DOES TRAINING MATTER?
CONSTRUCTION QUALITY FOR A NEW START TRANSIT SYSTEM: THE CASE OF TREN URBANO

By

Esther J. Lee

B.A., Government, 1997
Dartmouth College

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

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ABSTRACT

As with many other large-scale infrastructure projects, the construction of a transit project is potentially vulnerable to quality failures, which can lead to completion delays and cost overruns. Especially with technologically advanced, new-start transit projects, a limitation or lack of skilled labor can exacerbate those risks. This thesis examines the case of Tren Urbano in San Juan, Puerto Rico, a rapid rail project currently being constructed in an area with limited on-island experience in the design, construction, operation or maintenance of such a technologically sophisticated transit system. The motivating question for this thesis is, does training matter for construction quality?

The research findings of this thesis show that the multiple prime contractors operating under similar contractual arrangements and resource conditions in San Juan exhibit variations in the quality of construction. Research findings also reveal variations in the type of training programs established by the contractors. A limited conclusion is drawn that although training of inexperienced labor does not single-handedly insure high quality of construction, it nevertheless is important to the successful implementation of project design. Thus, this thesis argues that in order to maximize the quality of construction in a new transit system, the client-owners should create an appropriate strategy which carefully assesses and matches three factors: 1) procurement strategy, whether the conventional design-bid-build or innovative design-build arrangement, 2) contractor competence and experience, and 3) the existent local labor skill level or training capacity.

A successful procurement strategy for the construction of future extensions to Tren Urbano should therefore consider: 1) choosing best-value bids over low bids, where the contractor has exhibited expertise and 2) training a broad range of skill sets, that includes explicit attention paid to the construction laborers and monitoring inspectors crucial for the quality of construction. Successful training should be tailored to pre-empt potential breakdowns of a particular procurement strategy. Furthermore, the training should also be an intentional, collaborative effort between the public education sector, the private construction sector, and an expanded labor union presence, and should fit within an overall industrial development policy of the government. An important theoretical contribution of this thesis is the expansion of the technology transfer discourse from a focus on an educated managerial class to include the ramping-up of skills for low-skilled, often uneducated, labor in order to expand the labor market for economic development while improving the profitability of the private sector ventures utilizing local labor.

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As iron sharpens iron, so one man sharpens another. Proverbs 27:17

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It is for the many experienced, skilled, competent workers to-be to whom this thesis is dedicated.

Soli Deo Gloria.

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LIST OF ACRONYMS

ASC	Alignment Section Contract
DB	Design-Build
DBB	Design-Bid-Build
DBOM	Design-Build-Operate-Maintain
FTA	Federal Transit Administration
GMAEC	General Management and Architectural and Engineering Consultant ; consultant to the Tren Urbano office
PRDTPW	Puerto Rican Department of Transportation and Public Works
PRHTA	Puerto Rico Highway and Transportation Authority
QA	Quality Assurance
QC	Quality Control
STT	Siemens Transit Team
STTT	Systems and Test Track Turnkey
TU	Tren Urbano
TUO	Tren Urbano Office
USDOT	United States Department of Transportation

CHAPTER 1

INTRODUCTION

The employment issue is important for not only the FTA workforce, but also our transit industry workforce. Policies and procedures do not build projects - people build projects. Transit is not about tracks - it's all about people. We face many challenges in terms of attracting the right kind of professionals who need to understand issues of complexity when building large projects or meeting the mobility needs of various constituent groups.

- Jenna Dorn, FTA Administrator

1.0 Introduction

The growth of a transit system occurs either by the expansion of the system through extensions to existing infrastructure, or by the start of a new system that is often reliant upon new technologies. The complexity of fundamental inputs, processes and networks that must first be established usually make the introduction of a new more difficult than extensions to existing systems. Further challenges are posed when a population of engineers, architects and other design professionals, as well as construction, operations and maintenance professionals inexperienced in the new technology must implement the new system.

Technology transfer programs were introduced to facilitate learning in the process of transferring technologies to new locations. While originally a concept in manufacturing industries, the infrastructure development industry has also taken hold of the technology transfer paradigm. Yet, often, technology transfer programs are geared towards a more educated level of people shaped to become the future managerial professionals and leaders within the industry at the local level. This visionary, long-term strategy is a necessary and crucial objective that should be met in the implementation of a new technological system. Technology transfer programs for managers, however, do not necessarily address the problems incurred on the site of actual construction or service provision.

In the development of large-scale infrastructure projects such as that of transit systems, the construction industry often experiences problems of cost overrun, time delay and/or sub-standard quality work. Although it is common in the construction industry for budgets to escalate beyond original estimates, cost controls for certain projects are better managed than others. The same is true of meeting a target schedule in project delivery. The quality of construction is particularly problematic in locations which are inexperienced with technologically advanced infrastructure projects, such as in developing country contexts. The accessibility to, and quality of material inputs is often the focus of discussion surrounding construction quality improvements. Yet, the craftsmanship of the laborer – the ability to use new technology and materials by implementing appropriate processes and techniques —may be a significant factor in construction quality that is ignored by managers.

1.1 Research Question and Objectives

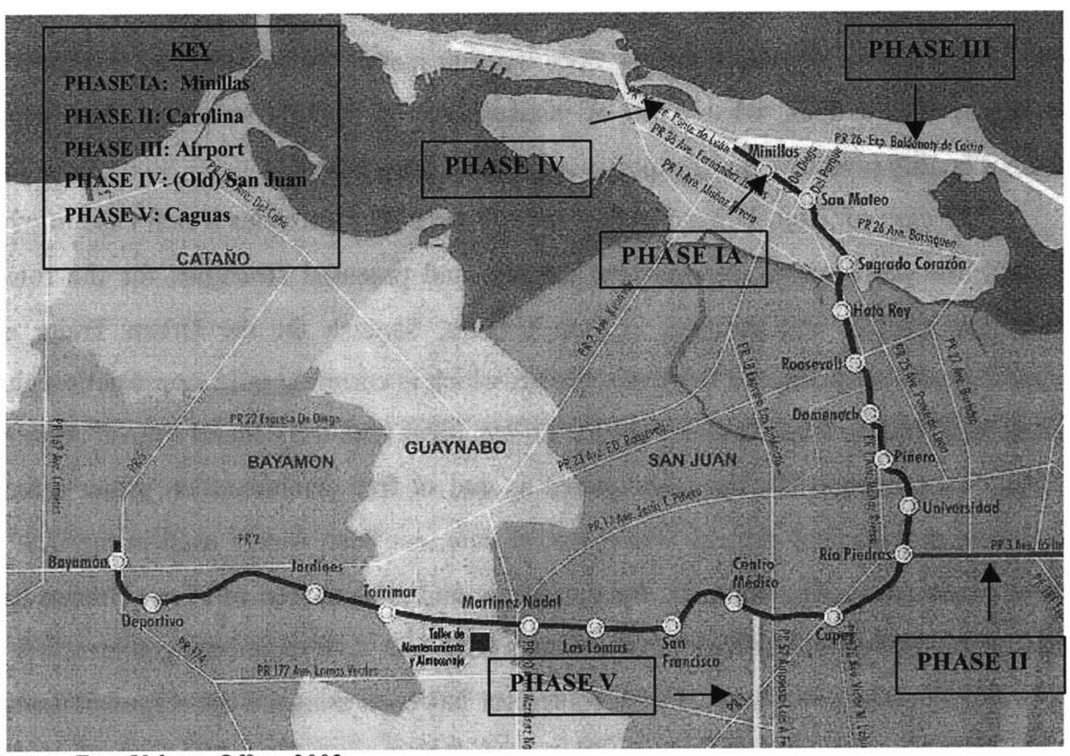
This thesis addresses the issues of knowledge transfer and the development of skills for inexperienced laborers in the construction of new transit systems. Thus, the motivating question for this thesis is, does training matter for construction quality? To the degree that it does, what types of institutions and training structures can help to ensure a quality product from inexperienced construction labor?

The case of Tren Urbano in San Juan, Puerto Rico provides a rich case in which to study the problems of construction quality, and potential strategies for the role of knowledge transfer and training. Tren Urbano, Spanish for the Urban Train, is a technologically sophisticated rapid rail system which is currently in its construction phase in San Juan, Puerto Rico. Under a special arrangement with the Federal Transit Authority (FTA), Tren Urbano has been designated as one of five demonstration projects for an innovative procurement strategy which has, to date, not been widely used in the U.S. for transit construction. The contracts for the design and construction of Tren Urbano have been established as design-build arrangements with four civil engineering contractors for six of the alignment sections. A fifth contractor has been assigned the responsibilities of commissioning and integrating, operating and maintaining the entire system under a turnkey –design-build-operate-maintain –contract.

In addition to being one of the first cases for U.S. design-build for the construction of a transit system, Tren Urbano is Puerto Rico's first modern rail-transit system. The previously existing streetcars and trains ceased operation over 50 years ago. With the lack of experience in current rail technology, the local capacity to manage and implement the construction, operation and maintenance of the system is low at this time.

Already, a plethora of problems in the construction of Phase I have lead to multiple quality reports, such as change orders calling for rework, non conformance reports, and a 2+ year delay in systems opening and operation. Yet, according to the Tren Urbano Master Plan, five additional extensions are being considered. Already, the preliminary engineering work, environmental impact analysis for the 2km Minillas Extension (Phase 1A) has already been completed by the PRHTA. Designed to be completely underground, the project is estimated to cost $478 million (Mirandes, 2001).

Map 1.1: Tren Urbano Master Plan



Source: Tren Urbano Office, 2002

With the general question of the role of training in construction quality on the one hand, and the specific implications of the analysis for Tren Urbano on the other hand, the objectives of this thesis are twofold:

1. This thesis attempts to contribute to the wider discourse on training for the construction of a new transit system, presumed to be of interest to the FTA, local governments, design and engineering contractors, and international loan institutions such as the World Bank.
2. This thesis will offer specific recommendations for improved construction management and labor performance in the construction of future extensions, presumed to be of particular interest to the Puerto Rico Highway and Transit Authority. Towards that end, this thesis will also identify areas where the level of skilled labor has contributed to the construction quality outcomes of Phase 1.

Training and workforce development are critical to develop the next generation of transportation construction professionals. One of the major purposes of this research is to help improve the framework for the human resource management of a technologically advanced transit system such as that of rail rapid transit. More specific to Tren Urbano, the findings of this research are intended to inform the overall management strategy of human resource development in both the management and implementation of construction for future extensions.

1.2 The Framework

As previously established, the design, construction, operations and maintenance of a new-start transit system is particularly challenging because no pre-established institutions or labor capacity exists to address these functions. Often, a lack of institutions and training programs to cultivate the necessary skills within the new-start region may also be lacking.

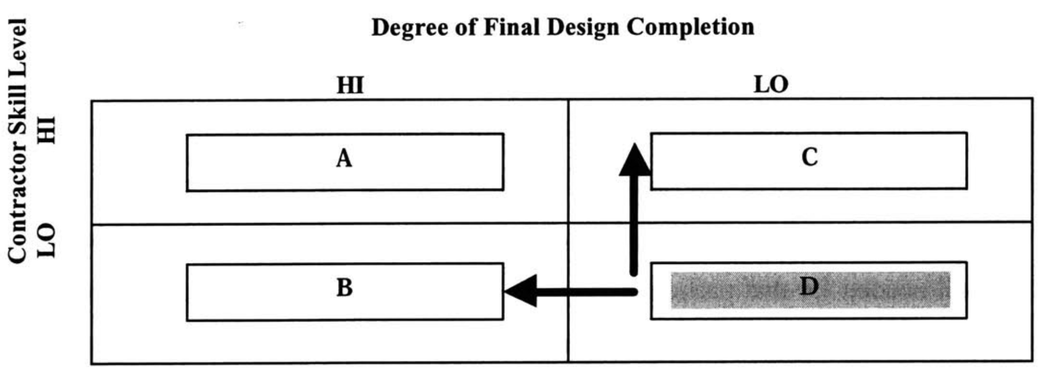
This thesis focuses on the construction quality aspect of a new-start transit system. In discussion of construction quality, inspection plays a central role. The current mainland-US model of transit infrastructure construction relies heavily on the monitoring and inspection functions of a quality assurance/quality control (QA/QC) system to ensure quality outcomes. Presuming that a quality outcome is the responsibility of the contractor, QA/QC is meant to control inputs (i.e., quality of materials) and outputs (i.e., products of work) of the construction process. A considerable amount of time and money has been invested in developing, studying, recommending and establishing various quality improvement schemes, including systems such as total quality management systems (TMS), ISO 9000 quality assurance standards, and global benchmarking practices (Mrawira et. al, 2002, Bubshait et. al, 1999, Jaafari 2000). The models of quality control and quality assurance assume, however, that the construction industry has the capacity to perform its functions, i.e., that a qualified labor pool already exists and must therefore only be monitored to ensure conformity to specifications .

Construction quality is primarily left out of technology transfer discourse. Technology transfer discussions tend to ignore the low-skilled construction laborers who perform the initial construction work, although much literature exists on knowledge transfer schemes aimed towards managers and management processes. Construction quality, however, is an important meeting point between public and private objectives. In the case of transit system construction, the transfer of knowledge benefits both the public sector (usually with governments as the client-owner and commissioning agent of a transit system) and the private sector (the engineering, architecture, construction contractors and sub-contractors commissioned to design, build and sometimes operate or maintain the transit project). For the public sector (i.e., government), knowledge spillovers are sought to upgrade the productive potential of the citizenry, which can then lead to economic development and growth for the society as a whole. For the private sector (i.e., contractors), knowledgeable design and management professionals and workers are sought to increase organizational productivity and quality levels, which can then translate into improved performance in meeting cost, time and quality targets necessary for profitability.

Procurement strategies influence the overall management and organization of construction project delivery, which affects the types of skills necessary for contractors and the government. The conventional procurement strategy for large transit infrastructure projects has been a design-bid-build, where a complete design is established before the project is put out for construction contractors to bid upon. An alternative procurement strategy, design-build, has gained consideration within the last ten years, and provides as little as 10% of a design before putting the project out to bid. With more of the onus on the contractor for the design, as well as construction of the project, a higher degree and breadth of competence and performance is expected from the design-build contractors. A design-bid-build procurement strategy has a high degree of design specifications at the outset of the project, while a design-build strategy intentionally leaves the degree of design specification flexible to capitalize upon contractors' proprietary competencies and/or to achieve efficiency of fast-tracking (to be discussed further in Chapter Two). But the relative responsibility for skill training is usually not explicitly stated. Rather, the relative responsibilities for training and developing a skilled labor force is implicitly assumed.

In this thesis, a framework for understanding when, how and why certain types of training did and did not work will be established. Figure 1.1 below illustrates the framework:

Figure 1.1: Skills-Design Specifications Framework



Boxes A and B illustrate situations where the specificity of design is high. This is usually the case for design-bid-build. The construction outcome is primarily dependent upon the design specifications, and the contractors' abilities to conform to the pre-established details.

Boxes C and D refer to situations where complete designs for the project as a whole, i.e., sum of the parts, have not been pre-established as in design-bid-build. In design-build, construction is allowed to begin before 100% of the complete designs have been approved. This does not, however, translate into an endorsement for beginning construction on components of the project without a design. Rather, the procurement strategy allows for construction to begin on portions of the project which have complete design already approved by the client-owner, even while other portions of the project may still be in the design-approval process. Theoretically, then, design-build should also have high specificity of design before construction of individual components, although the aggregate whole is not at 100% design completion.

This thesis argues that the design-build strategy assumes high level skills of contractors and workers (Box C). In the case of low level skills of contractors (Box D), the effective strategy would be to either move them up vertically to the realm of Box C by intensive and effective training programs, or to move them over horizontally to the realm of Box B by changing guidelines on the degree and breadth of complete designs necessary before construction begins. Since the focus of the thesis is skills training on the work site, the relevance of different procurement strategies is how those procurement strategies may affect the need and/or training provision of work site skills.

Table 1.1 contrasts the two procurement strategies and an associated skill level needed according to the stage of the transit construction (design, construction, monitoring/inspection, and project oversight control) and actor (client-owner, contractor management, construction labor). The four stages of transit construction – design, construction, monitoring/inspection and project oversight control each identify the type of skill needed for that particular stage. The stage and skill, in turn, are broken down into the relevant actors of client-owner, contractor management and construction labor. Although the type of skills needed do not vary much, which actor possesses the expertise does vary according to the procurement strategy and the assignment of responsibility.

Table 1.1: Procurement Strategy and Associated Skills

Stages in Transit Construction	Major Skill Needed	Actor	Procurement Strategy Level of Skill Needed: Design-Bid-Build	Procurement Strategy Level of Skill Needed: Design-Build
Design	*Architecture/ Engineering Skill*	*Client-Owner*	***Very High:*** Provides 100% design specifications.	***Low:*** Provides <100% design specifications
		Contractor Mangage-memt	***Low:*** Not necessary; potential to change design specifications through value-engineering	***Very High***: Necessary to innovate and complete design specifications to 100%
		Construction Labor	-	-
Construction	*Trade/Craft Skill*	*Client-Owner*	***Moderate:*** Restrain payment schedule to match construction compliance	***Moderate:*** Restrain payment schedule to match construction compliance
		Contractor Mangage-memt	***Moderate:*** Just implement 100% design specifications	***Very High***: Necessary to innovate and complete design specifications to 100% for quality construction
		Construction Labor	***High:*** Emphasize construction supervision to implement 100% design	***Very High:*** Emphasize construction supervision to implement 100% design or need to exercise judgment with incomplete design
Monitoring/ Inspection	*QA/QC Skill*	*Client-Owner*	***Very High:*** Reliance upon on QA/QC to monitor conformity to design specifications	***Very High:*** Reliance upon on QA/QC to monitor conformity to design specifications
		Contractor Mangage-memt	***High***	***Very High***
		Construction Labor	-	-
Project Oversight Control	*Management Skill*	*Client-Owner*	***High:*** Necessary to coordinate contractors and conformity to specifications Restrain payment schedule to match construction compliance	***Moderate:*** Reliance upon single contractor entity to perform coordination functions Restrain payment schedule to match construction compliance
		Contractor Mangage-memt	***Low***	***Very High:*** Necessary to coordinate all subcontractors and functions
		Construction Labor	-	-

While training alone does not assure quality, it is an influential enabling mechanism to aid managers and laborers to improve their productivity and efficiency for the benefit of an organization in particular, and a project in general. In the development of transit systems, the match-up between a particular procurement strategy and the local level of skill capacity is crucial. In deciding on a procurement strategy which maximizes the quality of construction in a new transit system, the client-owners should also assess a) the existing level of local construction experience, or b) the capacity to train the construction management and labor pool where the project is located. After this initial assessment, the procurement strategy should be either a) consistent with the capacity/ level of experience of the labor pool, or b) ensure appropriate training support for the labor pool.

1.3 Methodology

The methodology for this study consists of two main features. First, a brief review of the main theoretical literature is reviewed (Chapter Two). A discussion of the construction industry and its impact on the general economy of a society is followed by an overview of a conventional and an innovative project delivery/procurement strategy, and the quality control/quality assurance systems utilized. Finally, potential for local capacity development through training offered through existing public education systems, professional associations and labor union, and a collaborative provision between the public system, private contractors, professional associations and labor unions is reviewed.

Second, the case study approach is used to compare the quality construction records and training experiences of the Alignment Section Contract (ASC) Contractors in the Tren Urbano project. All the contractors operated under similar conditions, yet their work yielded different levels of outcomes. Within the case study, an assessment of the Puerto Rican context for a new transit system is made (Chapter Three). This includes the Puerto Rican construction industry experience, the educational/vocational opportunities, and professional associations and labor unions function in training. Then a review of contract clauses addressing training and contractor performance is made.

The Tren Urbano Case is then summarized and analyzed relative to the framework established in preceding chapters (Chapter Four). Information and data were collected through interviews via phone, e-mail, and in person, of project managers of the Tren Urbano/PRHTA and primary contractors, quality assurance/quality control managers, STT commissioning managers in charge of integration and interface issues, technology transfer managers and interns, international infrastructure development project consultants of World Bank, Inter-American Development Bank, and lawyers of the Tren Urbano Contracts. The performance of each ASC Contractor is assessed based on the percentage of work completion to date, and the number of non-conformance reports. The analysis of performance outcomes addresses three components: 1) degree of design completion; 2) explicit training programs (formal, limited and informal) and who provided it (private sector joint-ventures); and 3) the type of training that was successful and unsuccessful.

1.4 Scope

The focus of this research is on the construction work on-site. While many complaints about construction quality of Tren Urbano have been made, little analysis has been done on identifying why systematic mistakes continue and how to avoid recurrence in the future.

This research will not look at the indirect effects of an urban rail system as a catalyst for increased labor mobility and access to jobs (Buentello, 2000), or at transportation as a pre-cursor to economic development (Coloma, 1998). Instead, the research will identify how increasing the technical capacity of even a few local Puerto Rican contractors will have positive implications on the Puerto Rican construction industry as a whole. This research will not emphasize knowledge upgrading for mid and upper level engineers and managers within the construction of the Tren Urbano project because an established technology transfer program has already been targeted to them for advancing their skills. Similarly, this research will not emphasize the upgrading of government capacity in order to operate and manage the growing San Juan transit system because previous work has already been accomplished on this topic related to Tren Urbano (Ardila, 2001).

CHAPTER 2

THEORETICAL CONTEXT

It's tough. Workshops, information dissemination; there are so many issues. But it's the nature of the best of design-build. You have to make changes as you go along… there are disagreements, but there is dialogue.
- Steve Roescher, Siemens Project Administration Manager

CHAPTER OVERVIEW

In this chapter, I make a case for why knowledge-transfer can meet the profit motives of the private sector and the economic development motives of the public sector. First, I discuss the role of technology transfer in the economic development objectives of developing countries, followed by an overview of the potential economic impacts of construction industry investment. Second, I review the literature on construction project delivery systems and procurement strategies, with an evaluation of the strengths and weaknesses of design-bid-build and design-build. Third, I define and discuss the quality assurance/quality control system for monitoring and inspecting construction. Fourth, I make the case for why the conditions of a new-start transit system require a corresponding strategy for local capacity development. Within this section, I discuss the role of general education versus specific training, as well as review the potential resources for skills training provision. Emphasis is placed on the role of labor unions and associations, and other apprenticeship types of programs. Finally, I show what the motivations for local capacity building for the public sector, private sector and labor unions are, as well as how training should be a collaborative effort.

2.0 Introduction

The public and private sector share a common desire to realize a return on any significant investment they make. A private sector investment must be profitable enough to yield a financial return higher than the cost of the investment. The public sector, though also interested in a profitable investment and a primary interest in achieving high quality infrastructure and reasonable operation and maintenance requirements, plays an additional role as the guardian of the public good. Thus, it often seeks to realize social returns that do not readily translate into a monetary value, as well as to maximize positive externalities. On the basis of quality assurance, then, the role of training and skills development may suit both typically private as well as public sector goals. Knowledge-transfer, thus, can meet dual objectives: on the one hand, it can ensure a better quality product which can translate into more profitability, while on the other, it ensures local capacity development and potential investment for future economic opportunities. In order to maximize benefits to both the private and public sector, knowledge and skills transfer must be carefully managed.

2.1 Economic Development Objectives

Large infrastructure projects such as the Tren Urbano major rapid rail transit system provide a laboratory to investigate the dual objectives of the public and private sector and their interaction. While the public sector –the FTA and PRHTA –and the private –the various contractors and subcontractors in the construction, maintenance and operations of the system –share the goal of establishing a well-functioning rail system, the unique circumstance of Puerto Rico presents an interesting host of challenges. While a U.S. Territory, the island has many features similar to other transitional and developing countries around the world. Thus, like other developing countries, the Government of Puerto Rico seeks to glean whatever knowledge she can from foreign investors for the improvement of the conditions and capabilities of her citizens.

While theories of development for middle to low-industrializing countries remain diverse, technological innovation and education are commonly cited in development strategy literature (Amsden, 2001, Baumol and Wolff, 1996). An "advantages of backwardness" argument posits that imported goods from advanced countries offer a direct transfer of information on new technology to a "backward" country (Baumol and Wolff, 1996, Tran, 1988). The theoretical debates continue, however, with counter-arguments that such statements merely cloak the free-trade agenda of capitalist, developed world economies. Regardless of which camp one lies theoretically, economic growth in the midst of a very real, globalizing market implies that the receipt and adaptation of new technologies are imperative to economic survival, as well as industrialization and economic development.

For developing and transitional economies, access to new technologies and associated processes usually arrives through the dissemination of foreign technologies rather than through domestic innovations. Traditional technology transfer literature posits that the foreign technologies, however, are not limited to the mere transference of physical systems from an original user to a secondary user, but also includes the knowledge base which undergirds the creation, operation, and innovation of that physical system.

One of the motivating factors behind technology transfer schemes is that recipients would learn new technical processes and develop a capacity to attain a greater level of innovative capabilities. Amsden (2001) breaks technological knowledge into two categories: know-how and know-why. Know-how types of knowledge include production capabilities (i.e., design, manufacturing, low level operation and maintenance) and project execution capabilities (i.e., engineering, operation and maintenance, management capacities). Know-why types of knowledge include more advanced innovation capabilities that embody research and development (R&D). Such "knowledge-based assets" are the foundation of many globalizing firms and industrializing country strategy (Amsden, 2001). The following table maps out the logic:

Table 2.1: Levels of Skills – Level of Development

Level of Economic Development	**Level of Skill in an Industry**
Dependency	Foreign workers necessary for establishment and maintenance of the foreign technological system
Subsistence	Enough skills for local operation but nothing more; not necessarily reliant upon foreign workers
Innovation, independence, exporter	Learning takes place, and expansion on given skills for new creations; majority are local workers

As the scheme outlined in Table 2.1 describes, movement from dependency to subsistence to an innovative economic position has a corresponding level of skill associated within an industry, as well as composition of experienced foreign workers and newly-skilled local workers.

Technology transfer schemes are limited, as they traditionally focus upon an educated cadre of professionals of mid to upper management levels. This obscures the often important need for upgrading skills of lower status workers, who are often less educated. Successful transference of information and skills, however, must occur at all levels of production – "on the ground" as well as managerial – for two reasons. First, a better quality outcome will result if knowledge and skills are escalated by labor at all points within the production, or in the case of Tren Urbano, construction process. Second, ramping up low-skilled labor to a higher degree of skill and incorporating more people into the labor force by equipping them to work addresses the overall economic challenge of employment generation for the society as a whole rather than for the select few. For instance, while industries such as the hi-tech sector have a high education and earnings ratio in Puerto Rico, the gap between the high-skilled, high-earnings worker and the low-skilled labor continues to increase. Such a comprehensive measure for knowledge-transfer requires an intentional and strategic intervention to facilitate the process.

2.1.1 Economic Impacts of Construction Industry Investment

Traditionally, scholars have attempted to explain the link between transportation and economic development. Transportation is viewed as one of the factors for the means of production. Thus, a better transportation system can lower the costs of transporting both material supplies, and labors' access to work (Ardila, 2000, Buentello, 2000). Similarly, the construction phase of a transportation system, especially a large-scale, multi-phase, technologically advanced rapid rail transit line, is also an important stimulant to economic development. The construction phase of a project consists of physically building the transportation infrastructure, including the manufacture and installation of any subsystems, as well as testing for proper functioning (Lee, Sheehan and Mattson, 1995).

Construction can be linked to economic development in three ways. First, construction has an indirect effect on the economy due to its influence on the profitability of the transit system. A poorly constructed transit system can diminish profitability by generating increased costs in the short run (due to rework) and in the long run (due to higher maintenance needs). Similarly, a poorly constructed transit system may discourage potential riders either because it is perceived to be poor quality and therefore unsafe, or it actually does not function properly. Second, construction can stimulate employment generation. While it may not be the most widespread source of new jobs in the long term, it is nevertheless a crucial source. Construction jobs are temporary and seasonal, for they disappear once the facility is completed. Conversely, construction jobs provide opportunities for otherwise unemployed laborers to join the formal labor market or ramp up on their skills and productivity (Coloma, 1998). Third, the increased input of technical skills into the construction industry can instigate further growth of that sector for future infrastructure development and capabilities to do similar projects domestically, or as an export that industry. It is important to absorb new skills in order to develop the capability to innovate.

2.2 Construction Project Delivery System/Procurement Strategies

Increased public-private management of large infrastructure projects has brought greater private sector influence upon the delivery of infrastructure projects. Increased pressure to maximize a return on investment by maximizing efficiency and minimizing costs has created a renewed interest on various aspects of improving the efficiency, as well as quality, of infrastructure projects. As Mrawira writes, 'The key motivation for public-private-partnership delivery mechanism includes an unprecedented increase in the demand for infrastructure, the shrinking of public funds relative to infrastructure renewal and upkeep needs, and the potential for increased efficiency in private sector operations." (Mrawira, et. al, 2002).

2.2.1 Conventional: Design-Bid-Build

Design-bid-build is the conventional project delivery system where the client-owner contracts separately with a designer and a constructor (Konchar and Sanvido, 1998). Traditionally, the design must be complete before bids for construction can be solicited. Transit infrastructure in the US has traditionally been built using design-bid-build. In this strategy, the transit property client-owner hires an engineer to completely design a project, usually including stations, tunnels, systems and line sections. The completed designs are then put out for construction firms to bid, with the lowest-price bid usually winning the contract. Such a process is considered to ensure responsible, accountable engineering and as fair and transparent contracting process as possible.

Strengths

The design-bid-build strategy specifically provides more opportunity for the client-owners' control and input over design. A transit agency requiring a high degree of specificity for station or above-ground structures, may seek to maximize quality by exerting a great amount of control over the design. In such a case, design-bid-build would allow the agency to exercise the most direct and simplest amount of control over the design specifications.

Weaknesses

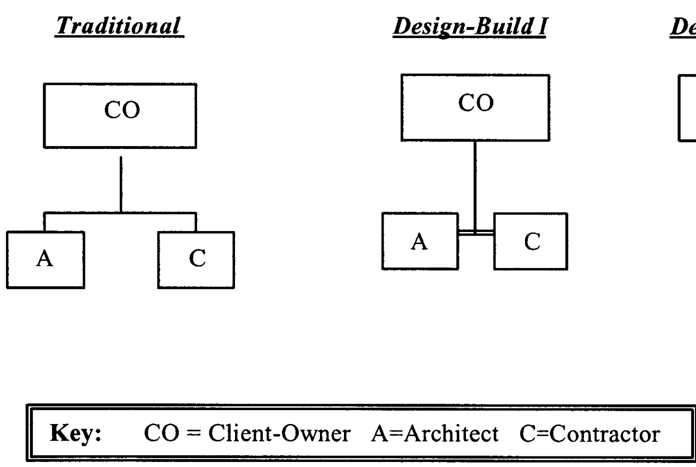
The high level of design specificity before bidding in a design-bid-build contract, however, also has its drawbacks. Information sharing and interaction usually occurs at the end of the design phase, with each separately contracted firm focusing entirely on its assigned portion, whether it be design or construction. With the increasing specialization of services, however, some observers conclude that this has been found to lead to "inefficient designs, increased errors and disputes, higher costs, and ultimately longer schedules." (Konchar and Sanvido, 1998, 435)

2.2.2 Innovative: Design-Build

Design-build has traditionally been a popular contracting methodology for the private sector. Within the U.S., design-build has been used within the auto and housing construction industries (Smith, 2002). The design-build experience has had limited usage within transit infrastructure, being limited to the procurement of large highway and bridge projects (Konchar and Sanvido, 1998). While a common project delivery method for transit construction in Europe and Asia, the U.S. experience has been limited. Recently, however, the U.S. Congress enacted specific authorization enabling federal contracting offers to use design/build for construction in the public sector.

In its most pure form, design-build is a project delivery system where the client-owner contracts with a single entity to perform both design and construction functions in a single design/build contract (Konchar and Sanvido, 1998). The contrast in methods of project delivery between traditional and design-bid are described in Figure 2.1 below:

Figure 2.1: Comparison Project Delivery Methods



Source:Mike Smith, Architect for Equus Group, 2002.

In a traditional project delivery mechanism, the client-owner contracts separately with an architecture firm for design, and a contractor for construction. In design-build, however, the client-owner contracts with a single entity, which will have the sole responsibility and accountability for both the design and construction of a project. The single source of responsibility can exist in a company which has both architecture and contractor functions in-house (Design-Build I above), a contractor who then subcontracts an architecture firm (Design-Build II above) or an architecture firm who then subcontracts a contractor (Design-Build III). Of the three design-build variations, the

Design-Build II model is the most common, with the Design-Build III model very rarely ever seen (Smith, 2002).

One form of design-build, design-build-operate-maintain (DBOM), is a procurement strategy where the contractor is given the operations and maintenance responsibilities for a designated number of years. This provides incentive for the contractor to design and construct with the longer time operations and maintenance prospects in mind, thereby creating a higher quality outcome. Additionally, design-build-operate-maintain establishes a contractor in an area for an initial number of years to help establish a professional capacity for the operations and maintenance of the system.

Strengths

Design-build allows maximum utilization of design documents by allowing the contractor to use as much of the incomplete design as possible while waiting for the finally approved and accepted design specifications to be returned. In design-build, construction can begin on as little as 10 % of a pre-established design, with the contractor given responsibility for bringing the design to completion. This allows the project to proceed under the competitive pressures to avoid delay, thereby increasing efficiency in time and cost savings. 'The lure of these alternative methods lies primarily in their ability to compress the schedule by overlapping design and construction and to create team synergies that can often expedite the project."(Ernzen and Feeney, 2002). In a survey of 351 building projects, Sanvido of the Construction Industry Institute found that design-build projects averaged 33% faster completion than traditional design-bid-build projects (Ernzen and Feeney, 2002).

The touted benefit and strongest motivation for creating a design-build contractual arrangement is because it provides a fast completion at low cost. Some elements of construction do not need 100% design before construction can begin. A decreased staff capacity and personnel available in a transit agency provides an additional incentive to delegate a greater amount of functions to the contractor. Additionally, the containment of responsibility within a single entity is argued to provide greater opportunity to manage interfaces in various aspects of the design, construction and sometimes even operation of the product or service. Incentives for an accelerated schedule and economies of scale are also projected benefits of a single entity for turnkey contracts.

Weaknesses

A discussion of design-build as an appropriate procurement strategy for transit system construction has led to an influx of recent studies. A delegation of representatives from the International Transit Studies Program conducted a study of Asian Infrastructure projects using the design-build strategy (Stark, 2001). They find that projects in areas of unknown or difficult environmental conditions may prove to be very expensive due to the amount of the contractors' price attributed to risk, while projects in well-known conditions where risk allocation is low may be the most optimal conditions for innovation in design and methods (Stark, 2001). Environmental conditions include civil engineering elements such as ground conditions and development density, as well as political and community relations factors as well. The Stark study concludes that larger or single design-build contracts with multiple contracts create interface problems which may negate the "savings inherent" in the design-build method.

The literature appears mixed on what are the most appropriate conditions for design-build to work. On the one hand, simple designs where innovation is desired, and where construction conditions are known are seen as the less-risky environment for greater risk opportunities to be taken (Stark, 2001). On the other hand, design-build is meant to maximize contractor flexibility and responsiveness to avoid lengthy design reviews and approvals for unknown conditions. What seems problematic or dubious, however, hinges upon the assumption that a long term construction program has developed a competent, stable, and professional workforce that is up to the task of innovation and less-controlled design specifications.

The successful use of design-build hinges upon the coordination of all the components within the design and construction process in order to minimize the incidence of claims due to errors and omissions. If each of the individual components is functioning properly, and communicating as well as coordinating well with the other components, a synergy results. For instance, the level of interaction between design and construction is critical to the execution of a design-build contract. If there is little communication or coordination, the potential to have inappropriate designs lead the construction effort can result. The inappropriate designs could be due to either a lack of construction site information flow going to the designer, or, the commencement of the work without final design approval.

2.3 Quality Control/Quality Assurance (QA/QC)

With the multiplicity of actors and complexity of contracts within a design-build procurement system, a mechanism to ensure quality becomes all the more important. A quality control management systems provides a system of accountability by the client-owner to the contractors, as well as a device for monitoring the work of several actors.

Mrawira et. al (2002) identify the primary actors involved in most public-private partnerships in highway mega-projects as the client-owner (public), agent of the client-owner (private), project developer team comprised of financiers, designers, builders, and an operation and maintenance company (private). "Given the diversity of the parties and ensuing complexity of the contractual relationships, a quality management system becomes extremely important,"(Mrawira et. al, 2002).

Definition

Quality has been defined as "the conformance to established requirements" which includes meeting the satisfaction of the user, client or public (Mrawira et. al, 2002). Quality assurance is important to avoid inefficiencies or other deviance from the specified standards of the project. According to Bubshait and Al-Atiq (1999), a quality management system is an internal quality system which executes activities "aimed at providing confidence to the management of an organization that the intended quality is being achieved" while a quality assurance system is an external quality system which executes activities "aimed at inspiring confidence in the client that the supplier's quality system will provide a product or service that will satisfy the client's quality requirements." According to the American Society for Quality Control (ANSI/ASQC Standard Q90-1987) and FTA QA/QC Guidelines, the definitions for QA and QC are (Enfiedjian et. al, 1997):

- *Quality Control* – the operational techniques and activities that are used to fulfill requirements for quality, i.e., techniques to ensure that products or services meet the specified requirements and goals. QC techniques include measuring, testing, inspecting and documenting processes or products such as specifications, manufactured equipment or constructed items.
- *Quality Assurance* – all those planned and systematic actions necessary to provide adequate confidence that a product or service satisfies given quality requirements. QA activities include ensuring project requirement development to meet the needs of relevant agencies, planning processes to assure quality, assuring equipment and staffing capabilities to execute project quality tasks, ensuring contractor capability to execute quality requirements, and documentation of all such efforts.

Quality Control tends to be comprised of field inspectors who check that engineering requirements are met and conformity to specifications are ensured. Quality Assurance tends to be comprised of managers who develop, institute, and assure that activities are geared to ensuring quality outcomes.

Non-conformance to established specifications or a poor quality facility result in increased short-term costs of time and finances for penalty fines and correction for the unacceptable work; long-term costs of increased maintenance and repair of reduced safety or premature failures and loss of user satisfaction can also result.

The assumed norm of the contractor is that "doing the job right the first time" would be more profitable, and the QA/QC functions would provide only a secondary accountability and check mechanism that would "rubber-stamp" effective progress on a work product. Some processes add value to a project, while others provide little to no value relative to the output of the process (Kirmani and Blaxall, 1988). Value-added refers to the difference between the value of a constructed product and the value of materials and services purchased from suppliers. Bubshait and Al-Atiq (1999) identify delays in processing, temporary or permanent storage, inspections and rework as non value-added activities, with value-added processes being defined when a noticeable change desired by the customer occurs, a customer would pay for the extra work, or the activity is done correctly the first time. From a contractor's perspective, then, it would appear that "doing the job right the first time" being a value-added activity would be preferable to retroactive rework which is a non value-added activity.

In a turnkey project, QA and QC responsibilities are assigned to the contractor, who in turn must prepare a Quality Program Plan to be approved by the client-owner. In the US, the approved program must conform to FTA guidelines and include any work of the subcontractors (Enfiedjian et. Al, 1997). This, then, is incorporated into contract documents. With the burden of quality control and assurance on the contractor, the client-owner's role in ensuring quality is that of "quality oversight".

2.4 The Conditions of a New Transit System

In the development of transit systems, the construction industry often experiences problems of cost overrun, time delay and/or sub-standard quality work. The construction of new-start transit systems is more complex than extensions to existing systems because all the inputs of the system must first be established. A first-time population of designers, constructors, operators and maintenance crews of a new transit system face the challenge of learning an innovative technology. Improvements in cost, time and quality goals are dependent upon increased productivity and quality levels of management and labor. Improvements to management and labor performance, in turn, are dependent upon the identification and development of enabling factors and attributes which help them to function better. Yet, the literature often studies labor issues based on quantitative analysis of productivity due to equipment improvements (Koehn and Atuahene, 1994), with little mention of the need for how to equip people to use the equipment, as well as other appropriate proceesses and techniques. Therein lies the role for local capacity development through training.

2.5 Local Capacity Development

The growth in sophistication and technology of the construction industry requires a growth in technical skills, as well as many other skills associated with more complex jobs: risk management, marketing, financial control, competitive bidding, protecting contractual rights, managing labor, and training the workforce (Kirmani and Blaxall, 1988). As an official at the World Bank puts it (Kirmani, 1988, p.7),

> The most striking feature of the industry is the division of production responsibility among many participants –owners, designers, contractors, subcontractors, material suppliers, equipment dealers, funding institutions and services such as transport, electricity and water. These participants perform various functions and belong to different organizations with different policies, objectives and practices. In this situation, the contractor is primarily a resource manager of men, materials, equipment, money and time, and a coordinator of the activities of many participants who are not directly responsible for the final product and over whom he has little control.

Jaafari argues that in the construction industry today, there needs to be a shift in emphasis from project quality management to construction organization performance, with special attention paid to the organization and human factors of the construction company (Jaafari, 2000). Opportunity for skills development occurs at every level and every phase of a construction project: management of the organization, quality assurance. This can result in accrued benefits to the project's constructed outcome and accrued benefits to the companies doing the work.

A long-term program for capacity-building in the construction industry, and the short-term project goals of construction completion are interdependent. Some argue that developing the construction industry is necessary for the host economy, and should thus be program-based rather than project-based (Kirmani, 1988). A program involves a public strategy involving actors from a variety of institutions in the private and public sectors, as well as leaders who have a vision and a strategy. At the same time, a private sector contractor must still meet his profit goal for the specific project. Training for project-specific activities should be incorporated into institutional development for longer-term development of the industry. Although training may be valued by an innovative contractor to increase his competitive advantage for future projects, it is more likely the government's objective to ensure the provision of training.

Incentives to invest in formal training in the construction industry are low, due to the variance in requirements of skills for different jobs and the transience of the labor force needed to do the job. The nature of construction work, as well as the necessary skills create a myriad of challenges to develop the construction industry. The skills needed range from technical concerns such as how to build in soil and weather conditions cheaply and quickly, masonry work, placing concrete, formwork, power distribution lines, maintenance and repair, to management concerns of multiple stakeholders involved in a project with a diverse workforce. Acquiring the skills within the construction industry can be slow in coming, often through "learning by doing" through a variety of construction jobs (Amsden, 2001). Appropriate channels for training in construction, then, can not be limited to just one sector.

2.5.1 General Education vs. Specific Training

According to Jaafari (2000), general education, skills and aptitude and specific training for specific purposes are two differentiated yet key aspects of training and education that are critical to building a successful construction business. He argues that the education system of the locale supplies the general education to create a skilled and trained workforce to the industry, and should remain the responsibility of universities, technical and vocational colleges, trade schools and apprenticeship schemes. Specific training, however, is needed to create a more dynamic and responsive organization to meet the needs of a competitive construction industry.

A basic education provided by the public sector (i.e., K-12) can increase the aptitude for learning and an individual's capacity to absorb new and complex information, while specific skills training provides the technical competence for very specific tasks. More formal schooling increases the basic learning skills and trainability of an individual. This translates into a higher "absorptive capacity" of an individual for skills training (Amsden, 2001). Increasing the absorptive capabilities of a citizenry lays a foundation for potential private sector investment to locate in an area for skilled labor.

2.5.2 Public Provision of Training

Existing federal programs may be a valuable resource for training in partnership with the private sector. The U.S. Department of Labor, Employment and Training

Administration, Office of Apprenticeship Training, Employment and Labor Services (OATELS) has created Apprenticeship programs to "stimulate and assist industry in developing and improving apprenticeship and other training programs designed to provide the skilled workers needed to compete in a global economy."(US Department of Labor, OATELS, 2002).

Established under the National Apprenticeship Act of 1937 (Fitzgerald Act) and amendment 50 Stat. 664, and 29 U.S.C. 50, the legislation promotes labor standards of apprenticeship. Sponsored by joint employer and labor groups, individual employers, and/or employer associations, apprenticeships combine on-the-jobtraining with related classroom instruction for high-skill occupations. A schedule of wages for the apprentice is progressive according to satisfactory completion of related instruction and on-the-jobtraining, based on the journeyworkers'hourly wage of the apprentices' occupation, with a maximum wage of 85-90% of the journeyworker rate. Completion of a one to four year apprenticeship (ranging from 2000 to 8000 hours) results in the earning of an Apprenticeship Completion Certificate, making the apprentice a recognized and qualified journeyworker within the United States.

Programs registered with OATELS must meet the established requirements. An apprenticeship Agreement between the apprentice and sponsor is a signed commitment by the apprentice to perform the required work and study and by the sponsor to keep the apprentice employed and to comply with program standards. Components of the program include:

- Structured, supervised, on-the-jobtraining by a skilled craftsperson
- Supervisor reviews, evaluates, maintains records of the apprentices' job performance
- Required, supplemental related instruction, with 144 hours minimum for each occupation through trade, industrial or correspondence course or self study approved by the registered agency

The Bureau of Apprenticeship and Training (BAT) registers programs and apprentices in the states where no other agency has been delegated the authority to do so. Delegated authority to register apprenticeship programs by the Secretary of the US

Department of Labor, a State Apprenticeship Council (SACs) also has the responsibility to protect the welfare of the apprentices, "ensure quality and equality of access to apprenticeship programs and provide integrated employment and training information to sponsors and the local employment and training community."(OATELS website) 27 States, the District of Columbia, the Virgin Islands and Puerto Rico have SACs while the remaining 23 states are BAT jurisdictions. The registered apprenticeship is "a voluntary industry-driven training program". Employers are eligible for the program with or without labor union participation. Individuals are eligible to become apprentices if they are at least 16 years old and meet program sponsors' qualifications.

In addition to the U.S. Department of Labor efforts, the National Skill Standards Board (NSSB) was created in 1994 by business, labor, employee, education, community and civil rights organization leaders to "build a voluntary national system of skill standards, assessment and certification systems to enhance the ability of the United States workforce to compete effectively in a global economy" (NSSB website, 2002). According to the NSSB, the provision of training for construction labor has been limited. It states,

> Traditionally, the position of laborer has been considered at or near the bottom of the construction industry when it came to formal training, prestige, and wages. *The vast majority of construction laborers have learned the required skills through informal on-the-job training provided by supervisors and more experienced workers.* Historically, neither technical schools nor community colleges have offered much in the way of training programs for construction laborers. And it is only within recent years that formal apprenticeship training has become available for construction laborers, including a registered apprenticeship program for construction craft laborers offered by the US Department of Labor, Bureau of Apprenticeship and Training (BAT). (italics mine, NSSB website, 2002).

In an attempt to address the increasingly complex needs of an increasingly sophisticated construction industry, the NSSB has categorized the workforce into fifteen industry sectors, and established an apprenticeship program for craft laborers in a variety of specialized tasks.

The BAT Construction Craft Laborer Apprenticeship Program requires 4000 hours of on-the-job training and experience, as well as supplemental technical instruction through classroom instruction, correspondence study, or home study. The employer is required to provide a progressive wage schedule reflecting the additional skills gained throughout the apprenticeship. 4000 hours of on-the-job training must be accrued for successful completion of the apprenticeship program. 1600-2000 hours must be spent on the acquisition of general construction skills, and 2000 to 2400 hours must be spent on the acquisition of specific construction skills. As of March 2002, other NSSB identified certification/apprenticeship programs for construction include:

- bricklayer and stone masonry work
- heavy industrial an commercial carpentry
- concrete and terrazzo work
- crane operators
- electrical work
- equipment operation, maintenance, and/or repair
- glass and tile installation
- heating, ventilation, air conditioning, and refrigeration,
- highways, streets and roadways,
- occupational health and safety
- special trades including plumbing, roofing, sheet metal, structural steel, surveying and welding

In the formal schooling realm, vocational schools provide instruction in techniques of a trade. While criticism of an impractical curriculum may exist, the benefits of public provision of trade-specific training include wider access to the training across a region, as well as a standardized skill set which can be verified through certification.

2.5.3 Associations and Labor Unions

Kirmani (1988) argues that the reason why contractors do not invest in formal training outside of the construction work is based upon the logic of a well-functioning apprenticeship program. Apprenticeship models provide a mutually beneficial arrangement for both the employer and the employee. The unskilled and semi-skilled trainees can learn, while the contractor produces while he trains and is able to pay a lower wage due to lower producitivity of the trainee. According to the guidelines for apprenticeship models in the U.S., however, exploitation is avoided by mandating progressively increasing wages corresponding to increased training levels.

A well-functioning construction industry should evolve dynamically, rather than be dictated top-down or un-managed bottom-up. The concerns of the management and implementation of on-site construction, thus, are an integral part of the healthy development of the construction industry. Organized interests through contractor associations and labor unions may not be a detraction as some would argue but a necessary addition to the equation of a healthy construction industry. Contractor associations and labor unions are major stakeholders who have a strong institutional interest in the upgrading of skills, in combination with a practical understanding of the skills needed.

Contractors associations provide an opportunity for contractors of an area to promote the interests of the construction industry. Working in close association with government, educational and training institutions, the professional standards and business ethics of the industry can be developed through such associations (Kirmani and Blaxall, 1988).

In an area where foreign companies enter a local market, local contractors may retain a competitive advantage in the recruitment of labor. Over time, they could weed out workers to retain some of the most highly skilled and best workers on the island. This provides them with local advantage over foreign firms that must enter the island and recruit new workers. Thus, the local contractor retains at least a partial monopoly on the best skilled workers on the island. Labor unions can function as a third party to break the monopoly of one particular entity or employer by providing training to a broader base of laborers. Unions, too, would thus attempt to create its own monopoly on skilled labor, but it is not exclusive to one particular company.

2.6 Provision of Training Services: A Collaborative Effort

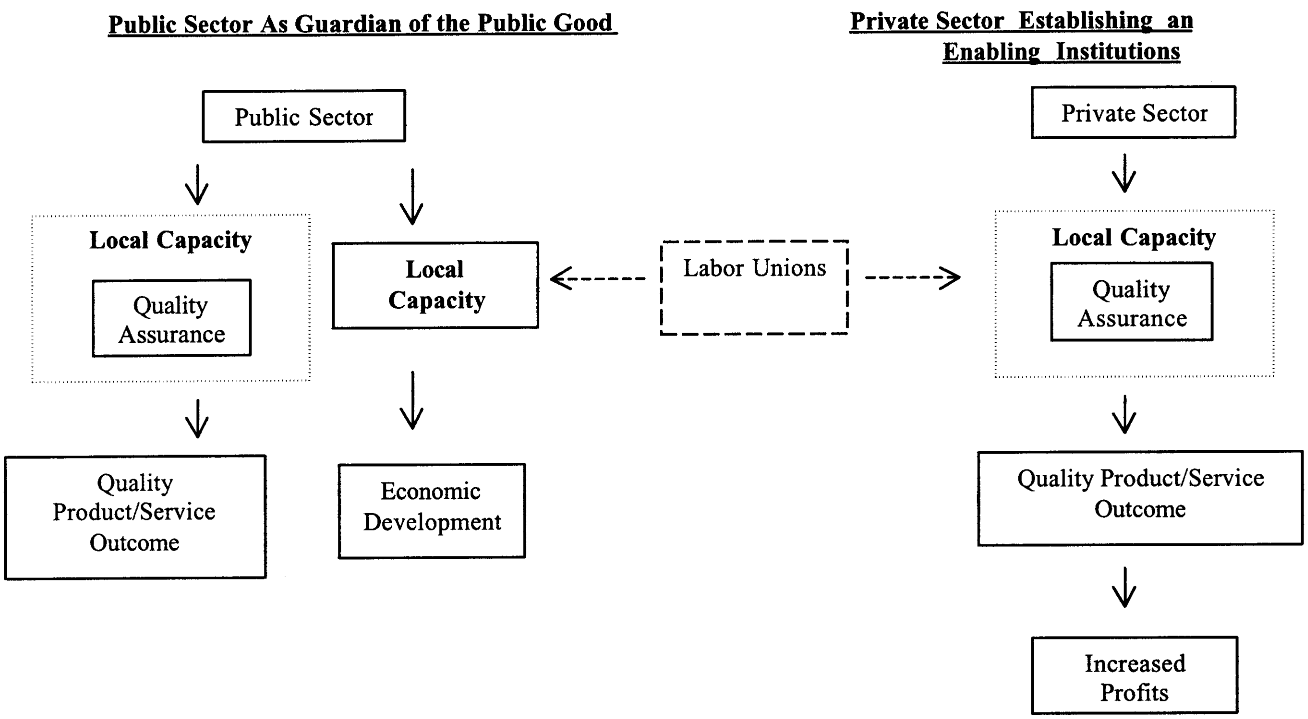
The motivations of the public sector and the private sector may differ, but the importance of training that both can hold in common. The public sector has two end goals: quality service provision, and economic development. Thus, quality assurance and local capacity development can be seen as vital to these two objectives, while it may be sacrificed in the service of quick project completion for political gain.

The private sector must meet its bottom line of profit. This can be achieved through increased profitability due to a better quality of construction which can then translate into a better quality of service. Thus, local capacity development can be seen as one of the many institutions ("enabling environment") and indirect means to helping to assure quality. Alternatively, the private sector can attempt to cut costs and produce a lower quality product with as little investment in materials, workers, or other necessary services.

Contractors who lack experience in the requisite skills for technologically advanced and complex, large projects may gain the important and relevant skills most quickly and cheaply through joint ventures or sub-contracting partnerships with experienced contractors. Collaboration between inexperienced domestic and experienced foreign contractors, as well as between large and small firms is also necessary.

Local capacity-building through the education and training of human capital may serve different functions within the public sector and private sector. For both the public sector and the private sector, local capacity development is most prominently seen as an environmental condition which enhances a process for the assurance of a high quality product or service. Although the public sector seeks a high quality outcome as a means for a quality service outcome, the public sector also seeks local capacity development as a means towards economic development through employee enhancement. Figure 2.2 illustrates the issues below:

Figure 2.2: Motivation for Local Capacity Building of Public and Private Sector



The task of creating construction industry training institutions is difficult because construction involves multi-sectoral activities and does not conveniently fit into any one particular sectoral ministry. Often, the industry is housed within the Ministry of Public Works. Kirmani and Baxall (1988) suggest that an effective institution would have a multi-disciplinary staff with representatives involved from ministries of public works, education industry, finance and planning. As a permanent institution, they argue, the institution should monitor and evaluate the industry activities, policy and strategy effectiveness, and performance indicators of value added, cost effectiveness, quality of work, and completion time.

The private sector may be the primary agent for training because the relevant and practical skills can be immediately implemented, and because employers have a stake in the quality. This can be ensured through the contract mechanism. According to an interview with one Tren Urbano architect, the provision of high-skills training would be better provided through private companies than through public education systems

(Medina, Personal Interview , 2002). He cites reasons of internal promotion as a natural impetus for professional development.

The provision and financing of training must be a collaborative effort by the public and private sectors, as well as with an independent third party of labor unions. Government institutions are necessary to establish a program which incorporates the private sector project visions within the curriculum for training the construction industry laborers. While the public sector has much to offer in education, a close link to industry is vital for the practicability of a general education.

CHAPTER 3

THE PUERTO RICAN CONTEXT

Building the project may be the easy part.
The tough part will be using the infrastructure to build a better community.
- Representative Martin Sabo

CHAPTER OVERVIEW

In this chapter, I assess the Puerto Rican context and conditions for a new-start transit system. First, I provide a general overview of the demographics, history, politics and economic indicators of Puerto Rico. Second, I review the construction industry experience in Puerto Rico, including her recent experiences with design-build, and regulatory constraints placed on quality assurance/quality control. Third, I review labor conditions, including general wage rates, structure of employment, union activity, and the shortage of skilled labor in construction. Finally, I review the institutions available for skills development.

3.0 Introduction

Historically an agrarian region, Puerto Rico has been transformed into a modern industrial society with a high degree of urbanization. Puerto Rico has a land area of 8,876 square kilometers. According to the 2000 U.S. census, Puerto Rico's population was 3.81 million, with 1.4 million people (36%) living within the San Juan metropolitan region. Puerto Rico is one of the most densely populated areas in the world. The San Juan Metropolitan Region has a population density of 3,500 people/square mile, while the capital city of San Juan rivals New York City with a density of 8,500 people/square mile at certain places. The population of the San Juan Metropolitan Area is expected to increase by 20% by 2010 (EIU Country Profile, 2001; Mirandes, 2001; Izquierdo 2001).

The rich population density is combined with highly concentrated patterns of development and a heavily motorized population. 63% of the jobs in the San Juan metropolitan area are within San Juan, with 26% of the jobs in Bayamón, Carolina, and Guaynabo (Mirandes, 2001). The recent increase in economic prosperity has resulted in a corresponding increase in consumption. The 1990 census revealed that 68.5% of households had at least one car, with 25.9% having two or more as of 1989 (EIU Country Profile, 2001). Puerto Ricans own 2.4 million cars, averaging approximately 620 cars for every 1000 people. There are over 150 vehicles per mile of paved road, which is three times more than the continental U.S. The San Juan metropolitan regional core holds close to 4,300 cars per square mile (Izquierdo, 2001). There is high car ownership among low income households.

3.0.1 The Puerto Rican Historical and Political Context

The unique circumstance of Puerto Rico lies in its relationship to the United States as a Commonwealth. Puerto Rico became a U.S. protectorate in 1898 after the Spanish-American war, after which the governor was appointed by the U.S. President until 1948. 1948 brought the first set of direct elections, followed by a vote by a 1952 by the U.S. Congress which proclaimed the official Commonwealth status of Puerto Rico. The present Commonwealth status of Puerto Rico provides for local gubernatorial, legislative and mayoral elections, as well as limited autonomy on tax issues, education, social policies, criminal justice, and other local affairs. Authority over federal matters such as defense, international relations, external trade and monetary policies remains with the U.S. Although Puerto Ricans are U.S. citizens and can move to the mainland as full U.S. citizens with full rights, they do not have the right to vote in U.S. presidential and congressional elections in Puerto Rico, and do not pay federal taxes (EIU, Country Profile, 2001).

The Partido Nuevo Progresista (PNP), which favors full U.S. statehood, governed the island from 1993 to 2000, but was replaced by the Partido Popular Democratico (PPD), which favors continuing status as a commonwealth. The current governor, Sila Maria Calderon, is the first woman governor of the island to date (EIU, Country Profile, 2001).

3.0.2 The Puerto Rican Economic Context

The economy of Puerto Rico is a mixed bag of developing country and developed country characteristics. The economic level is higher than other Latin American countries with a per capita GDP of $9,052 in 1990, but is only three-quarters that of the poorest mainland state of Mississippi (Baumol and Wolff, 1996).

Since 1975, the unemployment level has ranged between 15 and 20% of the labor force, motivating a large emigration of temporary and permanent Puerto Ricans to mainland cities. There has been virtually no restriction on emigration from Puerto Rico to the mainland U.S. Additionally, Puerto Rico has experienced a low level of labor force participation with high and increasing rates of unemployment. The average ratio of labor force to population in Puerto Rico has changed little, averaging around 30% since 1950 in comparison to the mainland U.S. ratios of 40% from 1950-1970, 47% in 1980 and up to 50% in 1990.

Table 3.1: Unemployment and Labor Force Participation

Period	Unemployment rate (%)	Ratio of labor force to population (%)
1950-1960	14.1	29.5
1960-1970	11.6	28.5
1970-1980	15.1	30.1
1980-1990	18.7	30.6
1950-1990	14.9	29.7

Source: From Estudios Técnicos Inc. Macro-economic Database, and Office of the Governor of Puerto Rico, Economic Information for the Governor, 1991 in Baumol and Wolff, 1996.

The average unemployment rate in 1993-1994 was 15%, but most recent data from 1999/2000 reports the unemployment rate to be at 11% (EIU, Country Profile 2001).

Traditionally, Puerto Rico has been heavily dependent upon the mainland U.S. for federal funds for social programs and various incentives for private industrial investment. One such incentive has been Section 936. Section 936 tax credits were added to the U.S. Internal Revenue Service tax code in order to attract investment in Puerto Rico in 1977, but will phase out by 2006. This special provision exempted U.S. firms locating plants in Puerto Rico from federal corporate income tax. Currently, an amendment to Section 936 has been introduced to U.S. Congress, which would create tax breaks for local U.S.-controlled foreign corporations (CFCs) in Puerto Rico; the legislative outcome has yet to be determined (EIU, Country Profile 2001). In addition to the uncertain future of tax incentives for U.S. firms, there is recognition that tax incentives alone are not enough to sustain high rates of growth. Alternative growth strategies are recognized by Puerto Rico as critical components for growth, such as investments in infrastructure, human resources, and technological development.

The standard of living in Puerto Rico has risen. In comparison to most other Caribbean Islands and countries of Latin America as seen in Table 3.2 below, Puerto Rico ranks as one of the largest economies in the region.

Table 3.2 : 1990 Real GDP per Capita of Select Caribbean, Central and South American Countries
(in 1985 international dollars)

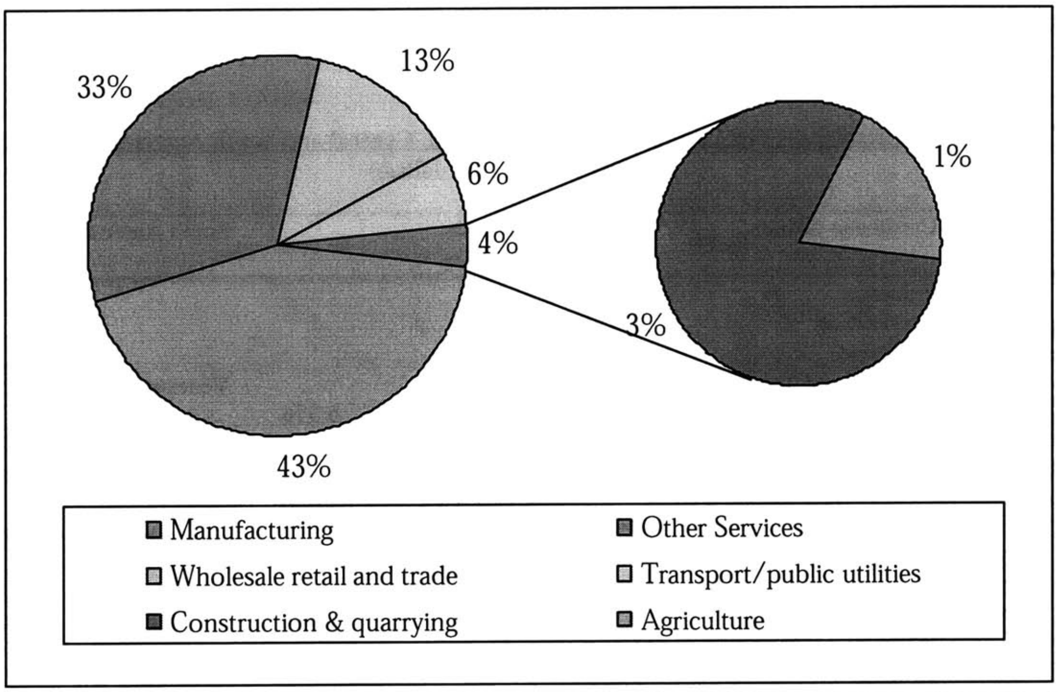
Rank	Caribbean Islands		Central America		South America	
1	Bahamas	12,559				
2	Puerto Rico	9,052				
3	Barbados	7,727				
4	Trinidad and Tobago	8,537			Venezuela	5764
5			Mexico	5,376		
6					Chile	3,988
7					Brazil	3,912
8			Costa Rica	3,616		
9					Argentina	3,505
10			Nicaragua	3,497		
11					Columbia	3188
12			Panama	3,021		
13	St. Lucia	2,689				
14	Jamaica	2,411				
15			Guatemala	2,078		
16					Peru	2,041
17	Dominican Republic	2,031				
18			El Salvador	1,737		
19			Honduras	1,297		

Source: From Penn World Tables Mark 5.5, in Baumol and Wolff, 1996.[1]

[1] The data provided in Table 3.2 are based upon the Summers and Heston information provided for 1990 real GDP of 150 countries. They express the data in 1985 "international dollars" derived from using purchasing power parity (PPP) exchange rates to convert each country's raw GDP figures into a standardized form for comparability. Thus, the real GDP (RGDP) refers to these standardized figures. From 1950 to 1990, the RGDP growth rate for Puerto Rico averaged 3.95% per year, following Japan (5.8%), South Korea (5.74%), Taiwan (5.67%), Malta (5.07%, Portugal (4.23%), Cyprus (4.12%) and Spain (4.04%). The Puerto Rican growth rate in RGDP is almost double that of any of the countries listed in Table 3.2. (Baumol and Wolff, 1996).

According to Economic Data from the Puerto Rico Planning Board, the Economic structure for Puerto Rico has not fluctuated much between 1996 and 2000. According to the numbers for 2000, the top three most important contributors to GDP were manufacturing (43%), services (33%), and retail and trade (13%). Figure 3.1 describes the GDP by sector in detail.

Figure 3.1: GDP by Sector (2000)



Source: From the Puerto Rico Planning Board in the Economist Intelligence Unit Country Profile Puerto Rico: Basic data, 2001/2002

The contribution of the construction sector to GDP has remained constant at 3% from 1996 to 2000. Given its status as one of the largest economies of the Caribbean-Latin American region, the potential to export and become a regional leader is tremendous.

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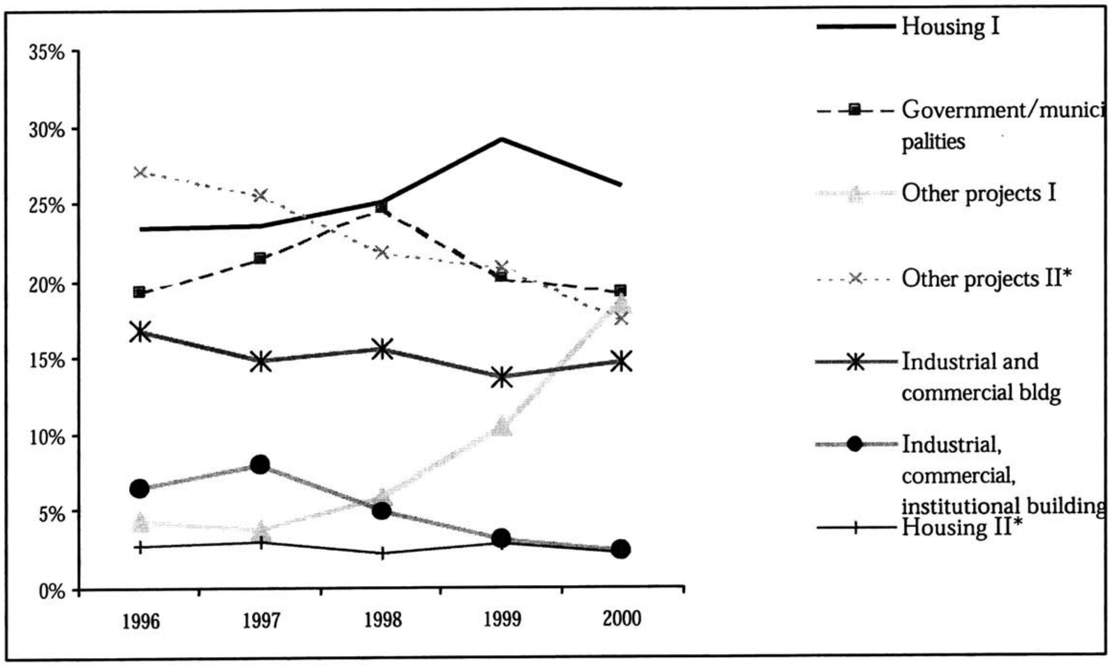
3.1 Construction in Puerto Rico

Although the construction sector was one of the leading sectors of the Puerto Rican economy in the 1950s and 1960s, its importance in the Puerto Rican economy has steadily contracted in the recent decades. Construction comprised 21% of Puerto Rico's Gross National Product (GNP) in 1972, it declined to 5.9% in 1983, growing again to approximately 11% by 1988 (Estudios Ténicos, Inc., 1994).

In the early 1990s, Governor Pedro Rosello and the Secretary of Economic Development and Commerce Luis Fortuno proposed a $7.78 billion government infrastructure program which was allocated to the Puerto Rico Aqueducts and Sewer Authority ($2.4 billion), the Puerto Rico Electric Power Authority ($1.6 billion), the Puerto Rico Telephone Co. ($1.8 billion), Puerto Rico Highway Authority ($1.5 billion), Solid Waste Management Disposal Agency (.62 billion) and the Port Authority ($.28 billion) (GMAEC, 1994). Although Puerto Rico enjoyed a boom in construction in the last half of the 1990s, it has again experienced a slow down in 2001 (EIU, Country Profile 2001).

Housing, public works projects and industrial and commercial building projects comprise the primary construction activities of Puerto Rico. As seen in Figure 3.2 below, housing projects have held the largest share of all construction activities (average of 25%) since 1996.

Figure 3.2: Percent of Different Construction Activities



Source: Data from the Puerto Rico Planning Board in The Economist Intelligence Unit Country Profile Puerto Rico: Basic data, 2001/2002./** denote that the data does not indicate why a differentiation is made between the two "other" and "housing" project categories. One possibility is that one type of activity is from the private sector, while the other is from the public sector.*

Public works projects have primarily consisted of roads and schools. Governor Rosellos' infusion of funds into the infrastructure programs in the early 1990s most probably explains the drastic increase in the "other projects I" portion of construction activity in the above figure.

3.1.1 Design-Build Experience

As described in Chapter Two, design-build is a delivery system where the client-owner contracts with a single entity to perform both design and construction functions in a single design/build contract. Puerto Rico has only a very recent history of design-build experience, primarily in road and bridge construction. The Teodoro Moscoso bridge was built in another innovative procurement approach, Build-Operate-Transfer (BOT) in which the contractor is assigned responsibilities for the design, build and operation of the system similar to the DBOM approach, but is expected then to transfer ownership to the government. Yet, because the design-build experience has been recent, and never used for a technologically sophisticated transportation project, Puerto Rico is limited in its accrued expertise in design-build practices.

3.1.2 Quality Assurance/Quality Control (QA/QC)

The Quality assurance/Quality control method of ensuring quality in project delivery is predicated upon another model of informal apprenticeship structures which hone the skills of laborers within the construction industry. Unless the same kind of apprenticeship structure is institutionalized formally or informally within Puerto Rico, perhaps the QA/QC model also needs to be altered or replaced for future phases of construction. Puerto Rican law states that in infrastructure project procurement, the Quality Control entity must be independent from the construction contractor (Woreby, Phone Interview, 2002).

3.2 Labor

Both U.S. federal and local labor laws are applicable to Puerto Rican firms such as the U.S. minimum-wage law and mandatory fringe benefits (e.g., social security) law (EIU, Country Commerce, 2001).

3.2.1 Wages

The minimum wage since 1997 has been $5.15/hour. Table 3.3 shows comparative figures for hourly wage compensation in Puerto Rico.

Table 3.3: Hourly Compensation

	Min	Avg	Max	Bonus (%)
Executive Secretary	10.62	13.21	15.98	7.4
Group Leader	11.09	13.99	18.8	10.3
Tool and die maker	9.78	11.85	13.96	8.4
Office Clerk	8.09	10.33	12.64	7.5
Materials Handler	7.09	8.41	10	7.5

Source: Puerto Rico Manufacturers' Association, 2000 survey in EUI, Country Commerce Profile, March 2001.Notes: Typical wage and salary for large manufacturing firms in 2000. Fringe benefits are additional.

These figures can be compared to the federal wage determinations for construction. Federal wage determinations issued by the U.S. Department of Labor under the Davis-Bacon Acts determine prevailing wage rates to be paid on all federally funded or assisted construction projects and are listed in Table 3.4 below:

Table 3.4: Federal Davis Bacon Wage Determination for Highway and Heavy Construction Projects in Puerto Rico (March 2002)

	Rates	Fringes
CARPENTERS	5.48	0.5
CEMENT MASONS	5.17	0.47
ELECTRICIANS	5.76	0.8
IRONWORKERS	5.15	
LINEMEN:		
Linemen	5.15	0.84
Telephone Linemen:		
Ground & Pole	5.15	
LABORERS:		
Laborers (unskilled)	5.15	0.43
Pipelayers	5.27	
PIPEFITTERS	5.15	
PLUMBERS	5.55	
POWER EQUIPMENT OPERATORS:		
Asphalt luters	6.74	3.11
Backhoe	8.25	0.59
Bulldozer	6.89	0.99
Crane	6.72	1.43
Diggers	5.91	
Grader	6.78	1.06
Greaser/Oilers	5.51	
Loaders	6.51	0.92
Mechanics	6.17	0.76
Paver	7	3.15
Roller	6.74	3.14
SCRAPERS:		
less than 18 CY	7.8	0.59
18 CY and over	8.1	0.59
Screedman	8.8	3.13
TRACTORS:		
less than 185 HP	8	0.59
185 HP and over	8.1	0.59
TRUCK DRIVERS	5.31	

Source: Federal Davis Bacon Wage Determinations website

Given these comparative figures, the average wage comparison of construction labor at $9-$11 is not "worth it." According to Telly Figueroa, Technology Transfer and Training Manager at Kiewit Construction in San Juan, citizens can earn more off of welfare or other, less labor-intensive jobs for a similar amount of pay (Figueroa, 2002). Tunnel diggers for Rió Piedras earned $13/hour, with double the pay for overtime. According to one electrical installation supervisor in the Tren Urbano project, the highest paid electrician earns $11/hr, while the entry level, uncertified electrician without a license is paid $6/hour (Woreby, Personal Interview , 2002).

Lower wages for construction often implies that the construction jobs will only be taken by illegal immigrants, usually Dominican. Yet, because of their marginal legal status within Puerto Rico, there is little, if any, political protection or institutionalized social service provision for them. With regard to the implication on construction quality, there are two potential choices to facilitate change in the quality of labor recruited for construction: 1) increase wages, in which, case better candidates for construction might take those jobs; or 2) provide training to all construction laborers, even if they are illegal, because a better quality product will result. Either way, improved training for inexperienced workers would be required.

3.2.2 Employment Structure

The number of employed people according to major occupational group is described in Table 3.5 below:

Table 3.5: Employed Persons by Major Occupational Group

	# employed (thousands)	%
Managerial and Professional	311	27%
Technical, Sales, Administrative support	301	26%
service workers	191	17%
Operatives and related occ	150	13%
Craftsmen, foremen, related occupations	115	10%
general labor worker	57	5%
farm workers	31	3%
	1156	100%

Source: June 2001 Household Survey Data from Estudios Técnicos, Inc.,2001.

Craftsmen, foremen and other related laborers make up 10% of total occupations, while general laborers make up only 5%.

Moving from share of employment by share of occupations to share by sector, construction and quarrying make up approximately 7% of the total share of employment in Puerto Rico. See Table 3.6 below:

Table 3.6: Puerto Rico Structure of Employment

	1990		2000	
	% total	Actual (thousands)	% total	Actual (thousands)
Agriculture	3.7	36	2.1	24
Financial services	3.1	30	3.6	42
Transport/public utilities	6.2	60	4.7	55
Construction & quarrying	5.7	55	7.3	85
Manufacturing	17.4	168	13.7	159
Commerce	19.2	185	20.6	239
Public Services	21.4	206	21.5	49
Others	23.1	222	26.5	307
Total	100	963	100	1160

Source: From the Department of Labor and Human Resources, Bureau of Labor Statistics Household survey in The Economist Intelligence Unit Country Profile Puerto Rico: Basic data, 2001/2002

The percentage share of construction employees follows public service, commercial, and manufacturing, but is ahead of transport, finance and agriculture. Occupying the middle range of the employment structure, the industry has potential to grow with the correct set of inputs.

3.2.3 Labor Unions

Trade Unions have never been a strong force in Puerto Rico. According to Operations and Maintenance Architect for STT, Ricardo Medina, the plumbers, electricians, and machinists/heavy equipment operators are organized, while carpenters are not (Medina, Personal Interview , 2002). The Labor Organizations Committee is a union umbrella group consisting of independent unions and three union federations: Concilio de Trabajadores (Workers' General Council), Central Puertorriquena de Trabajadores (Puerto Rican Workers'Central) and Federación del Trabajo (AFL-CIO). According to the former head of the AFL-CIO in Puerto Rico, Guillermo Reynolds, however, even these groups have not had much power (Reynolds, Personal Interview, 2002).

Public-sector unions (i.e., government employees) were legalized in 1998, providing collective-bargaining rights but no right to strike, and comprise the majority of unionized workers on the island (EIU, Country Commerce, 2001). According to the Puerto Rico Department of Labour and Human Resources, the percentage of unionized workers is 7%. Including members of brotherhoods, employee associations or other organizations, another 9% is represented (EIU, Country Commerce, 2001). Transport is one sector with high rates of unionized workers, consistent with the strength of organized labor within government.

Although union activity is low, a limited number of professional associations do exist on the island. The Association of General Contractors/Asociación de Constructores (AGC) is a professional organization of general contractors who are mostly interested in housing. Recognizing the need for skills development, the AGC created its own trade education division. The AGC has also formed a council comprised of 12 construction-industry associations, including electricians' and plumbers' groups.

3.2.4 Shortage of Skilled Labor

In the late 1990s, Puerto Rico experienced a construction boom, which has translated into a large construction labor shortage. During the 1990s, a variety of construction projects began at once, with Tren Urbano commencing construction and the Superaqueduct and Port. In February 2001, Puerto Rico had 10,527 licensed engineers and surveyors active in their professions, according to the Engineers and Surveyors Association (EIU, Country Commerce, 2001). In 1997, the average unemployment rate was 13.5%; of the 48,000 construction jobs available, 15% were unfilled (Casellas, 1997).

The EIU Country Commerce Profile (2001) indicates that the large amount of construction which led to a shortage of skilled workers led to an increase in illegal immigrants. One method of solving the labor shortage was to import Mexican labor.

U.S. Immigration and Naturalization Service (INS) agents arrested 49 Mexican Laborers in February of 2000 ("Puerto- Rico-Immigration," *Financial Times* 26 February 2000).

Compounding the labor shortage, natural disasters have also inhibited construction performance during the 1990s. In the fall of 1998, Hurricane Georges swept through the island of Puerto Rico. The Federal Emergency Management Agency utilized trucks for disaster relief and re-construction, not only tying up vehicles, but materials and equipment vendors as well (Cho, 2000).

It is not merely the sheer numbers of laborers that are lacking within the Puerto Rican construction industry, but the lack of *skilled* laborers. "The need for skilled laborers, especially in the metro areas, has reached alarming proportions, " Jorge Redondo, president of Redondo Construction, told the periodical, *Caribbean Business* (Casellas, 1997). According to a survey conducted by the AGC, heavy-equipment operators, masons, and steel-bar installers were in highest demand, followed by electricians and plumbers (Casellas, 1997).

Handiwork and craftsmanship in the mainland U.S. has an external certification process which demarcates the skill level and competence of specific trades. Certification would serve as a strong indicator of an individual's capability, and provide an official pre-requisite for recruitment and qualification for trade jobs. In Puerto Rico, however, no such certification process exists for welders, bricklayers, heavy equipment operators, and masons –trades that are crucial to the work of the rail construction (Medina, Personal Interview , 2002). The lack of certification requirements results in a failure provide an institutional validation of quality work criteria. The European model of paper qualifications for construction craftsmanship is a continuum, from an apprentice to a journeyman and finally a master (Feretti, Personal Interview, 2002).

3.3 Institutions for Skills Development

A major issue confronting companies conducting work on the island is strategizing for an effective mix of on-island labor with less experience and the more costly option of importing off-island labor. An important influence on such decision-making processes is an assessment of the general status of education provided by the existing public education systems on the island. The cheapest on island pool of labor is illegal immigrants. Regardless of the origin, the quality of the work is going to suffer if the workers are not skilled. Therefore, a lack of care and investment into the workers will result in poor quality work. Blaming a workers' status due to racial or even immigration violations will not get the job done.

The educated labor force has been marketed as an enticement for firms to locate within Puerto Rico. Indeed, the Puerto Rican population is among one of the most educated in Latin America, and does not trail far behind the mainland U.S., as seen in Table 3.7 below.

Table 3.7: Educational Enrollment*

	Primary School		Secondary School		Higher (University) Education	
Country	1965	1983	1965	1983	1965	1983
Puerto Rico	99%	104%	56%	76%	21%	49%
Average of selected Latin American and Caribbean countries**	93%	103%	24%	48%	5%	15%
United States	106%	100%	63%	85%	40%	56%

*Source: From the U.S. Bureau of the Census, Census of the Population, Detailed Characteristics 1960, 1970, 1980 in Baumol and Wolff, 1996. * Primary school enrollment, as a percentage of total primary school age group; Secondary School enrollment, as a percentage of total seconary school age group; Higher education, as a percentage of university age group. **Countries include Argentina, Brazil, Chile, Colombia, Costa Rica, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Peru, Trinidad & Tobago, Venezuela.*

As seen above, enrollment rates are nearly universal for primary school. The Department of Education coordinates the public-school system for the island. The education in Puerto Rico is free up to the secondary level, while tertiary (i.e., higher, post-secondary education) and professional training require tuition fees. Adult literacy is over 90% (EIU Country Profile, 2001).

The Education Department has $100 million budget to construct vocational schools from 1997-2001. Schools in Fajardo, Arecibo and San Sebastian were under construction in 1997, while $21 million school for Ponce was established. It is hoped that the number of trade school graduates relevant to the construction industry would increase by 18-20% (Casellas, 1997).

The University of Puerto Rico is organized similarly to a U.S. state university; in the 2000/01 academic year, 71,000 students were enrolled in 11 campuses (EIU, Country Commerce 2001). In addition, private universities and multiple vocational schools exist in the country.

Table 3.8: Institutions with Occupational Offerings (1999)

Institutions with Occupational Offerings	Total
Area Vocational School	4
Vocational high School	12
High School with Vocational Department	9
Specialized School	6
Specialized Vocational Center	6
Academic High School with Vocational Offering	107
Other Institutions	44
Total	188

Source: Estudios Tėnicos, Inc. 2001.

The number of vocational programs being offered provides an indication of the opportunities for skills development through public programs. It does not, however, provide information on current levels of the population actually being equipped with the relevant skills. Table 3.9 provides data from 1999 on the raw numbers of students enrolled within the respective technical programs.

Table 3.9: Number Enrolled in Public School Sector Vocational and Technical Education (1999)

Program	Occupational	Nonoccupational	Totals	% of total
Home Economics	2161	65876	68037	44%
Industrial Arts	255	37378	37633	24%
Industrial Education	15638n/a		15638	10%
Business Education	14019n/a		14019	9%
Marketing Education	8862n/a		8862	6%
Agricultural Education	1147	4921	6068	4%
Technical Education	2327n/a		2327	2%
Health Occupations Education	1622n/a		1622	1%
Total	46031	108175	154206	100%

Source: Estudios Tėnicos, Inc. 2001.

As described in Chapter Two, the U.S. Department of Labor, Employment and Training Administration, Office of Apprenticeship Training, Employment and Labor

Services (OATELS) has established a State Apprenticeship Council (SAC) for Puerto Rico. According to Nick DeLapy, Deputy Director of the New Jersey, New York, Puerto Rico and Virgin Islands region of the U.S. Department of Labor, Employment Training Administration, Office of Apprenticeship Training, Employment and Labor Services, the SAC in Puerto Rico has been inactive for two years. In fact, a scheduled compliance review of the situation in Puerto Rico is scheduled in the near future.

The preceding discussion of public opportunities for technical enhancement is not a prescription or argument for exclusive use of these existing programs. In fact, the large number of graduates and shortage of construction laborers indicate that there is a disconnect between the tertiary and technical education being offered, and the kinds of occupations and skills needing to be filled.

3.4 Conclusion

This chapter shows two major ideas. First, the Puerto Rican economy may have a role for an expanding construction sector, both for internal GDP growth and external export within the Caribbean and Latin American Region. Second, the figures describing the construction industry characteristics give mixed signals. On the one hand, the number of available skilled workers is perceived to be in short supply, while on the other hand, plentiful public sector educational and technical programs exist. One explanation for this disconnect may lie in the need for the public sector education sector to link up more tightly with the private sector projects that are currently in progress on the island.

A tight public-private partnership, or at least coordination and collaboration between the two sectors, would provide mutual benefits: jobs available for those educated within the technical skills programs, and appropriate skills that are critical and timely for the contractors currently conducting the work. This would free up the private sector from having to shoulder the entire burden of skills development and training while at the same time meetings its objective of having a continuing stream of ready laborers. Similarly, the public sector technical education programs would be improved in its practicability of education offered, rather than being limited to skills and techniques that may be rendered moot and no longer applicable to current industry standards.

CHAPTER 4

THE TREN URBANO EXPERIENCE

Training synchronizes the experiences of everyone.
- Hassan Sawan, Contract Manager for Bayamón

CHAPTER OVERVIEW

In this chapter, I assess the construction quality performance among the Alignment Section Contract (ASC) Contractors and training. First, I provide an overview of the Tren Urbano project, including a review of the major actors involved in project delivery. Second, I review the obligations for training and technology transfer as written within the contract documents for each of the ASC contractors. Third, I assess the and compare construction performance of the ASC contractors by looking briefly at percentage completion to date, and analyzing the number of nonconformance reports (NCRs). Fourth, I identify three general construction challenges as gleaned from extensive interviews and analysis of other studies: design difficulties, quality control difficulties, and implementation difficulties. Finally, I review some best practice anecdotes of training conducted among the ASC contractors.

4.0 Project Description

Tren Urbano (TU) is a fixed guideway rail transit system of the San Juan Metropolitan Area created to serve as the core for a multimodal transportation system. The idea has been discussed for decades, but the present project began in 1989, when the PRDTPW first proposed the system to alleviate the traffic congesting the urban roadway networks of San Juan. The Tren Urbano system consists of a 17.2 km (approx. 12 mi) Dual-Track Heavy rail line, consisting of 9.3 km of (52%) elevated structures, 6.5 km (40%) of grade and retained cut structures, a 1.4 km (8%) tunnel, 16 stations and storage and maintenance yard. The expected ridership of the Tren Urbano System is 115,000 passengers per day with travel time of approximately 30 minutes from end to end.

The estimated total project cost is currently \$2.036 billion (2002 estimate). Of that total, the U.S. government is providing approximately \$1 billion, \$307 million of which is directly from the discretionary funds for transit from the federal government (FTA Section 5309 New Start funds described below), \$259 million from FTA "flexible" funds[2], \$141 million from FTA Section 5307 funds, and a \$300 million TIFIA[3] award in recognition of the national and regional significance of the project. The remaining cost is financed through local funding through local revenues raised from the Puerto Rico Highway and Transportation Authority (PRHTA). The receipt of federal funds obligates Tren Urbano to comply with federal regulations, such as the American Disabilities Act, Labor standards, OSHA, and "prevailing wage"(Davis-Bacon Act) laws.

This unprecedented system qualifies for what the Federal Transit Administration (FTA) deems a New Starts program. The New Starts program is a discretionary fund administered by the FTA for "supporting locally-planned, implemented, and operated transit 'guideway' capital investments" such as heavy rail, light rail, commuter rail and even bus rapid transit systems. The Transportation Equity Act for the 21st Century (TEA-21) authorized \$8.44 billion in Section 5309 for funding through fiscal year 2003. Eligibility for FTA Section 5309 New Starts funding is limited to any rail line or other fixed guideway system with a separate right-of-way used exclusively for mass transportation or high occupancy vehicles (FTA, *New Starts*, 2002).

Tren Urbano was designated as one of five demonstration projects for a Turnkey Demonstration project by the FTA in 1993, under the Intermodal Surface Transportation Efficiency Act (ISTEA). As a fast-track turnkey system, the contracts for the design and construction of the Tren Urbano system have been established as design-build and design-build-operate-maintain (DBOM) arrangements. Tren Urbano is not, in the purest sense, a full turnkey project; rather it is a split turnkey contract. In a split turnkey, the systems work is separated from the civil work (Enfiedjian, 1997). Thus, the alignment of Tren Urbano has been divided into seven subsections. Six of the sections were

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[2] A provision included in ISTEA and TEA-21, flexible funds can be used either for transit or highways, based on local planning priorities rather than restrictive program eligibility definition (FTA website).

[3] Transportation Infrastructure Finance and Innovation Act of 1998, part of TEA-21

awarded to joint venture partnerships between international and Puerto Rican civil engineering contractors, while the remaining portion plus responsibilities of commissioning, integrating, and overseeing the entire system were given to another major contractor.

The objectives of the Tren Urbano procurement strategy as stated within a report prepared by the consultants to the PRHTA, the General Management and Architectural and Engineering Consultants (GMAEC, 1994), were to:

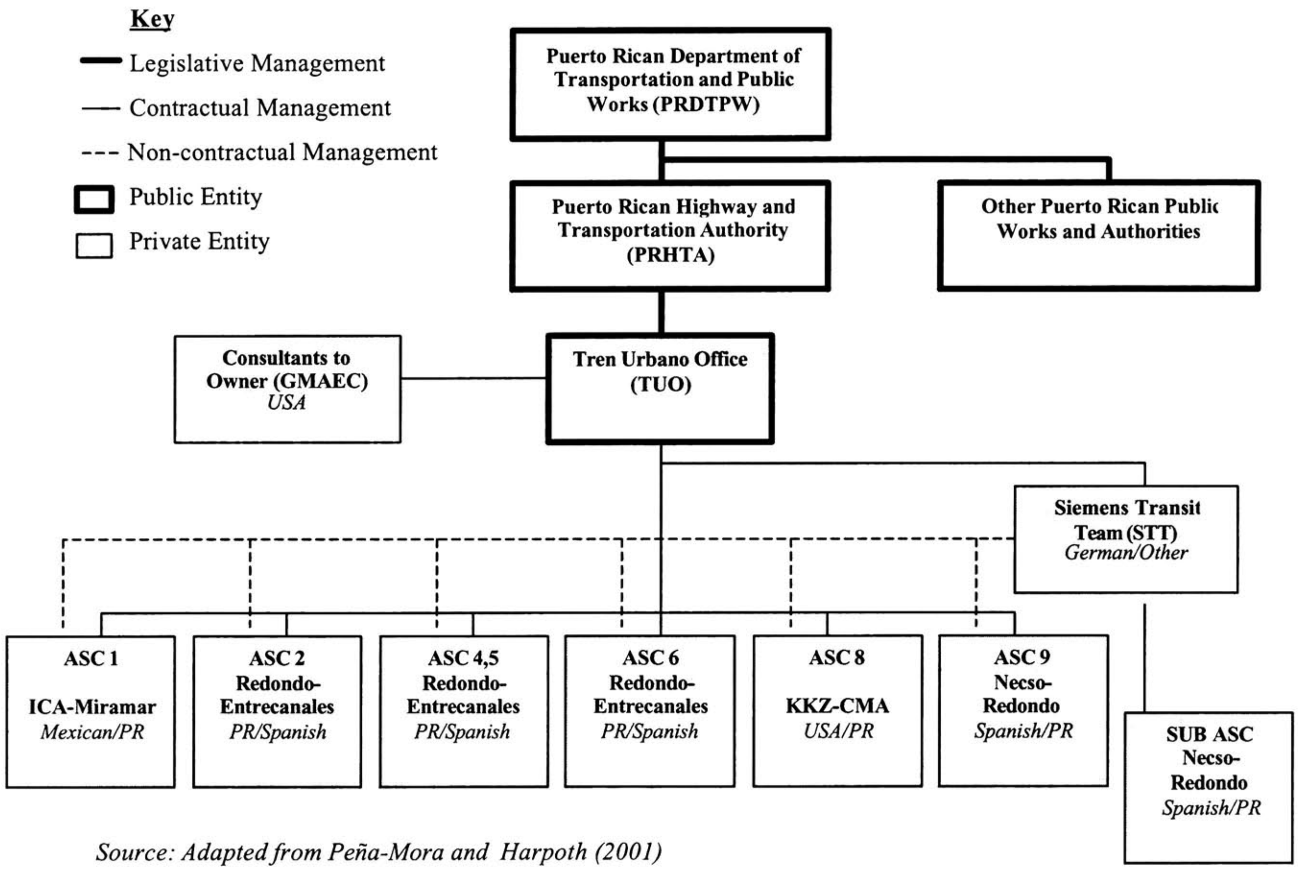
- Control interfaces between the separate subsections
- Minimize costs and encourage private funding finance
- Ensure operations-driven design
- Accelerate start and completion of construction
- Maximize technology transfer
- Promote owner control

Another objective of this approach was to ensure a "more stable and predictable level of operational quality and operating cost." (TU Office, 1998). The expected benefits of the DBOM approach included an increase in technical expertise at all levels, more opportunity for local participation, and flexibility in scale and scope.

Major Project Delivery Actors

As Figure 4.1 below shows, the project delivery mechanism of Tren Urbano involves many actors from both the public sector and the private sector.

Figure 4.1: Tren Urbano Project Delivery Method



Source: Adapted from Peña-Mora and Harpoth (2001)

The client owner of the project is the government of Puerto Rico, namely the PRDTPW through the auspices of the PRHTA. The Tren Urbano office was established initially for the design and construction of the Tren Urbano project, rather than as a separate transit organization. The GMAEC operates and supports the Tren Urbano office staff with technical consulting services. Established in 1994, the GMAEC is comprised of a joint venture between the U.S. mainland private firms of Daniel, Mann, Johnson & Mendenhall and Frederic R. Harris Inc. with San Juan-based engineers, Eduardo Molinari and Associates and Barrett and Hale and Associates. In 2000, the GMAEC housed 150 people, not including staff of the PRHTA (Cho, 2000).

The TU office not only houses private sector entities, but public sector entities as well. The PRHTA staffs the top- level managers of the project. Additionally, the FTA staffs an in-house consultant at the TU office to provide project management oversight (PMO) with TU staff through regular monthly and quarterly meetings. The FTA and TU staff meet regularly through quarterly meetings (Alvarez, Personal Interview, 2002).

According to the design-build procurement strategy, the contractor is given the responsibility to ramp up the initial 30% design provided by the TUO to 100% of the design concept. Although the final design is left to the discretion of the contractor, the PRHTA can intercede at any time to request changes.

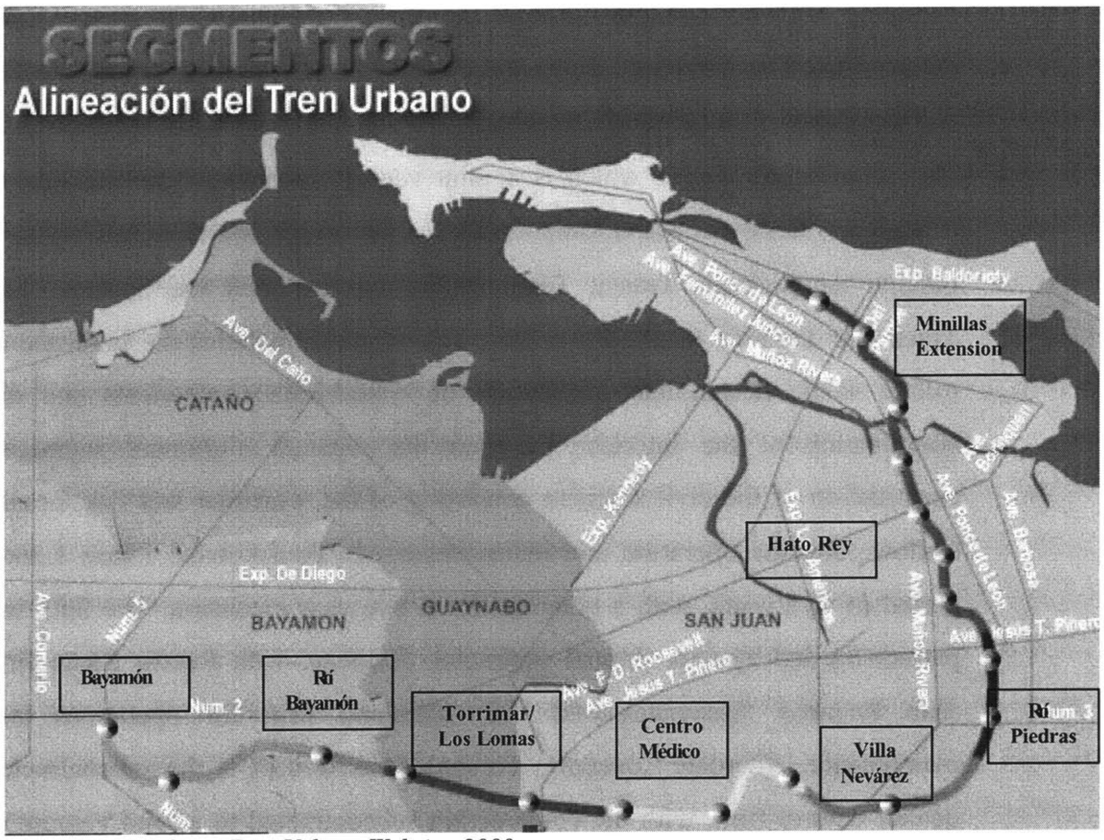
The private sector contractors are just as varied and numerous as the public sector client-owner of Tren Urbano. The six civil engineering Alignment Section Contracts (ASCs) are composed of multiple actors consisting of principals, subconsultant designers, subcontractors for fixed facilities, subcontractors for quality control, and subonctractors for the systems (STT only- for all trackwork, power, communications, train, electric, vehicles, operations control center) (Sheehan et. al, 1998). As seen in Figure 4.1 above, the contractors and subcontractors are a mix of mainland U.S., international, and local Puerto Rican firms:

- The Mexican-based I.C.A. is in a joint venture with the San Juan-based Miramar for the Bayamón Contract (ASC 1).
- One of the most established Puerto Rican firms, Redondo, partners with the Spain-based Entrecanales for the Río Bayamón (ASC 2) , Centro Médico (ASC 4,5), and Villa Nevárez Contracts(ASC 6). Entrecanales is a Colombian firm, brought in because of their experience with design-build in Medellin, Columbia (Ardila, 2002).
- The joint venture of Kiewit Construction, Kenny Construction Co., Chicago, and H.B. Zachary Co. (KKZ) are partnered with managing designer CMA Architects & Engineers (CMA) for the under ground tunneling portion of the project in the Río Piedras Contract (ASC 7). The Omaha-based Kiewit

company has worked on over 100 tunnel projects in the continental U.S., including highway sections through the Rocky Mountains, passenger train tubes below San Francisco Bay, and sewage tunnels linking Boston to the Atlantic Ocean ("Construction Hurdles," *The Omaha World*, 18 April 1999).

- The Spain-based Necso, which is a joint venture including Entrecanales, is partnered with Puerto Rican Redondo for the Hato Rey Contract (ASC 8,9).
- Finally, the Siemens Transit Team (STT) was awarded the Systems Test Track and Turnkey (STTT) in 1996. The contract includes the purchase of rolling stock, design and installation of systemwide components and the coordination of the interface between the separate alignment segments, construction of the civil segment consisting of the Torrimar and Los Lomas stations, and the operation and maintenance of Tren Urbano Phase 1 for a period of five years, with a potential for a five year extension. The STT is a partnership led by international contractor Siemens, with Puerto Rican firm Juan Requena Associates and U.S. mainland firm for operations and maintenance, Alternate Concepts. Parsons Brinckerhoff is the subcontracted quality control firm, with the construction subcontracted to a joint venture of Redondo-Perini.

Map 4.1: Tren Urbano Alignment Section Segments



Source: Adapted from Tren Urbano Website, 2000

Each of the Prime contractors were selected based on their fulfillment of certain minimal performance standards and their estimated bids. According to a report by Booz-Allen & Hamilton, Inc. (1999), the proposals were evaluated based on three major criteria and sub criteria. The major categories for evaluation were Category I: Experience, Technical and Management, Category II: Price, and Category II: Financial Capacity/Risk. The Category I: Experience, Technical and Management sub-criteria included:

- Individual integrity records[4], past performances of contractors, subcontractors and key personnel evaluated based on "consistent, effective, and successful" work on previous projects.

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[4] After the bidding process, the owner of Redondo was indicted for corruption, but due to the legally binding contracting and selection process, the selected contractor could not be overturned or dismissed (Salvucci, Personal Communication, 2002).

- Minimum technical qualifications established by the PRHTA, such as evidence of successful completion of comparable construction projects within the last 5 years, followed by further evaluations based on fixed facilities design and fixed facilities construction criteria.
- Experience and qualifications of key management team personnel, organization and management plans, as well as technology transfer and training programs, and PRHTA's Disadvantaged Business Enterprise (DBE) requirement as basis for evaluation.

4.1 Contractual Obligations for Training and Technology Transfer

The contract documents for each of the Tren Urbano ASC contractors make some mention of training. Each of the contracts contains details about a technology transfer clause, yet the portions on training vary by contract. Table 4.1 lists the type of training included within the contracts.

Table 4.1: Contractual Technology Transfer and Training Requirements by Segment

Alignment Section	Contractor	Training/Tech. Transfer Requirements	Date of Contract
Bayamón: ASC 1	Ica-Miramar	General training clause; technology transfer	1 August 1996
Río Bayamón: ASC 2	Redondo-Entrecanales	General training clause; technology transfer	26 February 1997
Centro Médico: ASC 4, 5	Redondo-Entrecanales	General training clause; technology transfer	9 January 1997
Villa Nevárez: ASC 6	Redondo-Entrecanales	On-the-job-training clause; technology transfer	16 June 1997
Río Piedras: ASC 7	KKZ-CMA	On-the-job-training clause; Technology transfer	18 April 1997
Hato Rey: ASC 8,9	Necso-Redondo	On-the-job-training clause; technology transfer	29 May 1997
Systems and Test Track Turnkey Contract +	Siemens Transit Team	Technology transfer	26 June 1996

Source: U.S. DOT, FTA, Government of Puerto Rico Highway and Transportation Authority, Contract Book 1: General, Phase I of Tren Urbano for Bayamón, Río Bayamón, Systems and Test Track Turnkey, Centro Médico, Villa Nevárez, Río Piedras, Hato Rey

4.1.1 Technology Transfer

A prominent component of the Tren Urbano project is the $10 million Technology Transfer Program. The Tren Urbano Technology Transfer Program is geared towards professional capacity building for students with college degrees; it, therefore, is not intended to address the vocational or technical training needs that might arise from construction labor. The following is a sample of one Contractors' proposal for technology transfer:

Example: Schedule of Technology Transfer Options for the Bayamón Contract

University Program $59,730.00

- Up to 3 high school scholarships for aptitude in science and math
- Up to 3 university scholarships for aptitude in architecture, engineering, construction management per student per year- Field trips to office and site
- University lectures by personnel from office
- Student seminars: lecture and discussions, 2 day seminars
- Student mentorship
- Award program for faculty members with excellency in leadership and academic knowledge in architecture, civil engineering and construction management

Student Internship Program $103,815.00

- Up to 3 interns in architecture, engineering, construction management
- Student internships abroad in the Ica offices or sites of Mexico for 2 months, all expenses paid

Employee Mentorship Program $ 93,852.00

- Employee internships abroad in Ica office and construction sites in Mexico for local entry or mid career employees from Puerto Rico

Peer Partnership Program $1,454.00

- Professional seminars for 2 day seminars

Other proposed tech transfer enhancements

- Publications, series related to Tren Urbano, one year quarterly publication

Source: Bayamón Contract, 1996

4.1.2 General Training Clause

The general training clause includes slight variations of the following:

> Training Program shall be consistent with and be further developed based upon the training section of Contractor's proposal as approved by the Authority. Any differences from, or changes to, the proposed and approved Training Program shall require approval by the Authority. Guidelines and requirements for the Training Program are specified in the applicable Contract Exhibit.... Costs are included in the contract price. (ASC 1,2,4,5 contracts)

4.1.3 On-the-job Training

The Rí Piedras Contract for Phase I includes a section for an On-The-Job Training (OJT) Program to be approved by PRHTA and implemented by the Contractor. The purpose of the OJT Program is to develop trainees who successfully complete the training to "the full journeyman level" for trades specified in the Contract Documents. According to the contract, a journeyman is defined as a craftsperson considered to be "capable of performing all the major duties of a particular trade." The Contractor is obligated to identify the trades involved in the work where on-the-job training will be provided.

The primary objective of the OJT Program is explicitly stated as training minorities and women who are traditionally underrepresented in the construction industry. Thus a "systematic and direct recruitment" of individuals fitting the bill is obligatory. In particular, women are to be given special consideration according to a under-utilization index detailed in the PRHTA Affirmative Action Plan. No trainees who previously completed a training course leading to journeyman status or employed in the trade are eligible, although participation for a training program in another trade is allowed. Hence, the program is truly targeted to those without previous experience within a particular trade.

Participants of the OJT Program are full-time employees of the Contractor and subject to all laws applicable to other regular employees, including the payment of at least federal minimum wage and fringe benefits. The Contractor is also obligated to provide a copy of the OJT Program to each trainee and the Contractor in charge of the work, as well as necessary materials for training. Apprenticeship programs would qualify for the OJT if registered with the U.S. Department of Labor, Bureau of Apprenticeship and Training, or Puerto Rican agency recognized by the Bureau, or approved by the U.S. Department of Labor, Manpower Administration, Bureau of Apprenticeship and Training. Offsite training that does not exceed 50% of the total training is permitted within the terms of the contract. In the provisions of the contract, on-the-jobtraining is to occur throughout the construction under the contract for training intervals of six months or longer. Within each training interval, the OJT Program is to provide training for five or more trainees. Once the trainee successfully completes the OJT Program, the Contractor provides the trainee with a certificate certifying the type and length of training completed satisfactorily.

The Contractor is obligated to receive approval for a proposed OJT Program, including a training schedule corresponding to the Contractors' construction schedule, *"prior to commencing any Work."* (Contract documents, italics mine). Records of persons employed under the OJT Program, including payroll records and weekly summary of training are required to be kept on site by the Contractor. Penalties for not providing the training for the approved OJT Program include the withholding of payment equal to three times the wages that would have been earned by the trainees if the training had been provided. Similarly, if the Contractor withholds wages or compensation due to the trainee, the PRHTA can pay the applicable amount directly to the trainee and withhold three times that amount from the payment to the Contractor for the work.

The costs of training obligations within the approved OJT Program are included in the Contract Price; thus, the PRHTA pays for the training. Within the Special Provisions for the Contractor in Article 5, the Contractor is to allocate at least $250,000 per year during the term of the Contract.

If the Contractor subcontracts portions of the work, the training can be arranged by the Subcontractor as long as the delegation of training obligations is explicitly set forth. The Contractor, however, retains primary responsibility for ensuring compliance with the approved OJT Program.

4.2 Construction Performance Comparisons

This section discusses the construction performance comparisons among the ASC contractors. The following describes the degree of design completion and construction challenges confronted, as well as identification of explicit training provisions (formal, limited and informal) and the type of training that was successful and unsuccessful.

The segments of the Tren Urbano Alignment are diverse, and pose different challenges to each of the ASC contractors. Generally, the types of construction work on TU consist of laying the track/guideway, constructing the fixed facilities, and conducting the electrical wiring and integration. The following table summarizes the contractor, assigned contract sections, elements within the contract, type of alignment and progress of each of the TU sections:

Table 4.2: Alignment Progress as of 31 December 2002

Contractor	Segment	Contract	Alignment	% Complete	
				Design (CA)	Construction
Ica-Miramar	Bayamón	Bayamón Station	Elevated	100	73
	ASC 1	Deportivo Station	Elevated	91	74
		Bayamón Guideway		100	99
Redondo-Entrecanales*	Río Bayamón ASC 2	Jardines Station	At Grade	100	76
		Río Bayamón Guideway		100	100
	Centro Médico ASC 4,5	Las Lomas Station	At Grade	98	65
		San Francisco Station		98	56
		Centro Médico Station	At Grade	98	64
		Centro Médico Guideway		100	100
	Villa Nevárez ASC 6	Cupey Station	Elevated	98	43
		Villa Nevárez Guideway		100	100
KKZ-CMA	Río Piedras ASC 8	Río Piedras Station	Undergrnd	100	88
		Universidad Station		100	86
		Río Piedras Tunnel		100	100
Necso-Redondo	Hato Rey ASC 9	Pinero Station		85	72
		Domenech Station		75	49
		Roosevelt Station		75	47
		Hato Rey Station		85	65
		Sagrado Corazón Station		80	43
		Hato Rey Guideway		100	100
STT	STT	Torrimar Station	At Grade	100	58
		Martinez Nadal Station		100	85
		Storage & Maintenance Facilities		100	90
		STT Guideway		100	92
		Interface/commissioning		n/a	n/a

*Source: Ricardo Alvarez, Tren Urbano Project Manager, Presentation 8 January 2002; Alignment and Cost figures from Rodriguez 1996 and GMAEC 1994. Notes: *Redondo-Entrecanales is also a subcontractor to STT and responsible for all the trackwork of the system.*

While nearly all sections of the guideways are complete, the fixed facilities are taking considerably more time to finish than originally anticipated. Originally, the targeted service opening date was November, 2001.

A detailed analysis of the scheduling delays is outside the scope of this thesis, but the above table of percentage completion provides a cursory indication of the varied performance among the ASC contractors. In assessing the progress of each section, however, among other factors, one must take into consideration a) when the job was begun and b) the difficulty of the job. For instance, the lower percentage of completion in the Hato Rey contract can be explained in part by the fact that it was the last contract to be awarded and so had the least amount of time for work. Nonetheless, all are beyond the contractually specific completion date.

Interestingly, one of the most complex and technically sophisticated jobs is that of the Rio Piedras segment. 1.8 km of underground track plus two stations under historic buildings present the most technically sophisticated portion of the project. According to the 20-year Kiewit veteran and district manager in Puerto Rico, the Rio Piedras project was "one of the more challenging jobs" he had ever seen ("Construction Hurdles," The Omaha World 18 April 1999). The historic buildings can not be disturbed, and the streets are narrow and winding. Tunneling under the business district of Rio Piedras has lead to the discovery of either leaks or unknown utilities. According to 1999 estimates, the 105 supervisors directed a workforce peaking at approximately 500 people. Yet, the Rio Piedras contract is one of the more effectively constructed portions of the alignment section in terms of scheduling and quality.

Beyond percentage of completion, another indicator which attempts to more precisely estimate the quality performance of the ASC contractors is the number of nonconformance reports (NCR) written for each segment. Nonconformance reports are evaluations conducted by the Quality Control (QC) inspectors detailing various aspects of construction work which do not conform to the agreed upon design/construction specifications. The following table documents the number of nonconformance reports to date.

Table 4.3: Nonconformance Reports (NCR) to Date (March 2002)

Prime Contractor	Contract Segment	Start Date	Months of work	Job Difficulty *(Cost in $mill.)*	Total NCRs	Indicator 1: *(NCR/months)*	Indicator 2: *(NCR/(cost/ time))*
Ica-Miramar	Bayamón ASC 1	Aug-96	68	75	357	5.3	323.7
Redondo-Entrecanales*	Rí Bayamón ASC 2	Mar-97	61	35.2	203	3.3	351.8
	Centro Médico ASC 4,5	Jan-97	63	71.8	534	8.5	468.6
	Villa Nevárez ASC 6	Jun-97	57	47	362	6.4	439.0
KKZ-CMA	Rí Piedras ASC 8	Apr-97	60	225.1	377	6.3	100.5
Necso-Redondo	Hato Rey ASC 9	Jun-97	57	175	550	9.6	179.1
STT– Redondo Perini Joint Venture	STT	Jul-96	69	137.7	238	3.4	119.3

Source: Latch, 2002; Rodriguez, 1996. Note: NCRs on file to March 2002; Cost estimate of 1996.

To account for the variations in each job due to duration of work and difficulty of the job, two other factors were included in the assessment. The number of months of work on-the-jobwas considered to start at the date of the contract and continue to now; thus the total months of work is equal to the total months since the contract was first issued. The estimate used to best reflect the degree of job difficulty is the value of each contract segment (US $ cost).

The number of NCRs were standardized for comparison in two ways. Indicator 1 only takes into consideration the number of months on the job, describing the average number of NCRs for each month. Indicator 2 attempts to capture both time and job difficulty (cost) by dividing the number of NCRs by the monthly rate of cost. This provides an average ratio of NCRs per monthly rate per contractor. In comparing Indicator 2, Kiewit stands out as having one of the best records among ASC contractors (100.5 NCRs per monthly rate). The highest number of NCRs per monthly rate is over four times the amount of Kiewit at 468.6, held by Redondo-Entrecanales for the Centro Medico segment.

The factors are estimated values and do not completely depict the reality of the situation as accurately as one would like. The number of NCRs, for instance, are only the official documentation of problem areas; more problems could have arisen which required change but were not documented. Moreover, the construction work did not occur on a continuous basis from the start of the contract. Also, the contract values do not necessarily purely reflect job difficulty alone. With the understanding that all the figures provided are mere estimates, however, they nevertheless provide a first cut at attempting to assess the differences in ASC performance.contractors. The following describes the degree of design completion and construction challenges confronted, as well as identification of explicit training provisions (formal, limited and informal) and the type of training that was successful and unsuccessful.

4.3 Construction Challenges

Based off of in-depth interviews with 25 individuals among the TU offices and ASC management offices, three general areas of construction challenges have been identified: design difficulties, quality difficulties and implementation difficulties.

4.3.1 Design Difficulties

Portions of the construction quality can be attributed to difficulties with design. The stages of design for the civil contract begin with Category 1 client drawings, i.e., the 30% TUO designs, followed by Category 1 modified drawings (modifications that are "willingly recognized" by the ASC to match the field where alignment changes are made and a new baseline design is established from a feasible civil construction perspective) and finalized with a design issued for construction (design after a survey of the guideway and data for the building(s) has been collected). As Built drawings are the sketches after a survey of the built track; if there are mistakes, the contractor must go back refit the work. The Design Review process is, according to Joe Feretti, "undisciplined" and suffers from coordination problems (Feretti, Personal Interview, 2002). The design process involves multiple actors and approval processes, beginning with a 30% design provided by TUO, then an initial design by the Contractor, design approval by TU/STT, the implementation of the design by a separate contractor, followed by yet another subcontractor in charge of quality control and quality assurance. At each stage, potential for dispute or lack of appropriate information exists, which is especially debilitating for problems requiring immediate response.

The difficulties of design can occur at any stage of the design process, and become progressively more difficult to manage as the construction progresses. Construction begins with a structural plan, not an architectural plan (de Lemos, 2002). The original designers have not been allowed to participate in the design-build construction. Thus, the contractors' own designers have made the on-site design decisions (Mirandez, Personal Interview, 2002), leaving more room for straying from the original specifications. Once the construction work is complete, the client-owner loses leverage to force a contractor to go back to fix the original job and is vulnerable to increased costs. Even if the contractor does conduct the re-work, they are often slow to do so. Thus, establishing a process for achieving a quality outcome at the early stages is all the more vital.

In the Bayamón contract, the contractor I.C.A. attempted to coordinate among three different designers located in Boston, Mexico and Puerto Rico. The lack of coordination and communication led to poor design outcomes (Woreby, Phone Interview, 2002). For example, manholes in the elevated guideways were inaccessible because they were placed too close to the fixed facility (station). If the manhold had been moved just three meters, the problem could have been avoided.

In the STT contract, STT was given responsibilities for a portion of the alignment, as well as interface and commissioning responsibilities for the whole Tren Urbano system. The Interface Control Manual (ICM) details specifications for each of the ASCs outlined by STT to maximize integration between the alignment subsections. An Interface Inspection Report is generated every time there is a problem of nonconformity to the ICM requirement. All the items listed must be cleared before STT can enter and complete their portion of the overall system integration (i.e., power and track work). For example, laying down the electrical wire requires a certain width and distance of wiring conduits that must be pre-established. If the conduits are not sized or placed properly in the construction of a facility, the integration work must halt or be delayed. As illustrated, conformity to specifications is especially crucial for overall systems integration.

In order to more closely approach the design specifically of design-bid-build, the initial designs issued by TUO, the levels of design specification varied by alignment section. Greater specification was given the more difficult elements, and less was given to the easier elements (Salvucci, Personal Communication, 2002). The prime contractor was contracted to bring the design up to 100%, subject to approval. The average percentage of design completion provided to the contractors was 30% (Alvarez, Personal Interview, 2002), much higher than the 10% often cited in design-build literature. One of the ASCs, however, lobbied to begin construction even without 100% design. The PRHTA approved this request. Legally, the ASC was warned that they could proceed at their own risk, subject to liabilities to fix any mistakes that could potentially ensue.

4.3.2 Quality Control Difficulties

While the design difficulties encountered in Tren Urbano primarily center around lack of clear and finished specifications and coordination problems surrounding the definition and clarity of those specifications, quality control difficulties arise over the ability to uphold conformity to what can be already ambiguous specifications. According to Puerto Rican law, the quality control must be conducted by an entity independent from the contractor. Yet, the local Puerto Rican quality control companies had no prior experience inspecting a rapid rail project, and were unfamiliar with the special needs of the more technically advanced system of rapid rail. For instance, though firms are experienced in concrete mixture processes for roadways, they are unfamiliar with corrosion control for rapid railways. Furthermore, the limited knowledge and experience with the content of rail specifications has been exacerbated by limitations in English and unfamiliarity with the means of written specifications. According to once source, Puerto Rican construction firms are accustomed to relying heavily upon drawings to carry out the construction of jobs. But complex rail systems rely heavily upon written design specifications, which detail technical components that are often left out of the drawings.

The lack of experience with rapid rail specifications was thus a source of difficulty for the quality control aspect of the TU project.

In no cases did the original designers who provided the 30% designs and accepted the 100% designs have the on-site inspection prerogative or responsibility. This may make the responsibility for design less ambiguously that of the contractors' design firm, yet places additional responsibility and emphasis on quality control and quality assurance. Paradoxically, the subcontracted design firm and the subcontracted quality control firm have ethical responsibility to the client-owner but are contractually working for the contractor.

In Bayamón, quality control inspectors worked off the specifications provided by the contractor I.C.A, although they were not necessarily the final approved designs. In this case, the contractor exercised control over the quality control inspector. This occurred for 2 years before PRHTA entered and corrected this system. With the reform, inspectors began to report directly to PRHTA, and were released from contractor accountability (Woreby, Personal Interview, 2002).

In Río Piedras, the prime contractor, Kiewit, was able to negotiate an exemption from the independent quality control requirement, and utilized their own designer, CMA, to act as the quality control inspector. The caveat allows the designer to be the inspector, but not the prime contractor. CMA placed their designers on-site, and coordinated with the main office of Kiewit regularly. Thus, the designers' intentions were readily accessible to the construction managers and supervisors.

4.3.3 Implementation Difficulties

The difficulties encountered in design and quality control may contribute in part to more general implementation difficulties of the multiple contract design-build Tren Urbano ASC contractor arrangements. Especially in working with inexperienced workers, supervisors, and inspectors, ambiguity in design specificity can be a major problem. While designs establish the transit system specifications, and quality control monitors conformity to the specifications, the translation of the specifications from a paper form to actual product is the process of implementation. Although each contract ensures the criteria for the outcome of the final product, it does not specify, as Feretti puts it, "how to get there"(Feretti, Personal Interview, 2002). Assuming that the design specifications and quality control mechanisms were flawless, the construction outcome could still be of poor quality due to a lack of skill on the part of the laborers who are physically constructing the product or even the lack of experience on the part of management.

Whether poor quality construction results from a lack of coordination or inadequate experience and skills, there is a role for training in addressing the design, quality control, and implementation difficulties of construction.

4.4 Training

Expectations for training were explicit objectives of the Tren Urbano project and clearly delineated within the contract documents. The Technology Transfer program has proven to surpass minimum contractual obligations and target numbers. The general training clause may have been too general, with little enforcement mechanism to ensure that any program, if any had been submitted, was actually implemented. The on-the-jobtraining program, while specifically addressing the need to ramp up the skills of unskilled labor, was targeted more to disadvantaged citizens rather than open to the general public. Its intent, therefore, was more to incorporate otherwise minimally represented individuals within the construction industry, rather than to improve the work product of the construction project or the industry as a whole.

Contractually, each of the ASC contractors was obligated to submit an approved training program prospectus before construction work could begin. According to Lydia Mercado, manager of the Tren Urbano Technology Transfer program, since the inception of the program in 1996, each of the ASC contractors provided regular reports monitoring the technology transfer progress that had been made (Mercado, Personal Correspondence, 2002). Both Kiewit and STT superseded the basic contract requirements. The Tren Urbano Technology Transfer Office was also tasked to be the central source for overseeing training progress reports. The only contractor that consistently contributed reports, however, was Kiewit. Other contractors conducted limited training, but did not submit regular reports. On-the-job training requirements, specific to incorporating disadvantaged people into the construction work force, were monitored by the Civil Rights Office of the PRHTA. As evidenced by the descriptions following, other occasions of training occurred in limited and ad hoc forms.

According to the TU QA/QC Manager, QC folks received on-the-jobtraining when they and their consultants took readings, how to conduct NCRs, how to conduct a Receipt Inspection, how to check precast sound barriers, etc. The TU QA/QC office managers and consultants attended weekly and bi-weekly quality meetings with the Contractors and the QC inspectors, where they attempted to explain why and how quality was to be carried out (Latch, Personal Correspondence , 2002).

4.4.1 Lord-Mass Joint Venture: Partnership at Work

The Lord Electric Company of San Juan, Puerto Rico and the Mass Electric Construction Company of Massachusetts comprise the Lord-Mass Joint Venture (LMJV), subcontracted by the STT. LMJV is responsible for all functions for the installation of the train system, including power supply, signaling, train control, operations control center, and the design and installation of the communications system. Named as one of the more effective joint partnerships on the Tren Urbano job, LMJV facilitates learning and communication of information through direct partnership. The management team consists of 3 Mass managers and 2 Lord Managers, while all the labor used for the construction is Puerto Rican. LMJV addressed the shortage of skilled labor by teaming one experienced engineer with one superintendent electrician. Each superintendent is then teamed with 2 to 3 foremen, who are in charge of 5-6 people work crews (Woreby, Personal Interview , 2002).

4.4.2. Rí Piedras: Doing the Job Right

In Rí Piedras segment, Kiewit included extensive on-the-job training program. The trainings provided by Kiewit were continuous and on-site with hands-on demonstration and practice intimately interlinked with classroom training. The curriculum entailed trainee-directed learning, where it was self-managed learning.

Lesson plans were developed for welders, carpenters, miners, masons, electricians and flaggers, based on a U.S. National Construction Education Curriculum called, 'Wheels of Learning', tailored specifically to Rí Piedras, and a Trainer hired to train the trainees. Welders were trained in Rí Piedras for 1-2 weeks, certified, and retained for the job. All the foremen did the training, and, in turn, had daily morning meetings with their crews to pass on any information or new knowledge they had gleaned. At the end of the day, trainees would evaluate and test how well they had performed based on their new knowledge.

4.4.3 ICA and Pre-Cast Bridge Segments

The method of concrete construction chosen for rapid rail transit bridges is a pre-cast, post-tensioned segmental guideway. The specific method for concrete construction of the pre-cast segments was not known before in Puerto Rico. ICA was the first ASC contractor to do this at Bayamón. Forty-eight hours later, however, the first segments were demolished because of their poor quality.

In order to complete the necessary work, ICA needed to be finishing 22 segments per week, but were only finishing 1-3 per week. An expert bridge segmental specialist from Canada was hired, and within 2.5 months, work productivity improved significantly. They were soon finishing 22 pre-cast segments per week, producing at a rate which exceeded the capacity to store them (i.e., the structures were not being built fast enough). The specialist was then put in charge constructing the structures to receive the pre-cast segments, as well.

The consultant recognized 2-3 individuals who had the capacity to be trained closely, and developed a mentor relationship with them. He trained them, and the information, in turn, was funneled down. The training consisted of 1-2 hour time segments, every 2-3 days or as often as necessary. By default, the quality control inspectors on site were gaining skills, too, since they also were present at the time and location of the training sessions. Although the consultant provided the training in English, his second in command translated into Spanish (Woreby, Phone Interview, 2002). Much money was invested in him to maximize efficiency. According to Sawan, the savings generated through the efficiency of construction, however, far surpassed the cost of hiring him.

4.4.4 The Type of Training Counts

In a rail system, if the electricity is not properly channeled, the stray electricity could be stored up in an improper place, ruin the rebar and deteriorate the system sooner. The consequent operations and maintenance costs would be very high, showing up only 5 years later. To counter this, the QA/QC office hosted an Independent Inspectors' one day seminar. The training was in the form of a lecture to a large number of people, and the handouts and lecture were in English. According to one source, the inspectors had limited absorption, partly due to the language barrier, and partly because of the inundation of new information at once.

4.5 Conclusion

Varied performance among the ASC contractors are indicated through lateness in delivery and the number of NCRs for each contractor. While the degree of job difficulty is one factor in comparing the performances, all the ASC contractors face the same challenges of design, quality control and implementation difficulties. The lack of final design creates an ambiguity that causes the contractor, QA/QC firms, supervisors, and laborers to be unclear about the detailed specifications and procedures for carrying them out. This problem is compounded when the QA/QC firms are not experienced in transit construction, or any other firms involved in the implementation process are unskilled.

On the one hand, the contractor could attempt to negotiate the acceptance of lower quality work with the client-owner by preying upon schedule slippage. In the trade-off between quality and schedule, and the constraints of political office and the desire to complete projects within an official's term in office, contractors can attempt to escape the standards of high quality construction. Within the Tren Urbano experience, such a dynamic was in play and individual contractor philosophy was a major factor in the differences.

The ICA case exemplifies timely intervention by the client-owner, PRHTA, but that intervention undermines the responsibility and accountability for contractor management of the job. In the Kiewit case, the contractor accepted responsibility for training and implemented a formal program of training for construction. In the Redondo case, the contractor seems to willfully cause delay, confounding any attempt at a pre-emptive training strategy.

On the other hand, the contractor could provide training in order to construct a quality product more efficiently, resulting in quality outcomes, and improved cost and time savings. Although the contract states the need for training, beyond the technology transfer program, the ensuing training sessions conducted by ASC contractors were often reactive to problems and ad hoc. The costs incurred with retrofitting work and training sessions may have been avoided with an initial strategy for training. Moreover, the strategy for training should be carefully planned, with an assessment of the particular needs of the individuals to be trained. In the cases described above, training sessions that were conducted in a language more comfortable to the low-skilled workers, in shorter time spans over more frequent periods appeared to be more effective.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Overall in the transportation industry, states and public transportation agencies have focused on buses and trains, or making capital investments such as new lines or expansions. They have seldom focused on the people who operate the system or plan, design and construct new lines. There has been an emphasis on physical infrastructure without due regard to the human infrastructure required to carry out projects or operate systems.

- Lydia Mercado, Former Technology Transfer Manager of Tren Urbano

5.0 Conclusion

As seen through a review of the literature and study of the Tren Urbano rapid rail system, transit system construction projects are susceptible to problems of poor quality and consequent delays and cost overruns. The lack of client-owner expertise, as well as inexperienced contractors and construction labor, exacerbate the risks already associated with building technologically advanced, new-start transit projects. Given these conditions, this thesis poses the questions, 1) Does training matter for construction quality? 2) To the degree that it does, what types of institutions and training structures can help to ensure a quality product from inexperienced construction labor?

A limited conclusion can be drawn that, yes, training does matter. Training matters for the public sector, because, as the guarantor of the public good, governments are motivated to expand local capacity and skills development for economic development purposes. The principles for this reasoning were discussed in Chapter Two, while the specific Puerto Rican factors necessary for an assessment of the construction industry and educational/training opportunities were discussed in Chapter Three. General education is important for increasing the absorptive capacity of the labor pool. The resultant high-skilled labor can provide an incentive for firms to locate and spur industrial growth.

Training also matters for the private sector, because local capacity development can influence the construction quality outcome. The principles for this reasoning were discussed in Chapter Two, while the case was made for private sector interest and motivation in training in Chapter Four. Training can lead to higher quality, which, in turn, can lead to higher profits.

Delving deeper into the answer, however, spurs on other questions such as what kind of training, training for who, and training provided by who? In order to address these questions and formulate a more nuanced understanding of the role for training within the construction process, the type of procurement strategy chosen becomes prominent. Different procurement strategies emphasize who shoulders more of the responsibility for various portions of project delivery, such as whether the contractor or government is responsible for design completion, coordination among multiple parties, etc. The embeddedness of training within other project organizational and managerial issues makes the discussion of the role of training more complex, necessary. If a competent management is in leadership, but poorly skilled-workers are incapable of executing and implementing the project designs, then a problem results. Conversely, even the most sophisticated and highly skilled workers would be confounded by poor management. Thus, understanding the role for training must be enlightened by understanding the impacts of an overall project delivery plan/procurement strategy and managerial competence and experience. I argue that client-owners should create an appropriate strategy which carefully assess and matches the three factors of procurement strategy, contractor competence, and local labor capacity (existent or potential, through training capacity).

The following section describes the relationship between procurement strategy, quality and training, thus addressing the first question posed by the thesis. It is argued that successful training should be tailored to pre-empt potential breakdowns of a particular procurement strategy. The second question of institutions needed for training is addressed in the subsequent section. Primarily, this thesis posits that training should be provided in a collaborative effort between the public sector, private sector, and with an expanded role for labor unions, through apprenticeship programs and vocational/trade schools with curriculum fitting within an overall industrial development policy of government. This chapter finishes with a discussion of recommendations, and theoretical contributions and potential areas for future research.

5.1 Procurement Strategy and Quality

As addressed in Chapter Four of this thesis, the construction quality problems can be attributed to design problems, QA/QC inspection problems, and implementation problems. In assessing the factors which influence the construction quality outcome, an important influence on the design and construction process is the particular procurement strategy chosen for project delivery.

The labor forces' capability to execute an established procurement strategy is assumed rather than created. Especially with new-start transit areas without local rapid rail expertise, like that of San Juan, there is a need to address knowledge management of low skilled construction labor as well as the higher skilled architecture, engineering, and management skills.

As discussed in Chapter Two, the increased interest in design-build procurement strategy for transit system construction in the U.S. is attributed to the increased participation of the private sector in project design and construction, and even operations and maintenance. Design-build is lauded as a key for increasing efficiency of cost and time in the design and construction of an infrastructure project by relying upon contractor expertise for fast-tracking – an expertise based on the proprietary knowledge that the contractor retains from experience. The potential for increased efficiency, however, is based upon two key assumptions: 1) contractor expertise in design as well as construction, and the management capability to coordinate between all functions of contracted project delivery, and 2) contractor motivation to produce a high quality product.

The first assumption that the single entity contractor has expertise in design as well as construction may not be true. Experienced engineering and construction contractors may not know how to manage design, because their expertise and experience is in construction. Problems are exacerbated if the history and experience of the construction industry has relied upon a history of design-bid-build, where design expertise has been completely severed from the construction process. Even value engineering expertise, which provides a type of flexibility similar to design-build, has a limited scope in its indicator of contractors' ability to manage design-build; value engineering focuses on smaller-scale changes on portions of a system rather than on an entire system.

The second assumption that the contractor is motivated to produce a high quality product is also risky. Such reliance upon contractor responsibility runs the risk of an inferior construction outcome based on motivations of cost minimization or faster project completion. Ideally, the contractor would desire to create a better quality product the first time to maximize and capture profit. Conversely, however, contractors may be motivated by a strategy to minimize costs by producing only the lowest quality acceptable. This plays upon government's motivation to have timely performance, often due to the politics of completing a major public works project within a particular official's term of office. The contractor may be able to take advantage of the government's priority on schedule, and produce a quicker, cheaper, lower quality product. Moreover, contractors may deliberately delay design submission and even construction in order to create pressure on the government to accept below quality work.

5.2 Procurement Strategy and Training

This thesis argues that in order to maximize the quality of construction in a new transit system, the client-owners should create an appropriate strategy which carefully assesses and matches three factors: 1) procurement strategy, whether the conventional design-bid-build or innovative design-build arrangement, 2) contractor experience and/or training capacity, and 3) the local labor skill level or training capacity.

Both the conventional design-bid-build and innovative design-build procurement strategies have vulnerabilities where potential breakdown may occur in project delivery. Identifying and addressing those vulnerabilities is important especially for the construction of new-start transit systems in a location with limited local labor skills. Successful training should be tailored to pre-empt potential breakdowns of a particular procurement strategy, regardless of which procurement strategy is chosen, with emphasis on the accountability provided by a quality assurance and quality control system. To identify those weak spots and discuss potential training strategies, we revisit a figure from Chapter One below:

Table 5.1: Procurement Strategy and Associated Skills

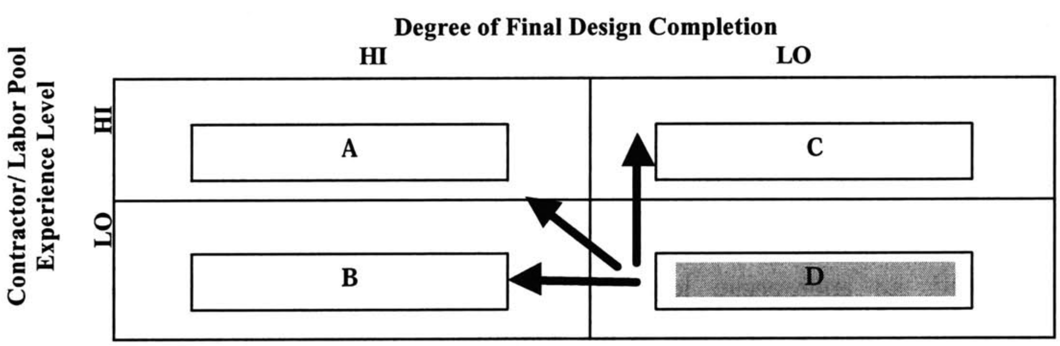
Stages in Transit Construction	Major Skill Needed	Actor	Procurement Strategy – Level of Skill Needed: Design-Bid-Build	Procurement Strategy – Level of Skill Needed: Design-Build
Design	Architecture/ Engineering Skill	Client-Owner	***Very High:*** Provides 100% design specifications.	***Low:*** Provides <100% design specifications
		Contractor Manage-mentt	***Low:*** Not necessary; potential to change design specifications through value-engineering	***Very High***: Necessary to innovate and complete design specifications to 100%
		Construction Labor	***Training Implication:*** Need designers to design with construction capability in mind.	***Training Implication:*** Need designers to design with construction capability in mind.
Construction	Trade/Craft Skill	Client-Owner	***Moderate:*** Restrain payment schedule to match construction compliance	***Moderate:*** Restrain payment schedule to match construction compliance
		Contractor Manage-mentt	***Moderate:*** Just implement 100% design specifications	***Very High***: Necessary to innovate and complete design specifications to 100% for quality construction
		Construction Labor	***High:*** Emphasize construction supervision to implement 100% design ***Training Implication:*** Simultaneous *and* proactive inspection during construction not after.	***Very High***: Emphasize construction supervision to implement 100% design or need to exercise judgment with incomplete design ***Training Implication***: Simultaneous and proactive inspection during construction not after.
Monitoring/ Inspection	QA/QC Skill	Client-Owner	***Very High:*** Reliance upon on QA/QC to monitor conformity to design specifications	***Very High:*** Reliance upon on QA/QC to monitor conformity to design specifications
		Contractor Manage-mentt	***High***	***Very High***
		Construction Labor	***Training Implication***: Need to construct with QA/QC function in mind.	***Training Implication***: Need to construct with QA/QC function in mind.
Project Oversight Control	Management Skill	Client-Owner	***High***: Necessary to coordinate contractors and conformity to specifications *Moderate:* Restrain payment schedule to match construction compliance	***Moderate:*** Reliance upon single contractor entity to perform coordination functions Restrain payment schedule to match construction compliance
		Contractor Manage-mentt	***Low***	***Very High:*** Necessary to coordinate all subcontractors and functions
		Construction Labor	n/a	n/a

The four stages of transit construction – design, construction, monitoring/inspection and project oversight control each identify the type of skill needed for that particular stage. The stage and skill, in turn, are broken down into the relevant actors of client-owner, contractor management and construction labor. Although the type of skills needed do not vary much, which actor possesses the expertise does vary according to the procurement strategy and the assignment of responsibility. The following is a discussion of each of these stages in greater detail.

5.2.1 Design Specificity

In the design stage, responsibility for design is higher for the client-owner in design-bid-build, while it is higher for the contractor in design-build. In both cases, however, the training implication for construction labor is that designers design with construction capability in mind. The completion of final design specifications is important in this regard. According to another figure from Chapter One, there is a relationship between the level of skill drawn from experience of the contractor/labor pool and specificity of design:

Figure 5.1: Tren Urbano Skills-Design Specifications Framework



Again, boxes A and B illustrate situations where the specificity of design is 100% complete and approved before construction begins (usually design-bid-build), and construction outcome is primarily dependent upon contractors' abilities to conform to the pre-established details. Boxes C and D refer to situations where complete designs for the project as a whole, i.e., sum of the parts, have not been fully specified and approved at 100% before construction begins (as in design -build).

In terms of level of complete design provided by TUO initially, and in terms of the available pool of experienced labor, all the ASC contractors fit within Box D initially. The ASC contractor performances were varied in view of this framework. Kiewit operated in a manner which could relegate it to Box C because the extensive training provided to on-site construction improved skill, even with the 30% design provided by TUO initially. It could also, however, be relegated to Box A, because the level of approved design specification was high before construction began. Alternatively, Redondo offered limited training, as well as starting construction off a lower level of approved design specifications. Thus, Redondo operated in a manner that would leave it within the Box D range.

This thesis points out that the design-build strategy assumes high level skills often associated with experience of the labor pool available to contractors (Box C). In the case of low level skills (Box D), the movement to a high skill – high design specification would yield the highest quality outcome (Box A). In order to get to the ideal type, a two-step process would be in order. First, an effective strategy could be to either move up vertically to the realm of Box C by intensive and effective training programs, or to move over horizontally to the realm of Box B by enforcing contractual guidelines on the degree and breadth of complete designs necessary *before* construction begins. Second, the alternative movement could follow, whereby the Box C contractor could next concentrate on improving design specifications and the Box B contractor could focus on training to ramp up the skill level of labor. If the capacity for particular processes or materials is advanced, an appropriate level of training should support the advanced process. Otherwise, a process familiar to the construction laborers may need to be utilized to maximize implementability.

5.2.2 Construction

Depending on who has ultimate responsibility for project delivery and management, the competence and skill level of the contractor and client-owner varies for project oversight control. Client-owner competence must be high for design-bid-build, in order to manage and coordinate all the contractors and conformity to specifications. Contractor competence must be even higher, however, for design-build, given the added need for coordination between design and construction, and the additional potential for incomplete design or other design failures.

In both cases, there is a need for the client-owner to exercise restraint in payment in order to elicit compliance with standards. Paying at a rate and schedule that is similar to the actual construction would be optimal, for paying too much ahead of time diminishes the client-owners' leverage over the contractor. The competence and capability of who performs the management functions is a vital factor to consider in considering procurement strategy and training implications.

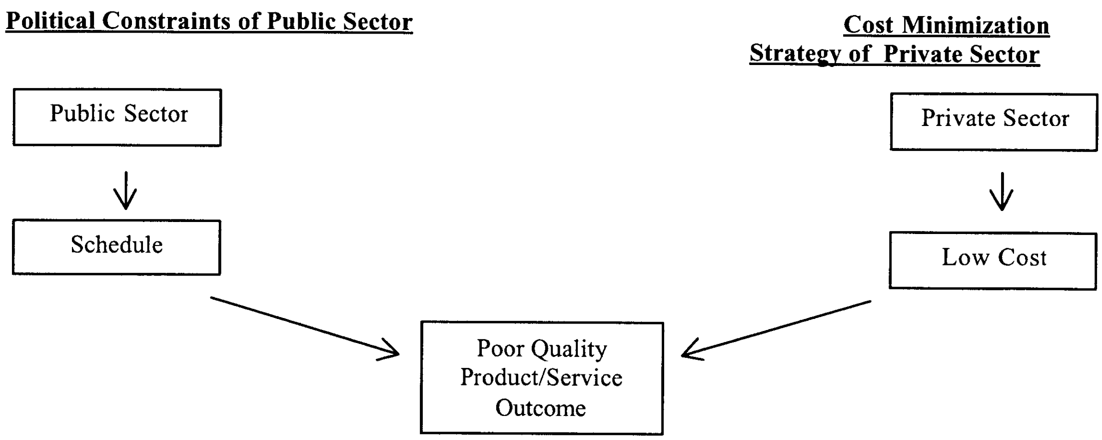
In the construction stage, regardless of which procurement strategy is utilized, the degree of construction labor skill required is high, though higher for design-build. Implementation of designs requires strong supervision, as well as adequate design. This need is compounded when a lack of complete design requires a use of personal discretion, which may not be well-founded without past experience. Another training implication at this stage is construction with an eye forward towards creating a product which can pass quality inspections.

5.2.3 Monitoring/Inspection

Monitoring and inspecting must be proactive and simultaneous with construction, instead of after the product has been complete. In both procurement strategies, high reliance upon the QA/QC mechanism translates into a need for strong training of that mechanism. In other words, training for the QA/QC inspectors may be as, if not more, important than training the actual workmen who implement designs.

As discussed previously, and described in Figure 5.2 below, the public sector exhibits vulnerabilities to short-term political considerations, making the need for an accountability system for quality control and quality assurance all the more essential.

Figure 5.2: External Impediments to Quality Product/Service Outcome



Design-build works well when the perceived interest of the client-owner and contractor are similar, and similar visions of project quality are executed. But the contractors' perception of interest and motivation is difficult to pre-screen in the bidding process. Making the quality of construction processes and outcome the legal responsibility of the contractor is vital, as transferring such legal responsibility to the client-owner could create a weakness in accountability.

Thus, a procurement strategy should evaluate the processes proposed by competing contractors to deal with skills training specific to quality control, including it as a basis for competition, and monitor to enforce that the winning contractor is complying with the proposed skills plan for quality control.

5.2.4 Project Oversight Control

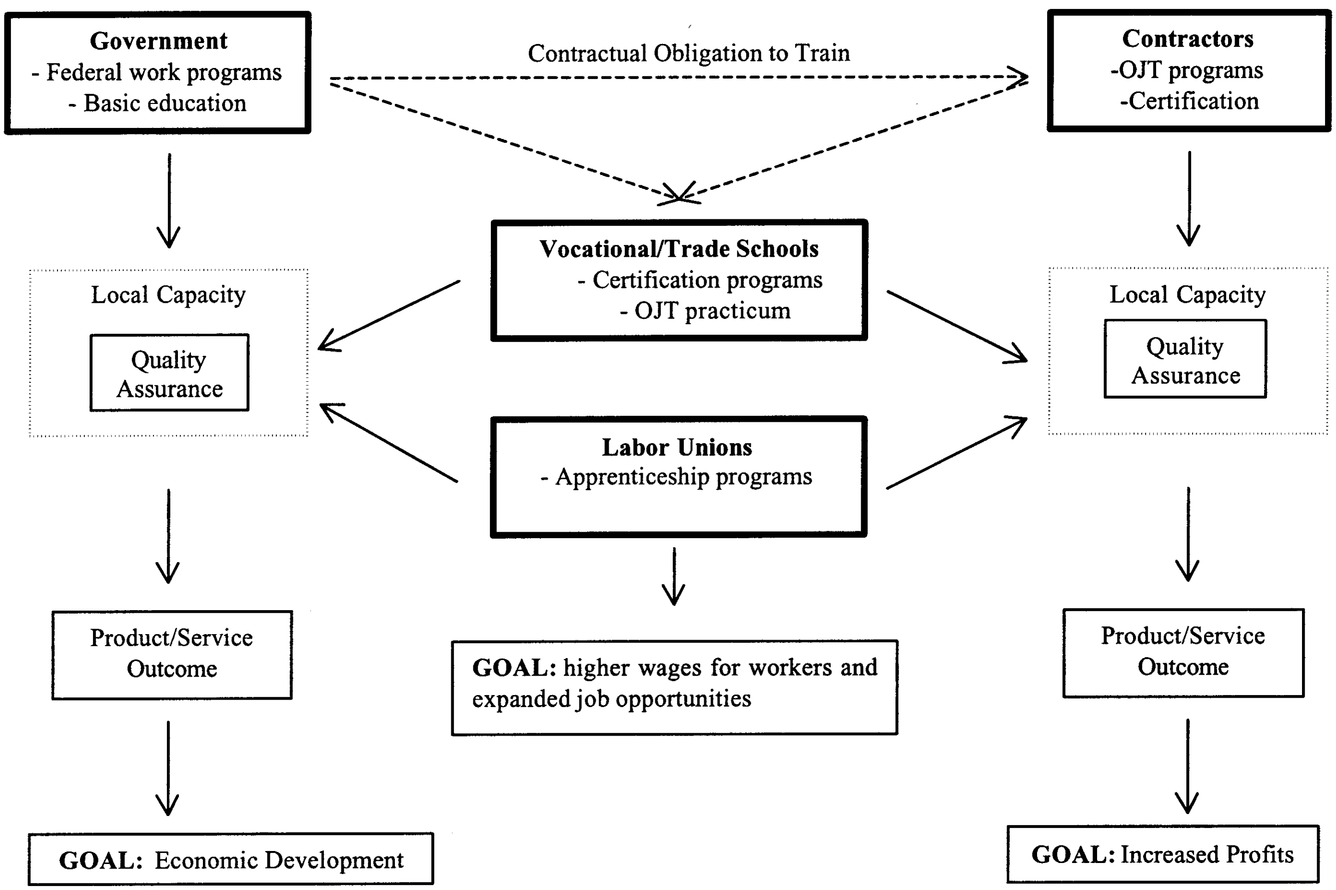
Depending on who has ultimate responsibility for project delivery and management, the competence and skill level of the contractor and client-owner varies for project oversight control. Client-owner competence must be high for design-bid-build, in order to manage and coordinate all the contractors and conformity to specifications. Contractor competence must be even higher, however, for design-build, given the added need for coordination between design and construction, and the additional potential for incomplete design or other design failures.

In both cases, there is a need for the client-owner to exercise restraint in payment in order to elicit compliance with standards. Paying at a rate and schedule that is similar to the actual construction would be optimal, for paying too much ahead of time diminishes the client-owners' leverage over the contractor. The competence and capability of who performs the management functions is a vital factor to consider in considering procurement strategy and training implications.

5.3 Collaborative Provision of Training

The training should also be an intentional, collaborative effort between the public education sector, the private construction sector, and an expanded labor union presence. As seen in Figure 5.1 below, the government could set up a contractual obligation for the private sector to provide training to its own laborers. At the same time, the government and contractor could both shape the vocational and trade school curriculum. Such coordination could improve the supply of relevant education and skills provided the public sector while at the same time creating a ready pool of laborers for the private sector. Similarly, the private sector could "outsource" its training to the public sector and/or labor associations with tight control over the relevance of the skills being taught and practiced.

Figure 5.3: Collaborative Provision of Local Capacity Building



A critical element of the collaboration would be to institutionalize informal means of apprenticeship by strengthening labor unions. Labor union training, such as that provided by the Carpenters' Union, would provide an invaluable source for upgrading work skills, and reducing the monopoly of workers held by local contractors. Similarly, Youth Apprenticeship programs could replenish construction labor shortages, provide access to federal funds, and provide a social service of youth investment.

Training should be demand-oriented and not supply-oriented. The program should be tailored to meet the needs, and potentially unique challenges of those needing the training. In the case of Tren Urbano effective training meant utilizing a familiar language in sessions over short, consistent times.

5.4 Recommendations

In the construction of future extensions, the conditions of local skill capacity would be different due to the previous experience in Phase 1. The labor pool and contractors are somewhat more experienced, and more aware of the challenges and impediments to construction of transit. It is important to be aware, however, that a choice awaits. On the one hand, the PRHTA could choose to continue with the same contractors for future construction due to their experience and developed skills, but exercise greater quality control and quality assurance with stronger punitive mechanisms. On the other hand, the PRHTA could choose to use similar design-build mechanisms or to shift to design-bid-build. A third alternative is to employ design-build, with more explicit attention on supervisor and worker training, and best-value contractor selection rather than low-bid. It would thus be up to the PRHTA to create a stronger requirement for training the labor workforce, in order to have the capacity to produce quality construction the first time.

5.4.1 Best Value vs. Low Bid

The client-owner should take advantage of the freedom from low bid in a design build procurement strategy to pick a bid based on best-value. Although low bids may appear low at the time of bid awards, the extra claims costs incurred due to the variety of factors described in this thesis may result in costs far exceeding a higher bid by a more experienced and reputable firm.

The liberty to choose a best-value bid allows greater freedom to choose a competent and capable contractor who can manage the project better, and who may provide a more transparent bid. Although it is difficult to pre-judge the contractor motivation in the bidding process, a best-value scheme creates the incentive for transparency. This counters temptations to underbid merely to win the bid, and could be pressured to include more investment in worker training. Paying more for a more experienced or reputable contractor can help the quality of construction because he not only possesses the competence, but also can establish training for others.

For example, in Rí Piedras, Kiewit's high bid price initially may have also been the more honest bid. The original TU project was estimated at $1.4 billion but has quickly escalated to a little over $2.0 billion over the 8 year lifespan of the project. Since the total number of claims awarded over time far exceeds the differential between the highest and lowest initial bids of a contractor, then it is likely to be more cost effective and ensure better quality results with a best value choice.

In the bid selection process, screen the qualifications not only of the primary contractor, but also the subcontractors with particular attention paid to training problems and the experience of managers. Include an assessment of the local capacity before embarking on a project, and a strategy, accountability mechanism, and schedule to help establish the institutions and training programs necessary to produce a quality outcome.

5.4.2 100% Final Design Acceptance

In the trade-off between quality and schedule, one method of client-owner control to ensure quality is to require 100% design acceptance before construction can begin. Although in theory, the lower design is intended to shift risk to the contractor, in actuality, the client owner has no means of eliciting quality before the work is finished. Without clear, final design and specifications, both to direct the supervisors and workers and facilitate QA/QC, ambiguity on expectations can lead to substandard work.

Taking the logic one step further, a modified design-build strategy, a "design-bid-design-build" strategy may be a prudent alternative to consider (Salvucci, Personal Communication, 2002). The modified design-build would provide an initial design (10%) followed by a bid-design-build where construction could not commence before 100% design completion. This may be the strategy to attain benefits of the 100% design specification of the conventional design-bid-build procurement strategy combined with the benefits of providing flexibility to contractors with innovative capabilities in the new design-build procurement strategy. Furthermore, such a hybrid allows the owner to retain leverage over the contractor by ensuring quality specifications before beginning construction. While this does not guarantee quality work product, it nevertheless allows begins the process with a clearly-defined specification.

The requirement for 100% design acceptance establishes a precedence for training to work by clarifying management and construction standards to which construction can refer. Regardless of whether the design is achieved through a design-bid-build or a design-build process, the designs are necessary to establish. Even the most skilled and trained workers would achieve poor quality, i.e., conformance to the specified standards, without a clear and clearly communicated plan up front. A training program is based upon the premise that a design is created, and that the help is needed to achieve a specified standard.

5.4.3 Quality Control Punitive Mechanism

The quality control firm must be given the real exercise of power, through the threat of a real punitive action. This may elicit greater voluntary compliance on-site if the inspector had the power to initiate and activate a "Stop Work Order." If there are no real punitive consequences for stopping shoddy or sub-par quality work, then there is little motivation for the contractor to correct inferior work.

The designer may be a better alternative to conduct inspections, rather than contracting an entirely separate inspector. This gives the designer more opportunities for input, as well as ensures a minimum level of competence among the inspectors.

Stronger quality control establishes the accountability mechanism necessary for training to be effective. Training to do the job right is useless if a process is established where doing it the wrong way, whether intentionally or unintentionally, is accepted.

5.4.4 Labor Union and Vocational/Trade Schools

The role of the labor union and increasing prominence of a revamped vocational and trade school provision of training would be of utmost importance to a revitalized training scheme for the construction industry in general, as well as for the Tren Urbano project in particular. Both labor unions and vocational schools have the potential to act as a go-between, drawing upon the best that the private and public sector have to offer. Access to governmental funds for education and training, as well as partnerships with private sector contractors through on-the-job apprenticeship programs would improve the public education provision of relevant training. The labor unions, also, are a vital protector and advocate for improved wages and expanded job opportunities within construction. Additionally, these two institutions may increase the professionalization of construction through a heightened certification process.

5.5 Theoretical Contributions and Future Research

An important theoretical contribution of this thesis is the expansion of the technology transfer discourse from a focus on an educated managerial class to include the ramping-up of skills for low-skilled, often uneducated labor. This not only serves to provide a greater local skills capacity to enhance the environment for private firms to employ skilled labor, but also serves the public sector objective to build local skills in depth, and in breadth. Emphasis on low-skill upgrade, particularly for the construction industry, would result in the inclusion of more members of the general population into the formal labor market.

Given the defined scope of this thesis, many opportunities for expanded or complementary research exist. For instance, reasons for the discrepancy between management incentive and construction outcome are worthy of future research. The design-build-operate-maintain (DBOM) is a strategy to shift risk to the contractor, who must operate the system with the consequences of poor work. Theoretically, the DBOM for STT should have shifted all risk upon the contractor and therefore produced the best results in quality because STT would have the added incentive of the long-term quality of the system for operations and maintenance. Furthermore, STT and Kiewit both have strong reputations of management expertise, as well as capable contract managers at both firms who have impressive decades of experience in transit construction and managing complex contracts. As the results of Chapter Four reveal, however, the two contractors had drastically diverse outcomes, with STT as one of the worst performers, with Redondo as their subcontractor and the Torrimar and the O&M facilities furthest behind in schedule and significant construction quality problems. Probing into factors which explain their differences, such as firm adaptability to new conditions, merit further research.

In the case of Tren Urbano, a joint-venture model of knowledge transfer seemed to be attempted. The inexperienced government (PRHTA) was partnered with experienced private sector partners (GMAEC) in the Tren Urbano Office. Similarly, the experienced prime contractors from U.S. mainland and foreign countries were partnered with inexperienced subcontractors from the island. In both cases, cheaper execution and increased learning seems to have been the goal. Further exploration into the assessment of how this scheme did and did not work, and why, could be a potentially fruitful piece of research that would complement the findings of this particular research.

Another issue needing further research is the question of a foreign labor component with high skills versus local labor component requiring more training investment. A study which evaluates the financial and social costs and benefits of various mixes of local and foreign labor would be a complement to this study.

The focus of this thesis was on construction quality in a new transit system. Attention to the operations and maintenance of a new transit system would also be beneficial. Other high technology industries, such as the growing pharmaceutical industry in Puerto Rico, as well as other high tech or service industries in developing countries would serve as a start for such a study.

Potential implications of training as it applies to quality control measurements could be broken down and assessed. The measurements for quality construction performance on craftsmanship and project delivery could include the following:

- On-time or delayed delivery –How well did the contractor meet their schedule requirements?
- Functionality – How well do the constructed products perform? In projects with multiple factors needing coordination, how well do the separate functions integrate?
- Aesthetics/finishings – How well does the work product meet the designers' aesthetic intent?
- Cost overruns – How well were additional costs avoided?
- Safety – How safe are the workers?

Looking more closely at these factors, and doing a more in-depth analysis on the factors influencing each of these categories, and identifying how training for workers could improve these specific categories would be a valuable addition to the work established in this thesis.

Another issue to explore in the future would be variations of the DBOM approach. A possible variation to the DBOM approach would be to break up the contract according to functions: tunneling, civil, finishing. The contractor could be specified according to specialization. For portions of the project where the client-owner either has specific standards that need to be met, or where the contractor does not have the capacity, do a design-bid-build procurement, where 100% of the specifications are provided before the project is put out to bid. For example, elements such as fixed facilities and guideway, track, and signaling portions might be appropriate for design-bid-build. While elements of significant proprietary contractor experience, such as tunneling, might best be conducted in a design-build arrangement.

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