puerto Rico should take advantage of the competitive market to provide emergency backup for the Tren Urbano. Considering the economic and political issues (3.8 Lesson 1) could assist the TUO in acquiring the best quality and best priced backup system for Tren Urbano. The following sections summarize Tren Urbano's options for requesting outside bids for providing backup power.

#### *4.2.1 Design-Bid-Build (option D):*

In DBB the "low-bid" construction contract is chosen. DBB may not be suitable for this particular situation, as reliability and time are more important to TU than cost. Tren Urbano must not lose sight of its concerns and interests in light of the fact that DBB is the most commonly used process. This is the process that the MWRA (Chapter 3) used in procuring its many levels of backup power and recommends against. Additionally, sources at the MWRA claim that this separate Design-Bid-Build process is too lengthy. Although this process often produces the lowest cost solution and has significant historical backing, it is slow, and quality cannot be guaranteed. Thus DBB is not an acceptable option. TU can learn from other organizations about prioritizing its needs and interests to avoid pitfalls others may have experienced (3.8 Lesson 4).

#### *4.2.2 Design-Build/Turnkey (option C):*

In Design-Build/Turnkey, selection is based not only on cost but also on several evaluation criteria set forth in the RFP. Therefore TU's priorities and interests can be addressed more thoroughly in this process than in DBB. A very specific RFP would be beneficial. When the design-build process is complete, the contractor turns the project over to the owner. In this case, the owner could be either Tren Urbano or Siemens, which has a five-year operation and maintenance contract. It would be preferable for Tren Urbano to make the payment to the contractor in one lump sum in order to insure the construction is finished such that Tren Urbano has time for acceptance testing before the opening of Tren Urbano. This process progresses much faster than the previously mentioned DBB process.

Changes can be made quickly and efficiently, although in this fast-paced project, there will not be much time for changes. Therefore a very specific RFP is important. Tren Urbano's needs are very specific, even down to the type of technology (first choice diesel, second-place natural gas) and the amount required. DB/Turnkey may be a convenient approach. Tren Urbano may choose to finance this up-front so costs do not spiral out of control. This would help to keep a project on schedule and within time constraints. It is important that TU consider its financing options and strategies when choosing the optimal procurement process (3.8 Lesson 3). Design-Build has been used in cogeneration and mid-sized fossil projects and there is currently enough expertise in the field to pursue the Design-Build procurement option.

#### *4.2.3 Design-Build-Operate /Design-Build-Operate-Maintain (option B):*

DBO is very similar to Design-Build and differs only in that responsibility of operations is added to the contract. DBOM is very similar to DBO with the significant addition of one more component: maintenance. Thus, a private entity would operate and maintain the facility. If the contract were awarded to Siemens, it would have to be written to ensure that the ownership and operation of the system would be a priority. The contract for emergency backup power can parallel the five-year operations and maintenance already contracted with Siemens. Alternatively, the contract could be written for a longer period of time if the TUO decides that this is the best way to insure that emergency backup power is a priority. If the contract were awarded to another private entity, Tren Urbano/Siemens and this private entity would have to enter into a contract specifying when Tren Urbano/Siemens would take over emergency backup power as part of its operations and maintenance. Tren Urbano must keep in mind that although this combined approach would guarantee stability in the long-term, it would also force Tren Urbano to be locked in to a price in the future when power prices may continue to drop as they have in the last 20 years. Thus, TU must be flexible enough to deal with long-term economic changes (3.8 Lesson 2). TU must also consider the legal and political ramifications of this approach (3.8 Lesson 1) as a DBO/DBOM method must be structured so the contractor does not compete with PREPA or make a profit from operations.

#### *4.2.4 Build-Operate-Transfer (option A):*

BOT is very similar to DBO/DBOM, but usually, in the BOT scenario, the financing is part of the contractor or bidder's responsibility. As mentioned in Lesson 3 in 3.8, it is advisable to seek out a variety of financing options in procuring power. However, in the case of emergency backup for Tren Urbano it looks unlikely that the private sector will be able to make a profit from the emergency backup power. First, operating such a stand-alone backup power system might be viewed as competition with PREPA and is highly regulated by Puerto Rican law. Second, even if the private entity were to devise a clever mechanism to sell back excess power (as emergency backup power will not be needed at all times) it is unlikely that PREPA, as the sole provider of power on the Island, will offer a reasonable price for it. The BOT would not be a viable option because any backup power must be completely funded by Tren Urbano and it would be unlikely that excess power could be sold to recover the cost. TU would be wise to anticipate the legal and political problems with this strategy as suggested in Lesson 1 (3.8) before attempting such a procurement for phase I or in the future.

## 4.3 Recommendations and Suggested Schedule

All of the methods except for DBB allow for fast-track completion, which may be necessary in a project already so severely pressed for time. All of the options except BOT call for Tren Urbano to finance the backup power generation. No one single method is the best option. Tren Urbano must use a process of elimination and choose the procurement option which best fits its needs.

If Tren Urbano wants to take advantage of the competitive power market to find the best quality and lowest price, it should prepare itself to go out for bid (options B or C in Figure 4.2). The power market is extremely competitive. Even though a Siemens change order is possible, going out to bid would most likely be more cost effective as it would force Siemens to submit a bid and compete in the selection process. Based on research of cost estimates in the power industry, it is possible to acquire 20 MW of backup power for 10 million dollars less than the capital costs estimated in the F. R. Harris report at $700-$800 per kW.[77] In this case, the TUO must swiftly decide, issue an RFP, solicit the bids, determine the winner, and negotiate a contract. After this, the process of designing, permitting, ordering generator sets, construction/installation, and testing is similar to what Siemens would have to do in a change order environment.

It is now possible to create a schedule of the tasks to be completed incorporating the anticipated time required for each task. Such a schedule is presented in Fig. 4.3.

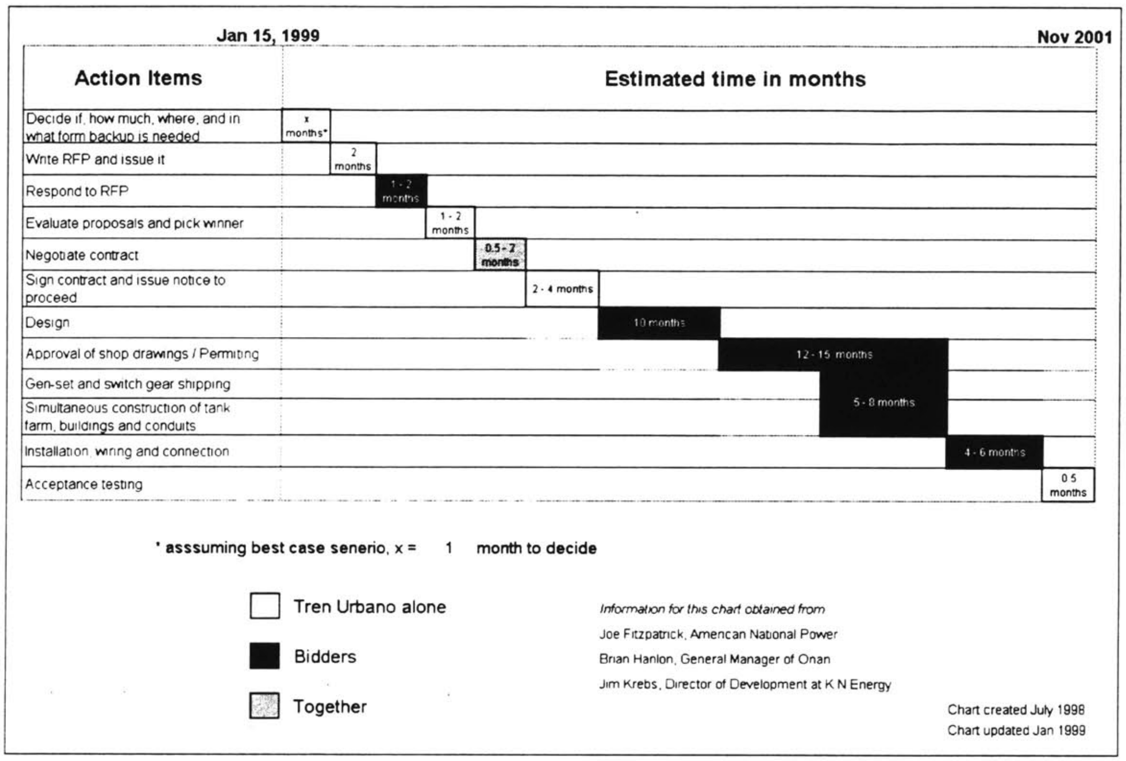


**Figure 4.3: Possible Schedule**

Figure 4.3 is a diagram listing important action items and the estimated time for completion of each action. The starting point is arbitrarily taken as Jan 15, 1999. Given the opening date of November 2001, the time to decide on the required backup power, marked as *x months* in the chart, is estimated to be 1 month assuming a best case scenario based on the minimum time estimate for each item. The chart shows events and timings for Tren Urbano acting alone, contractor(s) acting alone, or TU and contractor(s) working together.

The chart shows that it is possible to solicit bids in the time remaining before the opening of the Tren Urbano in November 2001. There is still a definite possibility of Siemens responding to the RFP with a good quality and competitive bid. TU would benefit from Siemens's expertise in power systems as well as with Tren Urbano and Siemens may submit a competetive bid in order to win the contract. A change order may not yield the best price.

If Tren Urbano cannot decide quickly and proceed with a competitive procurement process, Tren Urbano is by default committed to a Siemens change order (option E in Figure 4.1). In such a situation, the TUO must swiftly make a decision and then negotiate the contract. Siemens could immediately begin to design, place an order for the generator sets, and begin the planning process before a backup power is constructed and tested.

Figure 4.4 shows the timelines for two scenarios: out-for-bid and change order; both concurring at a "start date" at which the contractor would begin to design, permit, order and construct. This diagram illustrates that there is time for both options and shows estimates of how long each would take. Both options are possible, yet require slightly different times from the decision-date to the start date. Tren Urbano must decide by the decision date how much power is required for backup, how much it can afford, where the generating sites should be, and how many generators are required.

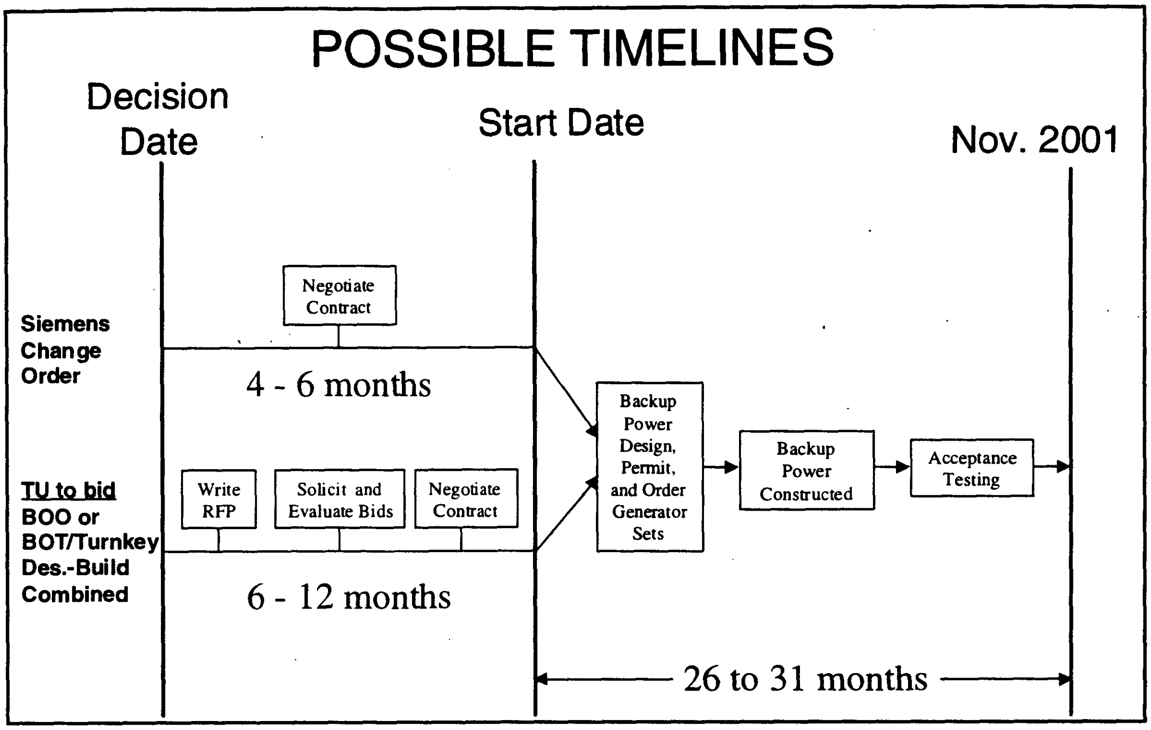


**Figure 4.4: Timeline for Siemens Change Order and Out-to-Bid Scenarios**

## 4.4 Preparation and Negotiation Strategies

In this section, preparation and negotiating strategies are outlined for the TUO in the two most promising scenarios: 1) if TUO goes out to bid 2) if the TUO must rely on Siemens for a change order.

### *4.4.1 Out to Bid*

The TUO must work as efficiently as possible and elevate the procurement of backup power to a top priority activity within the organization. The TUO must solicit bids from the private sector and specify the exact engineering requirements: diesel or natural gas, required amount and makeup of backup power generating capacity (four 5 MW generators or three 3.3 MW), and judge the bids on various specific evaluation criteria. The criteria may include prior experience, cost, and a specific management plan for meeting time lines. Potential bidders include Raytheon, Caterpillar, Siemens, GE, and Onan (a division of Cummings). Tren Urbano would benefit the most by exploring all possibilities including diesel generators from decommissioned nuclear power plants and other lower cost options.[78]

*4.4.2 Siemens Change Order*

Siemens Power Corporation handles many different requests for power. Even if Tren Urbano does not have time to prepare an RFP and solicit bids, Tren Urbano must evaluate the market and collect data on cost estimates from the competitors mentioned above. Siemens will have the advantage if Tren Urbano runs out of time and has no other options. Siemens could then charge a very high price for its backup power system. If Tren Urbano can be armed with market research and competitive prices, the TUO will be able to negotiate the fairest price from Siemens. The TUO should act in its interest and the interests of Puerto Ricans and re-evaluate the cost estimates in the F. R. Harris Report.

## 4.5 Summary of Chapter 4

Tren Urbano has different options for acquiring backup power. It can request a Siemens change order or initiate a procurement. A Siemens change order would be timely, but perhaps not cost-effective. Initiating a procurement would involve going out to bid, soliciting private sector expertise. Tren Urbano would select a DB/Turnkey (operated by Tren Urbano or Siemens) or a DBO/DBOM (operated by the vendor) delivery method. Tren Urbano would probably initiate a procurement with a fixed-price. These two delivery methods, DB/Turnkey or DBO/DBOM are the most viable considering the political, financial, and scheduling constraints. Also, a bidding process with these options would probably result in the most cost-effective resolution providing backup power. At best, Tren Urbano has one month from January 15, 1999 to make a decision on what it would like and how to proceed in order to meet the November 2001 opening deadline of Tren Urbano Phase I. This timeframe is based on the amount of time to solicit bids, negotiate the contract, permit, design, and build.

# Chapter 5: Conclusions

Puerto Rico's urban transportation system is greatly overburdened. The traffic congestion is increasing at an alarming rate and there is a lack of reliable public transportation especially in the San Juan metropolitan area. After almost 30 years of discussion and development, phase I of Tren Urbano, a 17.2 km stretch of heavy electric rail, will become a reality, opening in November 2001. This will service an estimated 115,000 travelers daily in the major San Juan area. In order for the Tren Urbano to be a success when it opens, it will have to operate safely and reliably. Frederic R. Harris, consultant to the Tren Urbano project, produced a study linking the reliability of the power supply to Tren Urbano to its success in attracting in keeping ridership high.

The opening of TU is expected to cause capacity shortfalls on the island. This shortfall is expected because Puerto Rico's power authority, PREPA, has had significant problems of reliability in their delivery of electric power, due both to increasing demands and to the vulnerability of their isolated power grid to hurricanes and storms that Puerto Rico frequently experiences. PREPA is rapidly improving its services, but there are still frequent brownouts. This uncertainty in the reliability of power will jeopardize operations and success of TU.

Backup power is therefore a mandatory component of Tren Urbano. F. R. Harris quantified the need for backup power as 20 MW, distributed at two key locations along the rail system. There are a number of procurement and delivery options in acquiring backup energy supplies as described in current literature and exemplified in past and present practices in the U.S.. There is no "best solution" but viable/practical options can be found through a process of analysis and elimination.

Case studies of other public and private organizations such as educational institutions, entertainment companies, and transportation companies that have had to address their backup power needs provide useful prior experience for Tren Urbano to study. These furnish a template for TU for avoiding potential pitfalls and for developing effective negotiating strategies.

This thesis analyzed the procurement process itself and drew lessons from the case studies of power procurement to identify the viable procurement options for TU. A graphical decision tree (Fig. 4.2) and a suggested timeline of action items (Fig. 4.3) encapsulate the findings of this investigation.

Tren Urbano has two viable options: 1) to go out and solicit bids for a Design-Build/Turnkey or a Design-Build-Operate/Design-Build-Operate-Maintain backup system. According to the schedule developed in Chapter 4, TU has one month to initiate and conclude the bidding process. 2) If not, Tren Urbano will be forced to provide the backup power through a Siemens change order. Option 1 has the potential of saving 10 million dollars for TUO.

The main thrust of the study presented was to critically analyze procurement options for backup power and recommend the most viable options for Tren Urbano. Towards this goal, a thorough study of procurement options in general was made. Case studies of other organizations that found solutions for their backup power requirements were also undertaken. Useful lessons from these case studies were drawn out and applied to the TU context. A methodology was developed for applying the principles of procurement in the specific case of the ongoing Tren Urbano project. The most viable options that meet schedule goals and are cost-effective were identified. Possible negotiation strategies for implementing these options in order to assure the success of the project have been developed.

# List of Abbreviations

(in order of apperance)

| | |
|---|---|
| TU | Tren Urbano |
| PR | Puerto Rico |
| US | United States |
| SJMA | San Juan Metropolitan Area |
| AMA | Autoridad Metropolitana de Autobuses |
| MBA | Metropolitan Bus Authority |
| TUO | Tren Urbano Organization |
| PRHTA | Puerto Rico Highway Authority |
| GMAEC | General Management Architectural and Engineering Consultants |
| STTT | Siemens System Test Track Turnkey |
| STT | Siemens Transit Team |
| DB | Design-Build |
| DBB | Design-Bid-Build |
| DBOM | Design-Build-Operate-Maintain |
| EIS | Environmental Impact Statement |
| PREPA | Puerto Rico Power Authority |
| UPS | Uninterruptible Power Supply |
| MW | Megawatt |
| MBTA | Massachusetts Bay Transportation Authority |
| MIT | Massachusetts Institute of Technology |
| MWRA | Massachusetts Water Resources Authority |
| MATEP | Medical Areal Total Energy Program |
| FPSA | Federal Property Administrative Services Act |
| ASPA | Armed Services Procurement Act |
| FAR | Federal Acquisition Regulation |
| RFQ | Request for Qualifications |
| RFP | Request for Proposals |
| DBO | Design-Build-Operate |

| | |
|---|---|
| BOT | Build-Operate-Transfer |
| CELCO | Cambridge Electric Company |
| KW | Kilowatt |
| EPA | Environmental Protection Agency |
| FERC | Federal Energy Regulatory Commission |

# Endnotes

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