



Quality Assurance and Quality Control Guidelines

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Of Transportation
**Federal Transit
Administration**

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13. ABSTRACT (Maximum 200 words) The Federal Transit Administration (FTA) sponsored the development of the Quality Assurance and Quality Control Guidelines to provide a resource for transit authorities and others undertaking capital projects. The FTA requires grantees undertaking major capital programs to prepare a Project Management Plan (PMP) that includes a Quality Plan. Even for those projects not considered major, a Quality Plan can be a useful tool for guiding activities to assure project quality. Chapter 1 presents definitions and provides an overview of quality in capital projects. Chapter 2 presents fifteen elements that should be the basis of a quality program. Chapter 3 discusses alternative approaches that depend on the type of capital project, the size of the project, and the use of consultants for project management; as well as an overview of the use of independent assurance programs, QA/QC in design-build projects, information on test lab accreditation, a description of the value engineering process, and a section on software quality assurance. Chapter 4 discusses the development of the Quality Plan throughout the different project phases from project planning, preliminary engineering and final design, construction and equipment procurement, and testing and start-up. The appendices provide selections of quality elements from several transit quality programs.				
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METRIC/ENGLISH CONVERSION TABLES

ENGLISH TO METRIC	METRIC TO ENGLISH
<p style="text-align: center;">LENGTH (APPROXIMATE)</p> <p>1 inch (in) = 2.5 centimeters (cm) 1 foot (ft) = 30 centimeters (cm) 1 yard (yd) = 0.9 meter (m) 1 mile (mi) = 1.6 kilometers (km)</p>	<p style="text-align: center;">LENGTH (APPROXIMATE)</p> <p>1 millimeter (mm) = 0.04 inch (in) 1 centimeter (cm) = 0.4 inch (in) 1 meter (m) = 3.3 feet (ft) 1 meter (m) = 1.1 yards (yd) 1 kilometer (km) = 0.6 mile (mi)</p>
<p style="text-align: center;">AREA (APPROXIMATE)</p> <p>1 square inch (sq in, in²) = 6.5 square centimeters (cm²) 1 square foot (sq ft, ft²) = 0.09 square meter (m²) 1 square yard (sq yd, yd²) = 0.8 square meter (m²) 1 square mile (sq mi, mi²) = 2.6 square kilometers (km²) 1 acre = 0.4 hectare (ha) = 4,000 square meters (m²)</p>	<p style="text-align: center;">AREA (APPROXIMATE)</p> <p>1 square centimeter (cm²) = 0.16 square inch (sq in, in²) 1 square meter (m²) = 1.2 square yards (sq yd, yd²) 1 square kilometer (km²) = 0.4 square mile (sq mi, mi²) 10,000 square meters (m²) = 1 hectare (ha) = 2.5 acres</p>
<p style="text-align: center;">MASS - WEIGHT (APPROXIMATE)</p> <p>1 ounce (oz) = 28 grams (gm) 1 pound (lb) = 0.45 kilogram (kg) 1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)</p>	<p style="text-align: center;">MASS - WEIGHT (APPROXIMATE)</p> <p>1 gram (gm) = 0.036 ounce (oz) 1 kilogram (kg) = 2.2 pounds (lb) 1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons</p>
<p style="text-align: center;">VOLUME (APPROXIMATE)</p> <p>1 teaspoon (tsp) = 5 milliliters (ml) 1 tablespoon (tbsp) = 15 milliliters (ml) 1 fluid ounce (fl oz) = 30 milliliters (ml) 1 cup (c) = 0.24 liter (l) 1 pint (pt) = 0.47 liter (l) 1 quart (qt) = 0.96 liter (l) 1 gallon (gal) = 3.8 liters (l) 1 cubic foot (cu ft, ft³) = 0.03 cubic meter (m³) 1 cubic yard (cu yd, yd³) = 0.76 cubic meter (m³)</p>	<p style="text-align: center;">VOLUME (APPROXIMATE)</p> <p>1 milliliter (ml) = 0.03 fluid ounce (fl oz) 1 liter (l) = 2.1 pints (pt) 1 liter (l) = 1.06 quarts (qt) 1 liter (l) = 0.26 gallon (gal) 1 cubic meter (m³) = 36 cubic feet (cu ft, ft³) 1 cubic meter (m³) = 1.3 cubic yards (cu yd, yd³)</p>
<p style="text-align: center;">TEMPERATURE (EXACT)</p> <p style="text-align: center;">[(X-32)(5/9)] °F = Y °C</p>	<p style="text-align: center;">TEMPERATURE (EXACT)</p> <p style="text-align: center;">[(9/5) Y + 32] °C = X °F</p>
<p>QUICK INCH - CENTIMETER LENGTH CONVERSION</p>	
<p>QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION</p>	
<p>For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price \$2.50 SD Catalog No. C13 10286</p>	

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J. Timothy Brown	Vice President, Quality Programs PARSONS
Tony Canuso	Project Manager Transportation Construction Services, Inc.
Khuong T Luu, P.E.	General Engineer, Region IX Federal Transit Administration
Dave McSpadden	Manager of Quality Assurance Metropolitan Transit Authority, Houston
Sam Nassif	Program Engineer Federal Transit Administration
Bill Rodwick	Chief of Quality and Safety Management MTA New York City Transit
Lou Viner	Assistant Director of Compliance Washington Metropolitan Area Transit Authority

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AA	Alternatives Analysis
A2LA	American Association for Laboratory Accreditation
ANSI	American National Standards Institute
ASQC	American Society of Quality Control
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
CII	Construction Industry Institute
CMC	Construction Management Consultant
DB	Design-Build
DCQI	Design and Construction Quality Institute
DOD	Department of Defense
FFGA	Full Funding Grant Agreement
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
ICBO ES	International Council of Building Officials Evaluation Service
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
LAP	Laboratory Accreditation Program
LIRR	Long Island Rail Road
NACLA	National Cooperation of Laboratory Accreditation
NIST	National Institute of Standards and Technology
NVLAP	National Voluntary Laboratory Accreditation Program
OSS	Office of Standards Services
PE	Preliminary Engineering
PMO	Project Management Oversight
PMOC	Project Management Oversight Contractor
PMP	Project Management Plan
PM	Project Manager
QA	Quality Assurance
QC	Quality Control
RCC	Rail Construction Corporation

RE	Resident Engineer
SEPTA	Southeastern Pennsylvania Transportation Authority
SPC	Statistical Process Control
SWTP	The Southwest Transit Project of the Chicago DPW
TQM	Total Quality Management
TRB	Transportation Research Board
VQS	Vendor's Quality System
VSDP	Vendor's Software Development Process
WMATA	Washington Metropolitan Area Transit Authority

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EXECUTIVE SUMMARY

The *Quality Assurance and Quality Control Guidelines* were first published in 1992 and this constitutes the first update to that document. The *Quality Assurance and Quality Control Guidelines* are for Federal Transit Administration (FTA) grantees that are undertaking design, construction, or equipment acquisition programs. FTA requires grantees undertaking major capital programs to prepare a Project Management Plan (PMP) that includes a Quality Plan. Even for those projects not considered major, a Quality Plan can be a useful management tool for guiding activities to ensure project quality.

For grantees undertaking multiple projects, the development of a project Quality Plan should be an outgrowth of a functioning quality management system. A comprehensive quality management system is comprised of a written quality policy, a written plan, written procedures, a management that supports and takes responsibility for quality, and personnel who undertake quality assurance and quality control activities.

Chapter 1 provides an introduction to quality, including guideline objectives, definitions, and a brief overview of various quality topics and QA/QC in the context of project and construction management. Also in Chapter 1 are descriptions of what makes up an effective Quality Management System, perspectives on quality from the standpoint of the service provider and user, a description of the inter-relationships and balances among quality, costs and schedules, an overview of the barriers to QA/QC and suggested resolutions, and a description of how to use these guidelines.

Chapter 2 provides a description of the elements of a quality management system. The elements should be considered in the development of detailed quality procedures. The fifteen quality elements are as follows:

1. Management Responsibility
2. Documented Quality Management System
3. Design Control
4. Document Control
5. Purchasing
6. Product Identification and Traceability
7. Process Control
8. Inspection and Testing
9. Inspection, Measuring, and Test Equipment
10. Inspection and Test Status
11. Nonconformance
12. Corrective Action
13. Quality Records
14. Quality Audits
15. Training.

Organization of the quality functions for a project should be tailored to the grantee's organizational needs and management structure.

Chapter 3 discusses alternative approaches that depend on the type of capital project, the size of the project, and the use of consultants for project management. Whatever the approach, the grantee has overall responsibility for an effective quality management system and needs to maintain some oversight responsibility for the project quality. Also covered in Chapter 3 is an overview of the use of independent assurance programs, QA/QC in design-build projects, information on test lab accreditation, a description of the value engineering process, and a section on software quality assurance.

Chapter 4 discusses the development of a project Quality Plan. This is an evolutionary process, during which different levels of detail are appropriate at the different project phases. The Quality Plan should be developed as part of the Project Management Plan at the end of the project planning phase, and should be modified as required to provide adequate project quality guidance during design, procurement, and construction. The authority and responsibilities of each component of the project organization need to be clearly defined, extending from grantee senior management to consultants, suppliers, and contractors. The Quality Plan needs to provide details of the quality management system requirements to be applied during the design process, including any quality assurance requirements to be carried out by design consultants. The Quality Plan should define the quality management system requirements to be carried out by construction contractors, construction management consultants (CMC), and equipment manufacturers. The Quality Plan should describe the quality oversight activities (e.g., reviewing, monitoring, auditing, etc.) to be undertaken by the grantee to assure that the plan is followed and effective.

Following Chapter 4 are the appendices that include selections from transit quality programs, selected documents from Long Island Railroad's Quality Management System, and seven case studies. These appendices are provided as references.

CHAPTER 1

INTRODUCTION

1.1 Guideline Objectives and Background

This report was developed in 1992 and subsequently updated in 2002 under the Federal Transit Administration (FTA) sponsorship to assist transit agencies in developing quality management systems and plans for their FTA-funded transit capital improvement projects. FTA regulations require each FTA funded major capital program to submit a Program Management Plan (PMP) for FTA approval. These regulations also stipulate that a Quality Plan must be referenced or included as part of the PMP.

FTA maintains oversight for the grants that it awards, but assigns the grant administration and management responsibility to the grantees. FTA's Office of Program Management delegates the responsibility for oversight of nearly all capital grants to the appropriate FTA Regional Office.

The *Quality Assurance and Quality Control Guidelines* is one of several initiatives undertaken by FTA to enhance the management of the projects that it funds. The initiatives have included guidance to grantees on topics such as insurance and value engineering; assignment of Project Management Oversight Contractors (PMOC) to provide technical support to FTA; and the development of the *Project and Construction Management Guidelines* [Ref. 38].

The *Project and Construction Management Guidelines* includes a brief description of QA as a part of a management control system. It suggests appropriate contents of a QA/QC program in preliminary engineering, final design, construction, testing, and start-up.

This *Quality Assurance and Quality Control Guidelines* document expands upon the QA/QC program guidance contained in the *Project and Construction Management Guidelines*. Its major purpose is to promote the development of grantee quality management systems consistent with contemporary FTA practices to affect successful implementation.

Before undertaking the 1992 effort, information was gathered through the PMOCs to determine the state of QA/QC programs for FTA funded capital improvement projects. Some 40 different projects were covered in this investigation, ranging in dollar value from less than a million to several billion. The findings were as follows:

- Much progress had been made in developing and applying formal QA/QC programs. Nearly three-quarters of the grantees had either a documented QA/QC program, or they utilized a CMC who had a QA/QC program. A majority of the formal written QA/QC programs were adopted in 1990.
- While less than half of the grantees had staffs dedicated to QA, this concept was growing. Many of the staffs that existed were newly formed.

- Substantive quality in the projects was found where there was enthusiasm for a quality program. Examples were found in old-line agencies and in newer agencies. These examples included a variety of QA/QC program types and staffing procedures.
- A formal written QA/QC program was particularly helpful for grantees with little experience in the particular project under construction. It was also helpful for old-line agencies that had evolved multiple quality programs that had not always proven effective.
- QA/QC was important in design as well as manufacturing and construction. Design errors were responsible for a large percentage of rework, so catching design errors had a high payoff.
- QA/QC programs seemed to work reasonably well in projects employing a CMC and an outside construction contractor. However, there was a need for the grantee to recognize their overall QA responsibilities, which could not be delegated to the CMC.

Conducting a similar study in advance of the 2002 update was not a requirement of the FTA because it was already keenly aware that nearly all of the conclusions of the original study were still valid. The only exceptions were on the positive side and consisted of the knowledge that in 2002 all of the larger grantees now had QA/QC programs and had staffs dedicated to QA/QC activities.

The remainder of this chapter defines a number of the quality concepts, gives a historic overview of their development and their relationship, and discusses QA/QC in the context of project and construction management. This chapter also includes a description of what makes up an effective Quality Management System, perspectives on quality from the standpoint of the service provider and user, a description of the inter-relationships and balances among quality, costs and schedules, an overview of the barriers to QA/QC and suggested resolutions, and directions for using these guidelines.

1.2 QA/QC Definitions

Following are definitions of various terms used in the quality field.

Quality Policy	"The overall quality intentions and direction of an organization as regards quality, as formally expressed by top management." [Ref. 52]
Quality Management	"That aspect of the overall management function that determines and implements the quality policy." [Ref. 52]
Quality Management System	"The organizational structure, responsibilities, procedures, processes, and resources for implementing quality management." [Ref. 52]
Quality Procedures	Written instructions for implementing various components of the quality management system. Procedures should identify what is to be done, who should do it, how, where, and when it should be done.
Quality Manual	The typical form of the main document used in drawing up and implementing a quality management system. The quality manual should contain the quality policy and written procedures. In larger properties, there can be more than one quality manual. For example, there could be a corporate quality manual, divisional quality manuals, and specialized quality manuals for design, procurement, and construction activities, prepared by those responsible for the work.
Quality Plans	A written description of intended actions to control and assure quality. The Quality Plan defines applicable quality policy for the project and applicable quality procedures. For new projects, Quality Plans should be developed consistent with all other requirements of a grantee's quality management system.
Quality Program	The coordinated execution of applicable QA and QC plans and activities for a project.
Quality Control	"The operational techniques and activities that are used to fulfill requirements for quality. " [Ref. 52] These techniques are used to assure that a product or service meets requirements. QC is carried out by the operating forces. Their job is to do the work and meet the product or service goals. Generally, QC refers to the act of taking measurements, testing, and inspecting a process or product to assure that it meets specification. It also includes actions by those performing the work to control the quality of the work. Products may be design drawings or specifications, manufactured equipment, or constructed items. QC also refers to the process of witnessing or attesting to, and documenting such actions.

Quality Assurance	"All those planned and systematic actions necessary to provide adequate confidence to the management that a product or service will satisfy given requirements for quality." [Ref. 52] QA emphasizes "upstream" actions that directly improve the chances that QC actions will result in a product or service that meets requirements. QA includes ensuring the project requirements are developed to meet the needs of all relevant internal and external agencies, planning the processes needed to assure quality of the project, ensuring that equipment and staffing is capable of performing tasks related to project quality, ensuring that contractors are capable of meeting and do carry out quality requirements, and documenting the quality efforts.
Quality Oversight (or Quality Surveillance)	A dictionary definition of oversight is "watchful care; general Supervision." Quality oversight is conducted by an organization that is ultimately responsible for project quality where other organizations have been assigned QA and QC. Quality oversight can range from an informal process of keeping in touch with the QA organization to a second layer of QA activities, depending upon the circumstances. Quality oversight verifies the execution of the quality program. Quality surveillance means the same thing as quality oversight.
Total Quality Management	An organization-wide effort that involves everyone in the effort to improve performance. It makes quality a primary strategic objective. TQM is achieved through an integrated effort among personnel at all Levels to increase customer satisfaction by continuously improving performance.
Major Capital Project	<p>A Project that:</p> <ul style="list-style-type: none"> • Involves the construction of a new fixed guideway or extension of an existing fixed guideway; or • Involves the rehabilitation or modernization of an existing fixed guideway with a total project cost in excess of \$100 million; or • The Administrator determines is a major capital project.

1.3 A Historical Overview of QA/QC and TQM

Dating back to the early crafts, product quality was a very personal product characteristic. Craftsmen earned their reputation by producing quality goods for each customer. With the industrial revolution and mass production, there was no longer a one-to-one relationship between craftsmen and customer. Specifications or standards for how to produce a product became the substitute for the craftsman's personal touch. QC was the function of inspecting the end product to determine if it met the specification or standard.

Standards became important not just to ensure that pieces fit together, but also to ensure the safety of the final product. As early as 1914, the American Society of Mechanical Engineers

(ASME) developed codes for boilers and pressure vessels. Use of these standards for boilers resulted in fewer failures, even as performance improved.

Quality standards began to be applied to the nuclear industry in the late 1940's, and in 1954 the ASME published ASME NQA-1, "Quality Assurance Program Requirements for Nuclear Facilities." This publication listed eighteen criteria for a QA program. In the nuclear industry QA refers to the entire QA/QC process.

Despite this earlier start, the real push for QA programs is thought to have come in the 1960's, when Robert McNamara introduced the concept in the Department of Defense (DOD) [Ref. 23]. McNamara wanted to cut the budget by transferring QC responsibility to DOD contractors, primarily manufacturers. DOD then had the QA responsibility where the purpose was to assure that the contractors carried out QC. The idea eventually spread to the construction sector of DOD and the Corps of Engineers instituted its own program in the late 1960's. With the Corps program, the construction contractor is responsible for QC while the Corps handles QA.

The Japanese adapted the statistical QC procedures promoted by W. Edward Deming, and the managerial performance approach advocated by J.M. Juran. These concepts combined with a highly educated Japanese work force, and with the Japanese approach to continual quality improvement, led to Japan establishing itself as the leader in quality in the electronics and automobile industries.

The Japanese went beyond concepts of QC and reliance on inspection and testing, to the point where high quality work is expected from the start. Japanese corporations expect an extremely high level of quality from their suppliers, and long-term relationships are built with those suppliers that can meet quality expectations. The Japanese use management techniques to involve the entire work force in quality improvement efforts. They make a continuing effort to understand the desires of the customers to ensure that they are building the right thing as well as building it right. Because of its broad scope, the Japanese quality programs have been described as Total Quality Management or TQM, rather than QA/QC.

TQM, QA, and QC represent a hierarchy. A quality program for inspection and testing of product is a QC program. The addition of QA activities should improve upstream processes as well as provide for verification of QC activities, and should greatly enhance the probability of compliance with quality goals. TQM will improve management procedures and processes in order to further improve quality and reduce costs. In the early 1990s, the transit industry appeared comfortable with QC, but was in the beginning stages for establishing QA programs.

1.4 QA/QC in the Context of Project and Construction Management

The function of project and construction management is to assure acceptable quality while executing the project on-time and on-budget. For an FTA grantee, acceptable quality has a broad meaning – it means meeting the needs of the public and satisfying all of the regulatory and operational requirements outside and within the agency.

The major reason for emphasizing the need for a Quality Plan in addition to the PMP is to explicitly recognize the importance of quality in constructed projects and in procurement. The job of project management is to manage schedule, budget, and quality of a project. However, since schedule and budget are easy to measure, and thus have been the traditional focus of management, quality processes have often been overlooked. The requirement for a specific Quality Plan for a project helps to address this imbalance.

1.5 Quality Management System (QMS)

Transit projects can involve many processes that vary in nature: planning, engineering design, systems design, software development, construction, and manufacturing. The manufacturing industry, which generally utilizes processes that are repetitive in nature, can easily make use of quality programs that are based on statistical QC techniques. The statistical nature of these types of quality programs facilitates process improvements through continual experimentation.

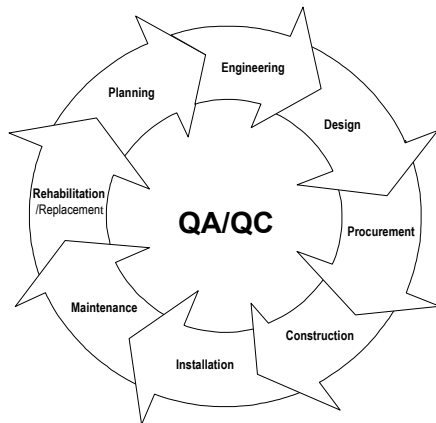
Planning, engineering design, and construction, on the other hand, often involve "one of a kind" projects where a quality management system that emphasizes effective management practices is more appropriate. Similarly, software development and systems design are related processes that require unique quality management systems and specialized quality tools and procedures.

1.5.1 Characteristics of A Quality Management System

An effective Quality Management System is not just one where good products and services are delivered. Rather, it is one that continuously seeks to improve the products and services being delivered and the corresponding delivery processes used by the organization. In order to establish an effective Quality Management System, the following characteristics are required:

- Leadership – adopting a quality policy, instilling a culture that values quality, involving all levels of management in quality initiatives, identifying a senior quality manager, providing resources and personnel to accomplish quality objectives, delivering products and services that always meet customer expectations.
- Design quality and prevention – developing products and services that meet customer expectations and reduce life cycle cost.
- Strategic quality planning – establishing a vision for the future of where and what the organization wants to be and developing a plan to arrive at that destination.
- Focus on customer satisfaction – clearly identifying internal and external customer requirements and making decisions that support the commitment to meet those requirements.
- Continuous improvement – identifying key areas for improvement, whether they are products and services or processes.
- Teamwork, employee participation – all employees participate to the best of their ability and within the bounds of their areas of expertise to deliver products and services that meet requirements for performance, cost, and schedule.
- Training and development – all persons at all levels within the organization receive basic and advanced quality training relative to their functional and managerial responsibilities within the organization.

The current move towards performance specifications contracting in the engineering and construction industry has been extended into the quality assurance/quality control programs to formalize the expanded definitions of quality within the project development process. As a result, agencies are instituting strong construction and procurement oversight programs in order to assure that quality design and workmanship is provided in a timely manner.



Traditional theories and practices of QA/QC have been effective in delivering successful project results. However, these theories have been somewhat limited or 'static,' focusing on the traditional project detailed design specifications. Industry experience illustrates that QA/QC is at the heart of the asset acquisition and management process. QA/QC lends itself to each stage in a project life cycle and should be thought of as a continuous or 'dynamic' process that should be applied throughout the asset life cycle. This concept becomes more apparent as we move towards performance specifications of the traditional civil elements and extend the concept into the vehicle and systems asset

types. The quality assurance life cycle approach extends into the operational aspects such as warranty provisions, preventive maintenance and safety programs and the rehabilitation and replacement of each asset type as it fulfills its life cycle design specifications.

As more focus is placed on performance specifications, under a systematic, life cycle approach, QA/QC becomes incorporated earlier in the project development process, starting at the project planning and engineering stages. The emphasis on QA/QC starts to expand, complementing the traditional QA/QC approach, as the project goes into engineering, design, procurement, construction, systems installation, operations and maintenance, and asset rehabilitation and replacement. Another distinguishing characteristic of a systematic QA/QC approach is the ability to address the root cause of non-compliance problems arising during the life cycle of a given project, rather than treating the symptoms of such problems, as is the case with the traditional approach. The importance of a systematic QA/QC approach is further emphasized in a Design-Build project development environment, where the project moves through its lifecycle stages in a 'continuous' rather than 'discrete' fashion.

1.5.2 Involvement

As stated above, a Quality Management System is one that is all encompassing. As a result, every person within the organization must participate to the extent that his or her job responsibilities dictate. This includes members of grantee senior management, functional management and project management, functional, office and shop personnel, including engineers and purchasing personnel, programs personnel, quality personnel, and operations personnel. In addition, all consultants, contractors and suppliers must become part of the process.

1.5.3 Implementation Process

In order to implement an effective Quality Management System, the following general steps should be followed:

- Senior management must commit to the development of a Quality Management System.
- All personnel should receive introductory and advanced training, as applicable, on general and specific quality topics.
- Customer expectations and requirements must be defined.
- Key processes must be selected for improvement.
- Data related to the products, services and the delivery processes must be gathered and analyzed.
- Feedback must be provided to the responsible managerial and functional areas for further process improvement.

1.5.4 Tools

There are many tools available to program/project managers and project and quality personnel to solve problems, control processes, improve products and services, and assure project success. A summary of those tools may be grouped into three broad categories:

- Statistical Process Control
 - Process analysis/flow diagrams
 - Check sheets
 - Pareto analyses/charts
 - Histograms
 - Cause and effects diagrams
 - Run charts
 - Scatter diagrams
 - Control charts
- Statistical Quality Control
 - Acceptance sampling
- Project-related tools
 - Pre-activity meetings
 - Partnering
 - Constructibility reviews
 - Design reviews
 - Progress meetings
 - Status reports
 - Action items lists
 - Non-conformance reports
 - Brainstorming
 - Quality Audits.

Utilizing or requiring consultants and contractors to use these tools will allow grantees to more effectively manage their projects resulting in reduced costs and efficient on-time performance. According to the International Organization for Standardization (ISO) proposed standard ISO 11462-1, some of the ways that effective implementation of Statistical Process Control SPC reduces cost and increases profit are [Ref. 6]:

- By managing the process more economically
- By reducing variation around target values
- By transferring variation in an in-process parameter to a controllable or manipulated process variable
- By providing signals of how a process is behaving, and how it is likely to behave, by assessing and quantifying what quality and consistency levels the process is currently capable of producing
- By identifying when to, when not to and where to look for assignable causes of variation or to make preventive process adjustments
- By pointing to potential root causes of failure modes and their sources
- By controlling and/or reducing random cause variation through process design changes, and other systematic changes to procedures.

A detailed explanation of each of these tools and how to use them is beyond the scope of these guidelines. However, these topics are covered in numerous textbooks, military and international standards, and quality control handbooks. Further, experienced quality control and quality assurance personnel are typically familiar with and know when and how to use and apply these tools.

One concept, however, that will be defined here is the concept of accuracy vs. precision:

- Precision – refers to the nearness of data to each other. When there is little scatter among the data points, the data is said to be precise. Whether the data is near or far from the standard or goal in question is not considered.
- Accuracy - refers to the nearness of the data to the standard or goal. It tells you how close you are to the bull's eye. Whether or not the data is scattered around the target is not considered.

When requirements for data are established, it is not enough to identify only accuracy or precision; both are needed. Further, when addressing data, it is not enough to say that it is accurate or it is precise; statements about both are necessary.

1.5.5 Root Cause Analysis

The tools identified in Section 1.5.4 will assist the project manager in identifying problems, quality or otherwise. Once a problem is identified, it is necessary to determine the cause of that problem. Sometimes the cause is very obvious and the resulting fix is very simple to implement. Sometimes the cause is not so obvious and the project manager needs to dig deeper to determine the cause. This process is known as Root Cause Analysis.

Root cause analysis is the concept of analyzing a problem beyond the obvious symptoms manifested by the problem and identifying the actual cause of the problem. A piece of equipment that is not able to produce product to the specified tolerance, at first glance, may appear to require adjusting, or replacement. However, the root cause of the problem could very well be operator error, incorrect drawings, unrealistic requirement, incorrect material, factory conditions, or some combination of all of these. Fixing the most obvious condition may not solve the problem and could result in further complications or delays. Consequently, all possible conditions and combinations must be explored before a problem can truly be eliminated and the equipment adjusted or replaced. Note that this is true whether the problem involves a piece of equipment, a process, or an individual.

1.6 Quality From Service Provider and User Perspectives

The definition of quality varies from grantee to grantee, from customer to customer, from contractor to contractor, from supplier to supplier, and indeed, from person to person. Depending on what a person sees or values in a product or process or project, the definition can vary vastly. It is virtually impossible for all parties to agree on one definition that satisfies everyone. Given the inherent “subjective” nature of the definition of quality, the need to utilize performance specifications becomes paramount. Performance specifications are geared towards product functionality, whereas prescriptive specifications are geared towards specifying the characteristics of a given product. Often times, it is this prescriptive methodology that limits the desired functionality and leads to higher costs to arrive at the desired quality. Research has demonstrated that quality expectations have been met (or exceeded) when agencies employed performance specifications in their procurement documents. By focusing on the functional elements of the end product, rather than the detailed characteristics of each subcomponent, the owner agency provides the contractor/manufacturer the needed flexibility to utilize their expertise in delivering a quality product that will not only meet the owner agency’s expectations, but also in a cost effective manner. The transit industry has been moving towards the implementation of performance specifications in the procurement of capital projects in order to reap the benefits of this approach. Nevertheless, within the transit industry, the definition of quality has definite connotations from the service provider and user perspectives. Following is a discussion of those perspectives and a description of the benefits of a successful quality program for the service provider and for the owner.

1.6.1 Product Characteristics

Each grantee project will have its own unique product characteristics or design features, even in those cases where the project involves similar product deliveries, such as buses or rail vehicles. A quality project or product is one that delivers to the grantee all of these features in a timely, cost effective manner. Not only must the product contain the requisite features, but also these features must effectively integrate and operate within the surrounding infrastructure in which the product will be utilized. As a result, the quality of the system or product should be evaluated, not as a stand-alone unit, but as integrated system. Additionally, the delivered project or product should be evaluated in light of its associated support materials, such as documentation, training, test equipment and spare parts. Although the user and service provider will view most of the product characteristics similarly on the surface, the underlying product characteristics and

support material will not be viewed at all by the user. Individual product characteristics are too numerous to list, but may be broadly described as features related to the product's design and its associated support materials.

1.6.2 Service Characteristics

In addition to product characteristics, each grantee project will require its own unique service characteristics. These service characteristics, when viewed by the service provider, will differ from those that will be expected by the user of the system. They differ in the sense that they represent the service delivered by the consultants, contractors, suppliers, etc. on the project. The user, on the other hand, views service characteristics by how well the service provider performs. Although some of the language that describes quality may be the same, e.g., on-time performance, the deliverer of the service will differ. Essentially, in one case the grantee is the recipient of the service and in the other case the grantee is the deliverer of the service. Some of the service characteristics are:

- Reliability
- Dependability
- Availability
- Responsiveness
- Competence
- Courtesy
- Credibility
- Security
- Accessibility.

1.6.3 The Service Provider

The service provider is generally the transit agency or port authority that provides transit services to the public. The grantee and transit agency are generally one in the same. However, within the transit agency is a broad range of functional and administrative departments, all of whom are typically customers and service providers to one another. For example, the construction management and engineering departments are typically involved in the procurement of systems and equipment that will be used by the operations department to deliver service to the riding public. Thus, the construction management and engineering departments are providing a service to the operations department that is providing a service to the public. Reversing the process, the operations department must provide their operating requirements to the construction management and engineering departments so that they can be translated into contract specifications.

At the opposite end of this cycle is the maintenance department that also provides a service to the operations department. Each of these departments, along with all those departments not explicitly mentioned, report to or provide a service to the administration of the transit agency. Thus, it is safe to assume that each and every individual in the transit agency is a "service provider" in some capacity – operations, engineering, construction, maintenance, procurement, etc.

1.6.4 The User

The user of the system is the public. In most cases, the public has the option to use or not use the services offered by the transit agency. Thus, the transit agency is competing for the dollars that will be spent by the public on transportation. These dollars are vital to the long term success of the transit agency and thus, the user is a necessary ingredient to that success.

1.6.5 Benefits to the Service Provider

When transit projects are successfully accomplished in a quality fashion, they offer the following benefits to the service provider:

- Successful, within-budget, on-time projects
- Reliable, safe, dependable equipment
- Effective, easy-to-use support materials
- Lower life cycle costs – materials, maintenance, etc.
- Involved, interested, satisfied work force
- Increased ridership
- Opportunities for growth
- Increased funding
- Improved image
- Transit-supporting public.

1.6.6 Benefits to the User

When transit projects are successfully accomplished in a quality fashion, they offer the following benefits to the user:

- Transportation that is accessible, easy-to-use, reasonably priced, reliable, safe, and dependable
- Transit alternatives that offer less stress and more peace of mind.

1.7 Inter-relationships and Balances Among Quality, Costs, and Schedules

1.7.1 Quality Attributes or Dimensions

As noted in Section 1.6 above, the definition of quality varies depending on who is doing the defining, be it grantee, customer, consultant, contractor, or supplier. Nevertheless, it is imperative that the grantee clearly identifies the “attributes or dimensions of quality” in their contract specification and purchase orders. By so doing, they can make clear to their consultant, contractor, or supplier their quality expectations and they will maximize the probability that the product or project they are procuring will satisfy their needs. Examples of quality attributes that can and should be specified include:

- Performance – a project’s main operating or functional characteristics
- Conformance – how the project will be measured as meeting the contract specification

- Reliability, maintainability, availability – the mean time or distance between failures, the mean time to repair, and the percent of time the system is available for service
- Aesthetics – appearance, color, etc.
- Features – functionality, beyond the main operating or functional characteristics
- Durability – ability to adapt to ambient conditions
- Safety – freedom from hazards
- Warranty – freedom from defects
- Service Life – expected time prior to major overhaul of the system.

In addition to specifying these quality attributes, it is imperative to specify the support materials that will allow the service provider to cost effectively maintain the system in a manner that will assure continued delivery of quality service to the user of the system. Examples include:

- Documentation – drawings, maintenance and operator manuals
- Training – maintenance (primary and secondary) and operator
- Test equipment – primary and secondary
- Recommended staffing levels
- Spare parts.

1.7.2 Quality Costs

Quality costs fall into two broad categories, the price of conformance and the price of non-conformance. The price of conformance is also known as the cost of detection and can be further divided into prevention costs and appraisal costs. The price on nonconformance is also known as the cost of lesser quality and can be further divided into internal failure costs and external failure costs. Figure 1-1 identifies examples of each of these categories.

As Figure 1-1 depicts, quality costs cover a wide spectrum and occur during all phases of the project. Although most nonconformance costs are borne by the contractor, the grantee may also experience unwanted costs as a result of nonconformance, such as loss of revenue, project personnel cost increases due to longer project duration, and extra force account costs associated with supporting the contractor. In addition, overall life cycle costs for such items as maintenance and spares will be typically higher for the grantee as a result of nonconformance issues that could not be resolved.

Grantee costs associates with conformance quality activities include design, process, and document control, inspection and testing, and audits and training.

Figure 1-1 – Summary of Quality Costs

Quality Costs	Examples
1. Price of Conformance/Cost of Detection	
A. Prevention Costs (Associated with assuring the product or project meets requirements)	Design analysis & reviews Training Prototyping Systems analysis Planning activities
B. Appraisal Costs (Associated with determining the degree of product or project conformance)	Audits Design checking Incoming inspection Supplies inspection Field inspection Testing Reliability/maintainability/safety analyses & testing
2. Price on Nonconformance/Cost of Lesser Quality	
A. Internal Cost of Defects or Failures (Associated with problems discovered prior to product or project delivery)	Assessment costs Scrap Repair Rework Downtime Schedule delays Cost of extended financing
B. External Cost of Defects or Failures (Associated with problems discovered after product or project delivery)	Warranty repair costs Customer complaints Product liability costs Transportation costs Labor, equipment, and materials Force account costs

1.7.3 Balancing Quality, Costs, and Schedules

It is evident from Figure 1-1 that the conformance activities are not just related to quality, but also fall into the category of good project management practices. Thus, it is difficult to clearly define how much is being spent on purely quality activities. Nevertheless, industry studies have shown that preventing defects avoids or reduces unwanted project costs and improves delivery performance. One rule of thumb is that every dollar spent on prevention saves \$10 in appraisal and failure costs [Ref. 8]. Further, quality expert Philip Crosby, in his 1979 book, *Quality is Free*, espoused the philosophy that the cost of poor quality is greater than the cost of preventing poor quality. Thus, he concluded that quality improvement efforts will more than pay for themselves [Ref. 15].

No discussion of quality costs would be complete without mentioning the impact of poor quality. Grantees are generally both consumers and providers of products and services. If the grantee accepts a poor design or approves nonconforming workmanship that does not satisfy their own requirements, they can be certain that the resulting product or service will not meet the

requirements of their customers, the public. This can have serious consequences resulting in the loss of ridership, the potential for liability, the loss of productivity, and an increase in life cycle costs.

Quality-related efforts are beneficial to the success, overall cost, and delivery performance of the project and that project managers must demonstrate diligence when making decisions that affect the quality-related efforts outlined in the 15 quality elements.

1.8 Barriers to QA/QC and Suggested Resolutions

1.8.1 Management Awareness

Managers have the responsibility for guiding the organization. They set the direction for the organization, establish the goals, and inspire the attitudes that drive their individual teams toward accomplishing the organization's mission. Most employees will focus on issues that they believe are of primary concern to their bosses. This attitude moves up and down the chain of command. There is no doubt that management is interested in providing quality products and services to their clients; however, the degree of interest is directly proportional to the actions of management. Simply put, actions speak louder than words and merely saying that you, as a manager, are interested in quality is not enough. Rather, grantee managers must:

- Establish a quality policy, quality guidelines, quality manuals and quality measures
- Provide leadership of, and actively participate in, quality initiatives
- Provide the necessary resources to accomplish quality goals
- Install an infrastructure that assures quality requirements are accomplished
- Make decisions that support an emphasis on quality.

1.8.2 Cost and Schedule Concerns

Although tight budgets and challenging schedules have historically been cited for not implementing quality programs and conducting quality efforts, the tide has changed over the years to where most transit agencies have dedicated quality departments and follow sound quality practices. However, at the individual project level, project managers are still faced with day-to-day decisions that must balance their short-term requirements with the agency's long-term goals. Further, although Section 1.7 purports that the long-term benefits of quality far exceed the short-term costs, these project managers are generally evaluated annually on their short-term performance. This may tend to impact their decision-making. The following suggestions may help to mitigate this concern:

- Senior management should be educated as to the wisdom of focusing on quality and the need to keep encouraging it.
- Life cycle costing should be used to evaluate decisions in lieu of simply using project costs.
- Senior management should support decisions that favor long-term cost considerations rather than short-term project costs.

- Project managers should be evaluated on the long-term implications of their decision-making.
- Project quality management should be organized so that decision-making is reported to, and can be supported by, senior transit agency quality management.

1.8.3 Resistance to Change

Many people and organizations are apprehensive of change and consequently are slow to change. It is only when the negative consequences of not changing outweigh the consequences of changing that change takes place. In fact, it was only after the Japanese auto industry successfully applied quality improvement concepts and posed serious competition to the American auto industry, that quality began to make serious strides in the United States. Thirty years later the FTA required grantees to seriously incorporate quality concepts in their projects and the result has been the successful application of these concepts and improved project performance. Thus, we can see how slowly change can take place.

Even though significant strides have occurred, there is still room for improvement in the transit industry. Some of the rules suggested by Juran to avoid resistance to change include [Ref. 34]:

- Select the right time to start
- Work with the recognized cultural leadership
- Start with small quality-related initiatives
- Provide participation in quality-related activities at all levels within the organization
- Provide enough time for change to take affect
- Avoid surprises that can negatively affect the outcome
- Treat people with respect and dignity
- Deal directly with the resistance.

1.8.4 Lack of Training

As noted in Section 1.5.2, a successful management system involves all personnel at all levels within the organization and even personnel outside the organization, especially those entities that supply funding. It was further noted that everyone within the organization should be trained in order to know what role they play in implementing an effective system. Training should start with senior and project management and work its way down into the organization. The quality department should receive parallel training in order to be in a position to help implement initiatives and provide additional levels of leadership within the organization. At the individual project level, the entire project team should be trained regarding the unique quality requirements of the project. As the project evolves, training should be expanded to include consultants, contractors, and suppliers, as required. Inspectors and other personnel may require specialty training or certification when performing critical functions, such as welding or inspecting pressure containers, etc. Finally, training is not a one-time event. Rather, it is an on-going process that helps to assure that all members of the organization, in general, and the project team, in particular, can successfully implement, and assure the success of, the organization or project's quality goals and requirements.

1.9 How to Use These Guidelines

Grantees should use these guidelines in the development of their quality plan. In order to develop an effective quality plan, the grantee should:

1. Read the guidelines in order to understand what constitutes a quality plan.
2. Seek advice and counsel from the regional FTA representative and personnel from other agencies about the development of a quality plan.
3. Collect source material that may be useful and applicable.
4. Determine which of the fifteen elements apply to the grantee's project(s).
5. Begin to establish the plan following the direction of these guidelines and the applicable elements.

Grantees should develop unique quality plans and quality procedures that satisfy their individual needs. The FTA recommends seeking the advice and counsel of other grantees who have developed successful quality plans in order to learn from their experience. However, the examples in these guidelines and other sources should only be used as reference material and should not be copied by grantees.

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CHAPTER 2

ESSENTIAL ELEMENTS OF A QA/QC SYSTEM

This chapter discusses the fifteen elements that are the basis for FTA's guidance regarding QA/QC involving design, procurement, manufacturing, and/or construction. In addition, this chapter provides some guidance in determining which elements are appropriate for different projects. Note that each project is unique in scope and size and not all elements are applicable to all projects. An analysis of the project is recommended in order to determine what elements are applicable and warrant procedures.

The background section describes the origin of the fifteen elements, other efforts to develop construction oriented QA/QC standards, the justification for FTA adaptation of the fifteen elements, and organizational definitions required to understand the fifteen elements.

The fifteen quality elements are as follows and should be considered in the development of detailed quality procedures:

1. Management Responsibility
2. Documented Quality Management System
3. Design Control
4. Document Control
5. Purchasing
6. Product Identification and Traceability
7. Process Control
8. Inspection and Testing
9. Inspection, Measuring, and Test Equipment
10. Inspection and Test Status
11. Nonconformance
12. Corrective Action
13. Quality Records
14. Quality Audits
15. Training.

Following each of the elements is a comment(s) section that includes information and guidance that can be used when developing the procedures.

2.1 Background

The fifteen elements were originally adapted from the 1987 version of the American National Standards for Quality Systems (ANSI/ASQC Q90 - Q94). The International Standards for Quality Systems (ISO 9000 - ISO 9004) were almost identical to the ANSI standards. Both sets of standards have been subsequently updated, but they still contain the fundamental information upon which these guidelines are based.

The ISO 9000:1994 standard has been revised to ISO 9000:2000. This new revision requires a significantly different format for documenting a Quality Management System. The original twenty elements have been reorganized into six basic elements. ISO 9001:2000 contains two conversion tables to show how the old elements are included in the new standard and visa-versa. This table is an ideal cross-reference for the FTA, grantee, and companies who use the latest ISO standard's documentation format. It can be used as an aid in indicating that all of the required elements of these guidelines have been properly addressed. ASQC (now ASQ) and ISO Standards represent sound management practice. Evidence of the acceptance of these standards to industry is the proliferation of companies that have become ISO certified over the past ten years.

A number of organizations have developed quality program standards for specific types of work. Among these are ASQ, which formed a Construction Technical Committee in 1982 to address construction quality; the American Society of Civil Engineers (ASCE), which addressed the need for a quality standard in engineering and construction; and the Construction Industry Institute (CII), associated with the University of Texas at Austin, which was founded in 1983 to improve the cost effectiveness of the construction industry. In developing the QA/QC Guidelines for FTA, consideration was given to adopting one of these standards. However, it was decided to use the more generic approach of the ANSI/ASQC Q90 - Q94:1994 standards. The reasoning is as follows:

- This standard has been broadly accepted in the United States and in the international community. There has not yet been universal acceptance of the various QA/QC guidelines for the design and construction industry.
- The capital programs of the transit industry include design and construction activities and equipment procurement. The ANSI/ASQC Q90 standard sets forth a generic quality program based upon sound management practices that is adaptable to all transit capital projects.
- The organization and management of transit capital programs can take many different forms. Some transit agencies may do construction activities in-house, they may hire a construction contractor, or they may hire both a CMC and construction contractor. Given the variety of formats, the most useful quality guidance would seem to be to present the essential quality elements, and let the transit agency determine where the elements are appropriate, and which organizations should have responsibility for implementation.

The fifteen quality elements are adapted from some twelve to twenty quality elements included in the ANSI standards. These fifteen are the elements most relevant to an FTA grantee. The elements should be seen as good management practice to ensure quality of design, manufacturing, and construction services. They are applicable not only for quality programs of the FTA grantees, but also for organizations providing goods and services to grantees.

Each of the elements may refer to QA or QC activities. QA activities include planning for quality activities and verifying that those activities were carried out. QC activities include the actual implementation of quality activities and the documentation thereof.

The elements sometimes refer to generic organizational entities that could be the transit agency/grantee or the construction contractor, for example, depending upon the role being played. Following are some of the generic organizational entities referenced in the quality elements:

Management	Management of the grantee or management of any contractor to the grantee.
Designer	The organization responsible for design. This could be the grantee itself, and/or a contractor providing architectural/engineering services.
Purchaser	The grantee or other organization responsible for specifying, contracting, and accepting requirements for capital goods or services.
Supplier	Any organization providing services, products, or materials for grantee capital projects. The supplier could be a product manufacturer, or a provider of raw materials.
Contractor	Any organization providing services or products to a transit agency under direct contractual agreement. The contractor could be part of the grantee organization in the case of force account work.
Subcontractor/ Subconsultant	Any organization supplying services or products under contract to a contractor. The subcontractor would not contract directly with the transit agency, but with a contractor or another sub-contractor.

2.2 The Fifteen Elements of a Quality Program

2.2.1 Element 1: Management Responsibility

The grantee should define and document a quality policy, and should communicate, implement, and maintain that policy at all levels of its organization. Management should designate a representative who shall have defined authority and responsibility for ensuring that the quality policy is implemented and maintained. Management should also identify those persons responsible for the quality assurance function and should define in writing the responsibility, authority, and interrelation of those persons.

The responsibility for and commitment to the quality policy belongs to the highest level of management. Management should, therefore, declare and document its commitment to quality. Management should ensure that the quality policy is understood, implemented, and maintained throughout the organization.

There should be a person designated as the representative of management who has the responsibility and authority to ensure that management's quality policy is implemented and maintained. Maintenance includes documented review of the policy at appropriate intervals to ensure that it remains suitable and effective.

Project personnel who have responsibility for ensuring or controlling quality should be identified and their interrelationships with project management defined. These relationships should be shown on an organization chart. In particular, the personnel should be identified who have responsibility to initiate action to prevent quality problems, to identify and record quality problems, to initiate solutions through appropriate channels, and to verify implementation of solutions to quality problems. Those personnel responsible for assuring quality must be independent of those having direct responsibility for the work being performed. This can be accomplished satisfactorily if those ensuring or controlling quality report on a level higher than those having direct responsibility for the work.

Comment:

A concern for the grantee is the assignment of responsibility for QA and QC. So far as possible, each organization involved in a transit capital project should be responsible for its own QC. Exceptions include the case where a grantee has its own materials testing laboratory and thus provides some QC for its construction contractors.

While consultants or contractors to the grantee can assume some responsibility for QA, this responsibility should not be completely delegated. The grantee should maintain a QA oversight capability to ensure that quality programs are working at the agency itself and within the supplier and contractor organizations.

The Army Corps of Engineers quality program is a successful model for construction projects. With the Corps program, the contractors are responsible for QC and the Corps is responsible for QA. The contractors may also have some QA responsibility as part of their own quality management system.

2.2.2 Element 2: Documented Quality Management System

The grantee should establish and maintain a documented quality management system to ensure project quality objectives are satisfied. The quality management system requirements should extend to the grantee's suppliers and contractors as appropriate.

Written procedures and instructions should be developed for activities affecting quality in design, procurement, manufacturing, and construction as applicable to the work performed. Procedures and instructions should also be developed for control of processes including inspection, testing, nondestructive examination, disposition of nonconforming product, corrective action, maintenance of quality records, quality audits, and training.

The procedures should contain a statement of the purpose and scope, and should contain any references to appropriate codes, standards, or specifications. In developing the quality procedures, consideration should be given to identifying and acquiring any inspection equipment, skills, or special quality processes needed to ensure quality performance. Inspection and testing techniques should be kept up-to-date. Where new techniques are being used for construction or manufacturing, adequate time should be allowed to develop appropriate quality procedures for the new techniques. The procedures and instructions should contain formats for the quality records needed to ensure that the procedures and instructions are followed and documentation requirements are understood.

Comment:

The quality procedures described above are generic to the design, procurement, manufacturing, and construction industry. Each transit agency determines which procedures are applicable to the specific capital project.

2.2.3 Element 3: Design Control

The designer should establish and maintain procedures to control and verify the design of the transit systems in order to ensure that the design criteria, other specified requirements, and requirements of the relevant regulatory agencies are met. Design control includes ensuring that the design requirements are understood, planning the design interfaces and design verification activities, executing the design verification activities, and controlling design changes through project completion.

The designer should prepare a plan for design activities. The plan should identify who has responsibility for the different design parts, and who has the QA responsibility for design. It should also identify the various organizational interfaces required between various groups producing and commenting on the design, and specify the information to be documented, transmitted, and regularly reviewed. Finally, the plan should specify how the operating and maintenance departments of the transit agency would interface with those producing the design.

Design input requirements should be identified, documented, and reviewed by the designer. Any ambiguity in the design input requirements should be resolved between the designer and those responsible for developing the requirements.

Design output should be documented. It should meet the input design requirements, include acceptance criteria, conform to appropriate regulatory requirements whether or not these have been stated in the design input requirements, and identify those aspects of the design which are crucial to the safe and proper functioning of the final product or system.

The designer should assign to competent personnel those activities required to verify the quality of the design. Design verification activities should include the carrying out of alternative calculations, independent checks of design calculations, specifications, drawings, and contract documents, conducting and documenting design reviews, undertaking qualification tests and

demonstrations, and comparing the design with a similar proven design, if available. Design reviews include reviews for constructibility, operability, and maintainability.

Appropriate procedures should be established for the identification, documentation, review, and approval of all changes and modifications to the design. This responsibility should extend to those responsible for construction or manufacturing to ensure compliance to design requirements and for development of "as-built" documents as part of the design documentation at the end of the project.

Comment:

Each group responsible for design should provide its own written QC procedures. These include peer review of drawings and check calculations. QA activities are performed to verify compliance to established QC procedures and to determine the effectiveness of the procedures in meeting quality program objectives.

The *Project and Construction Management Guidelines* uses the term "Control of the Configuration" to refer to control of design changes, and the related document control (see below). The following detail about configuration control was taken from the 1990 version of the *Project and Construction Management Guidelines* [Ref. 38]:

Configuration control consists of the evaluation, coordination, and approval or disapproval of changes in the configuration of an item after establishment of a configuration baseline. A configuration baseline consists of the approved or conditionally approved technical documentation for an item as set forth in drawings and associated lists, specifications, and referenced documents. In an effective configuration control program, drawings are uniquely numbered and otherwise identified. Specifications follow a standard format and each paragraph is numbered and identified. Complete drawing lists are established and the total number of drawings, the titles of the drawings, the revision status, and the dates the drawings were approved are recorded. Changes to approved drawings or specifications should only be made in accordance with established procedures. Permanent files are maintained of all contract documents which include historical information relating to all project changes. As the project becomes implemented, configuration control evolves to include the documentation of the completed improvement in terms of "as-built drawings."

2.2.4 Element 4: Document Control

Procedures for control of project documents and data should be established and maintained. The document control measures should ensure that all relevant documents are current and available to all users who require them.

Control of project documents includes the review of documents by authorized personnel, the distribution and storage of these documents, the elimination of obsolete documents, and control of changes to the documents.

Copies of the documents should be distributed so that they will be available at all locations that need them for effective functioning of the quality management system. Obsolete documents should be promptly eliminated from each work location. Any superseded documents retained for the record should be clearly identified as such.

The same authorized personnel who reviewed and approved the original documents, unless the control procedures specifically allow otherwise, should review changes to the documents and data. Changes should be promptly distributed to all locations, along with a master list enumerating the current revisions of each document.

Following are examples of the types of documents requiring control:

- Drawings
- Specifications
- Inspection procedures
- Test procedures
- Special work instructions
- Operational procedures
- QA program and procedures.

Comment:

A useful tool for keeping track of project documents is the Design Output Index that lists every document developed for the execution of the project. The Design Output Index contains a listing of the latest revisions of the following:

- Drawings
- Technical specifications
- Special processes
- Test specifications
- Engineering change notices.

2.2.5 Element 5: Purchasing

The purchaser should ensure that the purchased service or product conforms to the purchaser's specified requirements. The purchaser should require supplier quality programs appropriate to the work being performed and in accordance with these guidelines.

The purchaser should establish a documented list of acceptable suppliers and contractors for the desired service or product, consistent with applicable procurement requirements. The purchaser should select suppliers or contractors on the basis of their being able to meet contract requirements, including quality requirements. The quality requirements placed on the supplier or contractor will depend upon the nature of the service or product.

The contract or purchasing requirements should clearly specify the expectations of the purchaser, including relevant standards, drawings, specifications, process requirements, inspection instructions, and approval criteria for materials, processes, and product. The purchasing documents should be reviewed and approved by a designated authority for adequacy of specified requirements prior to release. The purchaser of services or products should ensure that the supplier fully understands the contract, agrees with the contract, and has the capacity to perform as required.

Where construction or equipment procurement is involved, the contract between the purchaser and the supplier should specify the right of the purchaser or other authorized representatives to carry out inspection and testing at the source and upon receipt to verify that the work or product meets specifications. Such provision should not absolve the supplier of the responsibility to provide acceptable work or product, nor should it preclude subsequent rejection.

Where equipment procurement is involved, the purchaser should define, as appropriate, the means and methods for handling, storage, packaging, and delivery of product. The purchaser should establish procedures to receive, inspect, store, and maintain equipment procured. Any equipment that is damaged or is otherwise unsuited for use should be documented and reported to the supplier.

Comment:

Purchasing requirements apply to all contractors and suppliers, including consultants, construction contractors, and manufacturers. The purpose of this element is to ensure that purchasing requirements are clear and complete, that the supplier understands them, and that appropriate quality elements are made part of the contract. Additional requirements, such as on-site inspection and handling and receiving procedures, may be required for construction or equipment procurement contracts.

The level of quality program specified in the contract will depend upon the complexity and importance of the service or product. For some projects, all fifteen elements of this quality guidance might be specified. In other cases, the supplier may only be required to use its existing quality program. In addition, FTA Circular 4220.1D “Third Party Contracting Requirements” delineates contracting requirements that to assist grantees in procuring third party services on capital projects receiving federal funding.

2.2.6 Element 6: Product Identification and Traceability

Measures should be established and maintained for identifying and controlling items of production (batch, materials, parts, and components) to prevent the use of incorrect or defective items and to ensure that only correct and acceptable items are used or installed.

Physical identification and control should be used to the extent possible. Where physical identification is impractical, physical separation, procedural control, or other appropriate means may be employed. Items that fail to possess identification, or items for which record traceability

has been lost, or items that do not conform to requirements should be segregated to prevent use or installation. An item should be able to be identified by how it is marked or where it is located.

Comment:

Product identification and traceability should take place during all the various production phases – from receipt of raw materials, components, or subassemblies through the manufacturing process, to delivery of final products or systems.

Traceability may mean traceable to a particular project, specific warranty, test report, supplier, point in time, purchase order, or through production.

Raw materials should be traceable back to a particular batch number, shipment number, packing slip, or invoice and should be accompanied by applicable test data sheets and material certifications.

Store room or inventory tracking procedures should allow for items to be traceable back to a particular order number, batch number, date received, test lot, or other pertinent source.

Assemblies in production should be traceable to particular projects through the use of some form of routing documentation. Routing documentation should contain sufficient manufacturing information, including work instructions, manufacturing standards, tooling, etc.

Final assemblies should be clearly marked with project numbers, model numbers, serial numbers, bar codes, etc., so that all pertinent information regarding that assembly may be retrieved.

2.2.7 Element 7: Process Control

Suppliers and contractors should identify and plan the production and installation processes that directly affect quality and should ensure these processes are performed under controlled conditions. Special processes, the results of which cannot be verified by subsequent inspection and testing of the product, should be continuously monitored.

To achieve accuracy and consistency in production and installation processes, the quality program should provide for:

- Documented work instructions where such are needed to ensure quality, use of suitable production and installation equipment, a suitable working environment, personnel qualifications, and conformance with referenced standards/codes and Quality Plans
- Monitoring and controlling of processes and product characteristics during production and installation.

Continuous monitoring and/or conformance with documented procedures is required during special processes, such as welding, nondestructive testing, and heat treatment, where the results

will impact quality of the final product, but where inspection after the fact will not reveal the deficiencies.

Comment:

A major issue in process control is to ensure that work is performed in the proper sequence. For example, welds should be inspected before they are painted. Earth should be compacted before concrete is poured. Documented work instructions can help with sequence control where there is complex work or when there are multi-disciplined interfaces.

2.2.8 Element 8: Inspection and Testing

Inspection and testing procedures should be planned and executed as necessary to verify quality. Procedures should be specified, implemented, and the results documented for receiving incoming products, and for final inspection and testing.

When products are delivered to the purchaser, it is the responsibility of the purchaser to verify they are in conformance with requirements. Verification should be in accordance with the Quality Plan or documented procedures. The extent of receiving inspection can vary with the amount of inspection at the source, the safety criticality of the product, and the confidence in the quality procedures of the supplier.

In-process testing and inspection of the work to verify conformance of an item or work activity to specified requirements should be in accordance with the Quality Plan or documented procedures. Both inspection and process monitoring methods should be performed, as necessary, to ensure that the specified requirements for the control of work processes and the quality of the item are being achieved throughout the duration of the work.

Final inspection and testing should ensure that all specified inspections and tests, including those specified for receipt of product or in-process work, have been carried out and the resulting data meet specifications. Final inspection and testing should be carried out and properly documented to ensure conformance of the finished product to the specifications.

Records should be maintained of the various inspections and tests to provide evidence that the product has passed inspection and/or test with defined acceptance criteria.

Comment:

Given that everything cannot be inspected, the following criteria are offered as guidance for what to emphasize in an inspection and testing program:

- Items or work affecting safety
- Items that affect system reliability
- Items that affect service life
- Long lead time items or custom manufactured items
- High visibility areas.
- ADA compliance items.

2.2.9 Element 9: Inspection, Measuring, and Test Equipment

Inspection, measuring, and test equipment required to carry out inspection and testing should be identified, controlled, calibrated, and maintained in order to demonstrate the conformance of work to the specified requirements. Provisions should be made for recalibration of such equipment in a timely manner.

Inspection, measuring, and test equipment used should meet the standards of accuracy for the measurements which are required. The equipment should be calibrated according to national standards where available, and to documented standards where no national standards exist. The equipment should be recalibrated at regular intervals, and the recalibration properly documented. A record of the equipment calibration status should be maintained.

The equipment should be properly maintained to ensure its fitness for use. When in use, the user should ensure that the environmental conditions are suitable for the use of the equipment. When inspection, measuring, or test equipment is found to be out of calibration, the validity of previous inspection and test results should be assessed and documented.

Comment:

All testing equipment must be calibrated prior to its use on the project. Periodic calibrations must be performed in accordance with certifying agency requirements and industry practice. ISO/DIS 10012, “Quality Assurance Requirements for Measuring Equipment - Part 1: Metrological confirmation system for measuring equipment” provides guidelines on the main features of a calibration system to ensure that measurements are made with the intended accuracy. ISO 10012-2:1997, “Quality Assurance for Measuring Equipment - Part 2: Guidelines for control of measurement of processes” provides supplementary guidance on the application of statistical process control when this is appropriate for achieving the objectives of Part 1.

2.2.10 Element 10: Inspection and Test Status

A means should be provided for identifying the inspection and test status of work during production and installation. The purpose of this is to ensure that only work that has passed the required inspections and tests is accepted.

The test and inspection status should be identified by means of markings, stamps, tags, labels, routing cards, inspections records, test software, physical location, or other suitable means. The status identification indicates the conformance or nonconformance with regard to inspections and tests performed.

Comment:

The inspection and test status of planning and design documents should be identified by suitable means that indicate the conformance or nonconformance of product with regard to checking and reviews performed.

The status of completed, tested and inspected construction should be kept as an ongoing record in the daily inspection reports. Nonconforming materials or construction should be recorded with location noted on inspection reports or nonconformance reports as applicable.

While some operations may be easily tagged in the field as to their inspection status, most are best recorded in the construction management or resident engineer's office through status reports, payment documents, marked up specifications, contract drawings or as-built drawings.

2.2.11 Element 11: Nonconformance

Procedures should be established and maintained to control nonconforming work, in order to ensure that such work is not inadvertently used or installed.

Nonconforming work should be identified, documented, and evaluated to determine appropriate disposition. Where practicable, nonconforming items should be segregated. Those activities affected by the nonconforming work should be notified. The responsibility for review and authority for the disposition of nonconforming work should be defined in documented procedures. Disposition of nonconforming work can include reworking it to meet requirements, accepting it with or without repair, using it for alternative applications, or scrapping it. A determination to accept nonconforming work, as is or with repair, should have the concurrence of the engineer of record. It may be advantageous to the owner to negotiate some form of compensation for accepting nonconforming work (e.g., additional spare parts).

Disposition of nonconforming work should be documented. Reworked or repaired work should be re-inspected in accordance with documented procedures.

Comment:

Contract documents should specify the definition of a nonconformance, including equipment, process, and contract nonconformances. When appropriate a board, made up of owner, contractor, consultant, and other applicable personnel should be established to determine the disposition of a nonconformance. Nonconformance conditions should be documented on nonconformance forms in reports, letters, memos, corrective action lists, audit findings, etc. It is imperative that all nonconformances be resolved in cooperation with project management and quality personnel.

2.2.12 Element 12: Corrective Action

Corrective action procedures should be established, documented, and maintained. These include procedures for investigation of the cause of nonconforming work and the corrective action needed to prevent recurrence, and procedures for analysis to detect and eliminate potential causes of nonconforming work. This element also includes implementing and recording changes in procedures resulting from corrective action.

Corrective action procedures should be established for:

- Investigating the cause of nonconforming product and taking the corrective actions needed to prevent recurrence
- Analyzing processes to detect and eliminate potential causes of nonconforming product
- Initiating preventative actions to deal with problems to a level corresponding to the risks encountered
- Ensuring that corrective actions are taken and that they are effective
- Implementing and recording changes in procedures resulting from corrective action.

Comment:

Corrective action should be taken with respect to nonconforming work in order to eliminate potential problems. One of four types of disposition may result from corrective actions: use-as-is, rework, repair, or scrap.

2.2.13 Element 13: Quality Records

Procedures should be established and maintained for quality records. These procedures should identify which records should be kept, responsibility for production and collection, and responsibility for indexing, filing, storage, maintenance, and disposition of quality records.

Quality records should be maintained to show achievement of quality objectives and appropriate functioning of the quality management system. Supplier, contractor, and subcontractor quality records should be included when pertinent.

Quality records should be legible and should specify the work involved. They should be kept in an environment to minimize deterioration and damage. Retention times and final disposition should be established and recorded.

Where specified by contract, quality records should be made available to the purchaser or purchaser's representative.

Following are examples of the types of quality records requiring control:

- Inspection reports
- Test data
- Qualification records
- Calibration records
- Nonconformances
- Corrective actions
- Audit reports.

Comment:

A useful tool for keeping track of the QA records is a QA Records List. This is a list of every document generated as a result of implementing the quality program. Note that all applicable records should be tracked and controlled, including those of contractors and subcontractors. Similarly, applicable contract documents should be tracked and controlled in accordance with grantee retention policies.

2.2.14 Element 14: Quality Audits

An internal audit should be established to ensure that the elements of the quality management system are functioning as intended.

Each audit should be scheduled. The frequency should depend upon the status and importance of the activity being audited. The audits and follow-up actions should be documented and conducted in accordance with documented procedures. The results of the audits should be presented to the personnel having responsibility in the area being audited. Responsible management personnel should take timely corrective action on the deficiencies found by the audit.

Comment:

Quality audits serve as a tool to reinforce quality requirements and should address root causes of non-conformances identified during the audit. Quality audits should be independent, scheduled, and performed to standards and/or checklists. Qualified quality personnel should conduct the QA audit in order to ensure that it provides substantive results. A final report that identifies the results of the audit should be generated, distributed, and tracked for disposition. The QA audit is not the same as a financial audit.

2.2.15 Element 15: Training

The grantee should establish and maintain procedures for identifying the training needs and provide for the training of all personnel performing activities affecting quality.

All personnel performing activities affecting quality should be qualified on the basis of appropriate education, training, and/or experience, as required. Appropriate training and qualification records should be maintained.

Comment:

A training matrix can be used as a tool for determining which personnel require which training. The training matrix lists the relevant personnel within the agency or within project consultants and contractors versus various quality related procedures. Figure 2-1 is an example of a training matrix.

Figure 2-1 – Training Matrix

	PROCEDURE NUMBER							
	1	2	3	4	5	6	7	8
CEO	CR		RA					
Project Manager	CR	RA	RA	RA	RA	RA	CR	RA
Project Engineer	CR	RA	RA	RA	RA	RA	CR	
Resident Engineer	CR	CR	RA	RA				
Inspectors		CR		RA	RA			RA
QA Personnel	RA	RA	CR	RA	RA	RA	RA	RA
	Key: CR is “classroom” RA is “read and acknowledge”							

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CHAPTER 3

ORGANIZATION OF A QUALITY MANAGEMENT SYSTEM

3.1 Grantee Organization and Responsibility

FTA grantees use many different organizational structures for carrying out capital projects. All work, including design, procurement, construction management, and construction may be done in-house or by outside suppliers or contractors. The organization of a grantee quality management system may also be structured in many ways; however, all of the applicable quality management system elements should be incorporated into the activities of the organizational entities involved in the program. The measures instituted should give serious consideration to minimizing the disruption to continuing grantee operations.

3.1.1 General Principles

In Chapter 2, the quality element "Management Responsibility" states that a person should be designated as a representative of management who has the responsibility and authority to assure that the management's quality policy is implemented and maintained. Those responsible for verifying that quality activities are performed in accordance with established requirements and procedures should be independent of those directly responsible for the work.

The fulfillment of management's responsibility suggests that:

- A quality policy should be adopted by the grantee's senior manager and accepted by all members of management.
- There should be a prevailing attitude that all members of the organization are responsible for the fulfillment of the quality policy, and management should look to all elements of the organization for assurance that quality is being attended to.
- There should be a person designated by and reporting to the senior manager to oversee the established quality management system and advise the manager of the effectiveness in meeting project quality objectives.
- Those responsible for ensuring quality should report one level higher than the activity with which they have oversight responsibility.

It is important to distinguish between responsibility for the quality policy and responsibility for quality of a project or activity. Each person responsible for a project or activity is also responsible for the quality of that project or activity. On the other hand, the QA staff is responsible for participating in the quality processes and for ensuring that these processes are working. If the processes are working properly within a project, there is more certainty that the project quality objectives will be achieved.

The QA staff should be seen by the PM as part of the team. The QA staff and the QC activities should be seen as helpful in preventing errors which could lead to significant problems and increased cost. The organizational structure should reinforce the concept that the QA staff is part of the project team.

An appropriate approach to carrying out the "Management Responsibility" element is for the grantee to have a "Director of Quality Assurance" reporting to senior management. Where the QA role is focused on capital projects, the Director of Quality Assurance should report to the manager responsible for the implementation of the capital projects. The advantages of such a structure are:

- The responsible management for the Grantee can be confident that appropriate attention is being paid to quality and that FTA funds are being used wisely.
- Quality is highly visible within capital projects of the grantee.
- QA activities are coordinated so that duplicate planning, training, and oversight activities are eliminated.

The Director of Quality Assurance should be responsible for verifying the implementation and maintenance of the grantee quality policy and detailed quality procedures. The Director of Quality Assurance should provide oversight of all quality activities, assistance to the PMs in the development of project Quality Plans, prevention and resolution of quality problems, oversight of contractor QA/QC programs, QA training programs, QA oversight, and QA audits.

As stated previously, FTA requires that major capital projects have a PMP that includes or references a Quality Plan for the project. Responsibility for quality within a capital project and for the Quality Plan should rest with the PM for that project. The PM should have access to QA and QC personnel to assist with project quality activities. A concerted effort to comply with quality requirements by those performing the work can significantly reduce the scope of a formal QA oversight activity.

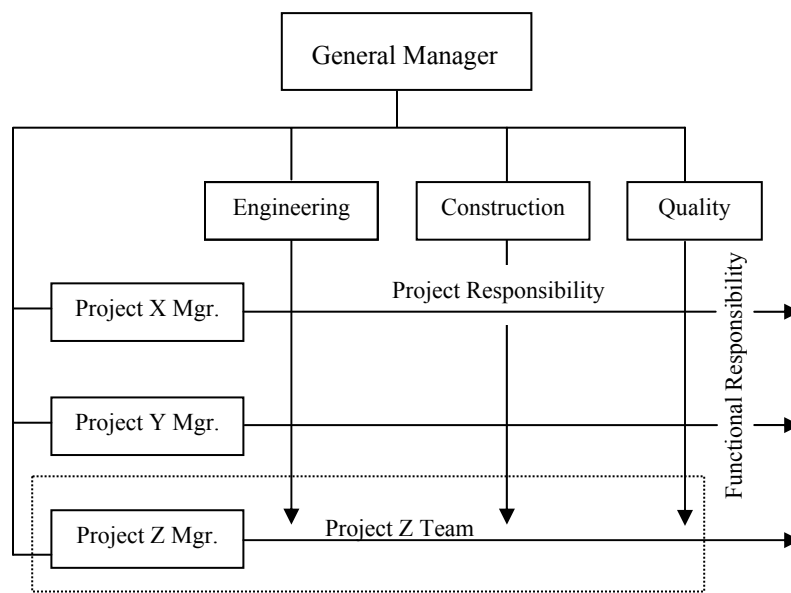
The matrix organization for project management provides a mechanism for the PM to have access to QA staff assistance, and for the quality oversight to be provided at a higher management level. Figure 3-1 depicts a matrix organization in which line departments with functional responsibilities are shown vertically and project organizations with project responsibilities are shown horizontally. The QA personnel work in partnership with representatives of engineering and construction on particular projects. This structure allows the QA representatives to be partners in the quality management system, rather than outsiders who are there to find fault.

Some grantees divide up the QA responsibilities and assign them to functional areas such as engineering, construction, or procurement. This approach recognizes the specialty skills that are appropriate for QA in these various areas. Indeed, in larger grantee organizations, it makes sense to have functionally specific quality manuals. However, it is less desirable to split the QA organization because it results in multiple quality programs and procedures within the agency

and a less visible program overall. Such a program can still provide adequate QA/QC at the project level, however.

There are situations where a grantee may not have a permanent QA staff. One example is where a grantee undertakes a one-time capital project where the quality function is a discrete activity developed solely as a part of the project. In general, a lack of a dedicated QA staff can cause a problem if the project faces budget or time pressures. A lack of a dedicated QA staff has often resulted in weakened quality programs.

Figure 3-1 – Matrix Organization



3.1.2 Project Management Plan Guidelines

FTA requires that its grantees undertaking a major capital project must submit a PMP for FTA's review and approval, both initially, and as changes are made throughout the project. Although FTA has some discretion in determining which capital projects are considered major, they generally include projects like construction of a new fixed guideway segment, extension of an existing fixed guideway, or modernization of existing fixed guideway systems pursuant to a full funding contract. As part of the PMP, FTA requires that the grantee include QA and QC procedures and define QA and QC responsibility for construction, system installation, and integration of system components [Ref. 38].

While PMPs are required only for major capital projects, they are encouraged for all projects because they are a very useful project management tool. Similarly, significant benefits can be derived from a Quality Plan even where the project is not considered major.

The PMP should be produced at the end of the Project Planning phase or at the beginning of the Preliminary Engineering (PE) phase of the project. The timing is essential for the Quality Plan as well, since the requirements for QA/QC in design should be specified at the time of the design procurement. The PM's expectations for a project quality management system must be made known in the procurement documents. These requirements should be a detailed extension of the PMP established QA/QC requirements.

The PMP should be updated as the project progresses through final design, procurement, construction, testing, and start-up. Likewise, the Quality Plan should be adjusted to reflect the organization and particular requirements to be instituted at each of these phases. Chapter 4 discusses the development of the Quality Plan for a project.

When a grantee has an existing quality policy and written procedures, development of a Quality Plan for a project can be done by adopting those procedures that are appropriate for the specific project or the project phase under consideration. Responsibility for preparing the plan could rest with the Director of QA or with QA/QC staff assigned to the PM. Ultimately, the PM must approve the QA/QC plan. The PM is ultimately responsible for the quality of the project.

3.2 Alternative Organizational Structures

Following is a discussion of alternative ways of organizing a quality management system given different project organizations and objectives.

3.2.1 QA/QC Program for Construction with a Construction Management Consultant

One alternative for organizing a major capital project is to use a Construction Management Consultant (CMC) to manage outside construction contractors. This type of project management organization has been successful in implementing QA/QC programs.

There may be a number of reasons for the success of this approach. First, a project can be a discrete activity organized to minimize disruption to the grantee's established internal relationships. Second, many experienced CMCs have adopted QA programs and have considerable experience in applying such programs for design and construction projects.

When a grantee uses a CMC to undertake the QA role for a project, the grantee still needs assurance that the project quality objectives are satisfied. The grantee cannot delegate this responsibility. Therefore, the grantee oversight of the quality process must be maintained to assure that it functions effectively.

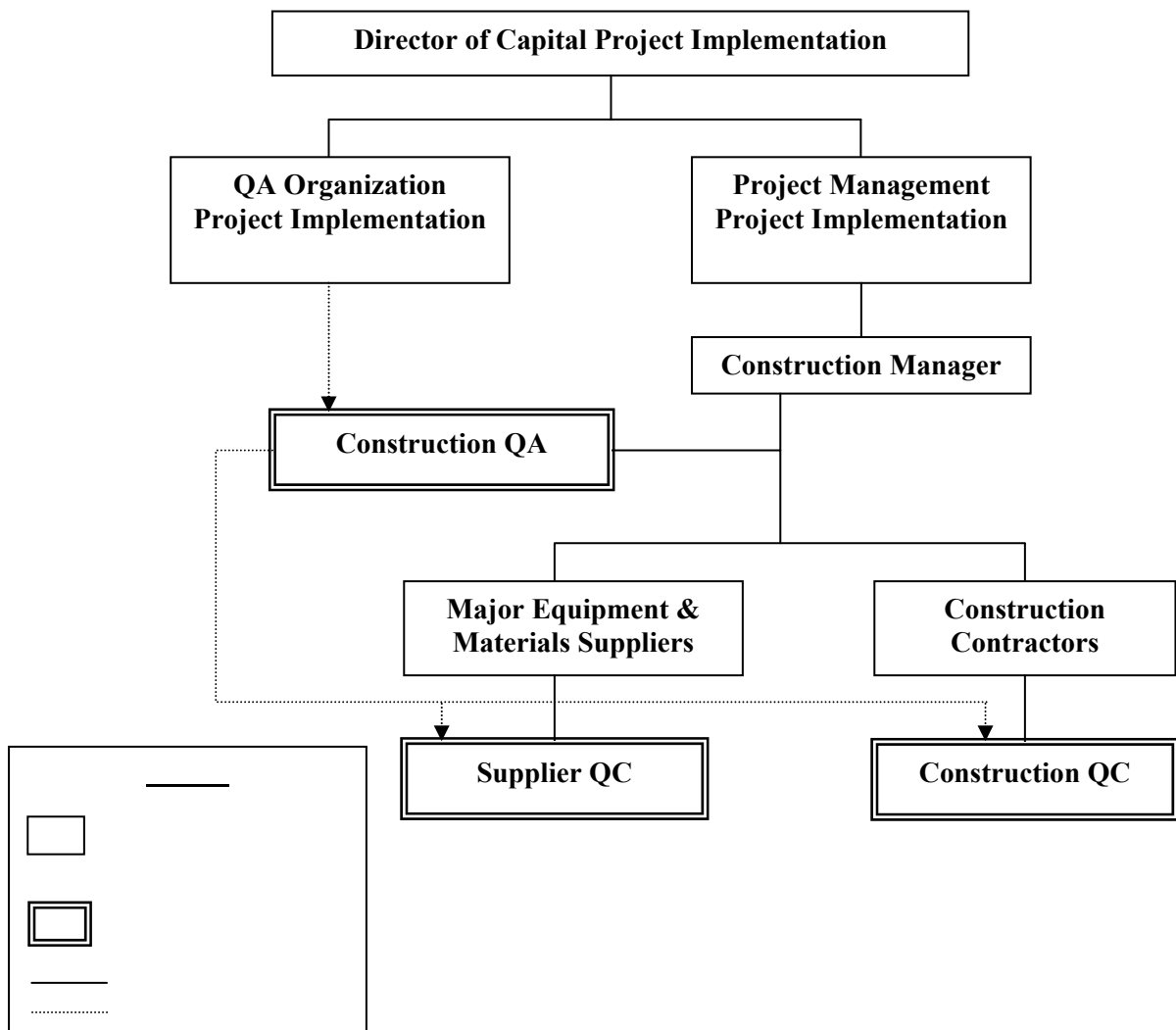
Figure 3-2 shows an organization chart for the project management and the quality organization for a project with a CMC. As can be seen from this figure, the construction contractor is responsible for QC. The CMC provides the QA, and the grantee provides QA oversight for the project.

In order for the structure shown in Figure 3-2 to be successful, all parties must understand their responsibilities and quality plan requirements from the beginning. The contract documents for

the construction contractors must specify the role of the CMC in providing QA for the project as well as the contractor responsibility for QC, including the development of Quality Program Plans. The construction contractor must provide the CMC with appropriate access for observation and inspection, and access to quality records. In most cases grantees have found it very difficult to achieve effective contractor quality programs when the CMC's QA role has not been adequately defined in the contract documents.

Likewise, the CMC must understand the grantee role in quality oversight of the project. That role needs to be spelled out in the request for qualifications and the contract document with the CMC to clearly indicate the approach the grantee will take to assure the CMC quality management system requirements are satisfied.

Figure 3-2 – Example of a Project Quality Organization with a Construction Management Consultant



3.2.2 QA/QC Program with In-House Construction Management

Another alternative for organizing a large capital construction project is to use internal staff for construction management. Construction is done either by outside construction contractors or by inside "force account" staff. Often this option follows the use of CMCs on long, multi-stage projects. Agency staff assume more and more of the responsibilities of the CMC, and finally take over all construction management functions.

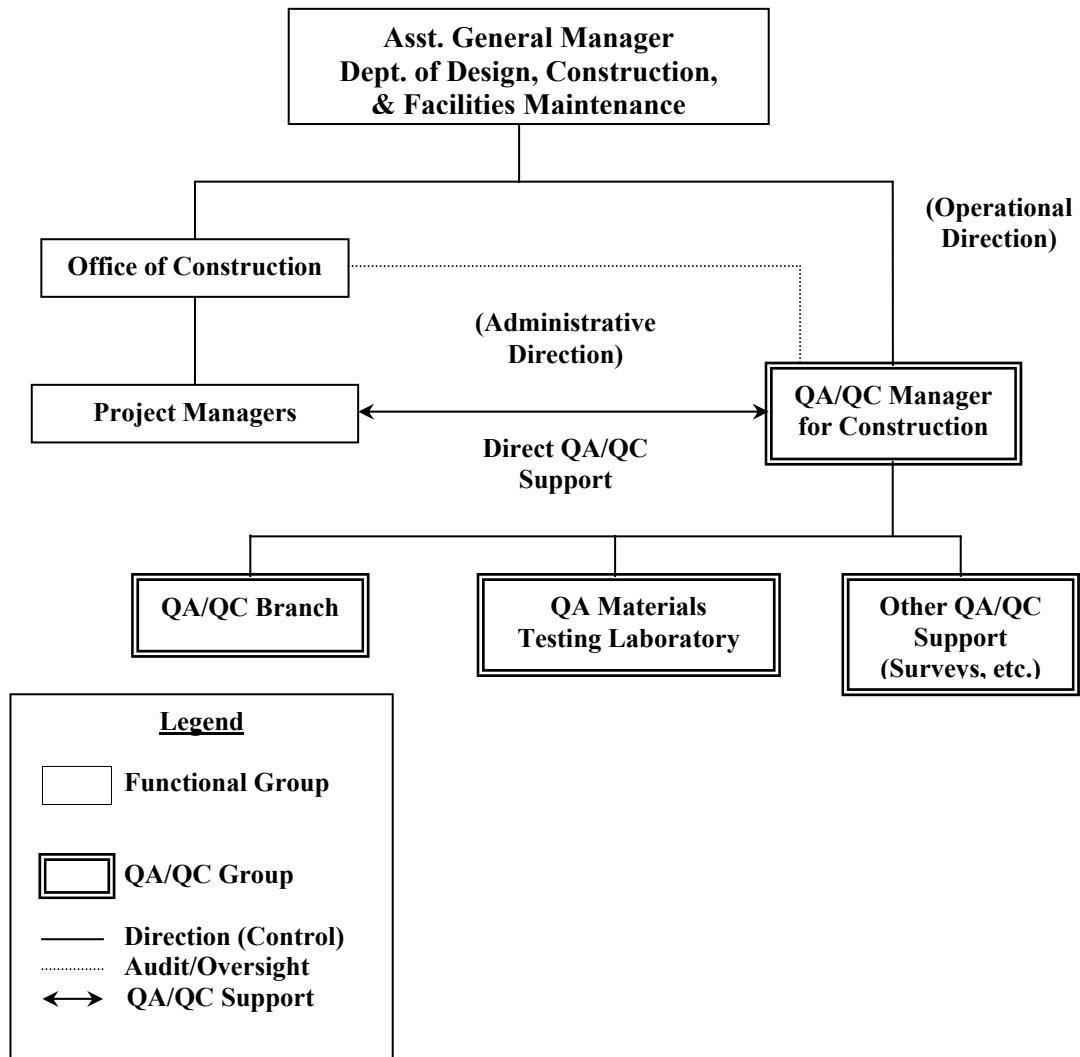
The grantee construction management should be responsible for QA for the project, and should have appropriate staff available for undertaking the QA role. The person designated to provide QA oversight for the project should verify to the grantee senior manager that the established quality management system is being appropriately applied. This oversight activity is especially important where the project scope does not justify a separate QA staff for the project, and where the PM/CMC staff assumes the QA responsibilities. Without oversight, this latter arrangement often leads to a weakened QA program.

Typically, where there is an outside construction contractor, that contractor is responsible for the QC system to be applied for the work performed. Often the construction contractor has its own QA/QC program that can be utilized where acceptable to the grantee. An exception in transit construction projects occurs where the grantee or a third party takes responsibility for materials testing, thus assuming a QC activity.

A similar approach for quality should be followed where construction is performed by force - account staff. The internal construction manager should be responsible for undertaking the QA role, while the force account staff should be responsible for QC. There should also be a person designated to provide QA oversight to verify to the grantee senior manager that the established quality management system is being appropriately applied. This later role is important, especially if the construction manager is not familiar with QA responsibilities and the quality management system.

WMATA is an example of a grantee that evolved from using a CMC to doing its own construction management. WMATA employs outside construction contractors. WMATA has a QA Manager for its Department of Transit Systems Development. The QA/QC Manager has staff for providing QA/QC support to the Project Managers. It also has a materials testing laboratory that provides some QC for contractor work. Construction contractors are responsible for QC, and WMATA has developed minimum specifications for the contractor QC program. Figure 3-3 shows the WMATA organization for construction projects.

Figure 3-3 – WMATA Organization for In-House Construction Management



3.2.3 QA/QC in Design

QA/QC in design is a very important part of a project related quality program. A study by the Construction Industry Institute (CII) [Ref. 9] showed that design errors caused 79 percent of the rework in construction, whereas construction errors caused 17 percent.

As with construction, there are many different ways for a grantee to organize its design activities. The grantee may use a management contractor for design and outside A&E firms to produce the design. The grantee may handle design management in-house and contract the design to an A&E firm. The grantee could handle both management and design in-house.

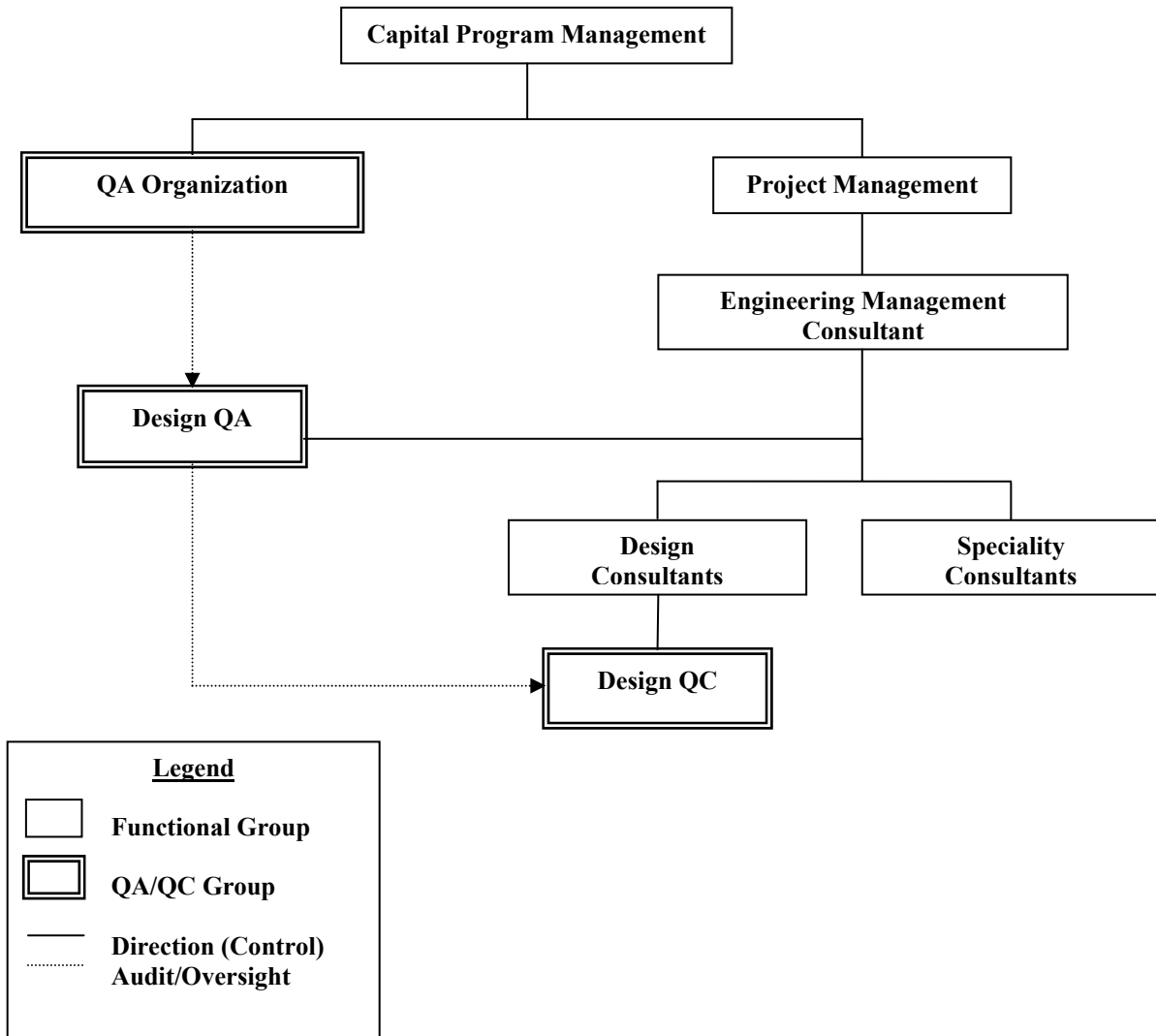
Quality programs in design can likewise vary to accommodate the management organization for design. Typically, the organization doing the design is responsible for QC for design.

The organization providing design management should be responsible for providing the QA system for design. Where an outside contractor is responsible for design management, any QA responsibilities should be specified early in the relationship between the grantee and the design management contractor. Likewise, the QA role of the design management contractor should be specified in the contract of the organization responsible for doing the design. The grantee needs to maintain an oversight role to acquire confidence that the quality management system for design is achieving the project quality objectives. Figure 3-4 illustrates an organizational structure for QA in design using an outside design management contractor.

Where the grantee retains responsibility for design management, the grantee PM should be responsible for establishing a design QA system.

Where the design effort remains entirely in-house, a two-tier organization for QA/QC is warranted. Those producing the design should be responsible for QC activities. The design management should be responsible for establishing a design QA activity for oversight of the design process. In this case, an independent QA audit might be conducted to assure design management compliance to the design procedures.

Figure 3-4 – QA/QC Organization for Design with a Design Management Contractor



3.2.4 QA/QC for Small Projects

Smaller grantees may not be able to justify a special QA/QC staff for a one-time project. Also, grantees may not be able to justify QA/QC staff for smaller projects such as bus storage and maintenance facilities. Nevertheless, each grantee still has the responsibility to assure that FTA capital funds are spent wisely. The PM of a small project should develop a quality management system for the project by determining which of the fifteen basic elements of a QA/QC program are applicable to the work being performed. Where the project is simple, where design and construction methods are standard, and where the risk of failure is low, the quality management system might be focused on final testing and inspection activities. Even so, many of the fifteen elements may be required to get to the final inspection and testing stage.

One approach for handling QA/QC activities on projects of limited scope is to make the construction contractor responsible for some QA and QC activities, and the grantee project management responsible for QA oversight activities. For example, the construction contractor could perform inspection and testing and provide the documentation thereof, document any design changes, inspect and track any purchased product, and document any nonconformance and corrective action. For a small project, the project management staff should undertake QA oversight activities such as witnessing testing, reviewing contractor documentation, and monitoring contractor compliance with its QA/QC program and other contract requirements. An option for providing QA oversight of both the project management and the construction contractor activities is to use an outside firm for this purpose.

Case History of a Small Project

A small rehabilitation project had many inter-disciplinary interfaces, and the project had to be performed while existing services were maintained. The owner knew the difficulties that the project would present and started thinking about ways to control cost, schedule, and quality during the planning phase of the project. Resources, including funding and manpower, were limited. The following actions were taken:

- The owner required the contractor to provide a QA/QC manual to cover the scope of the work.
- The owner required that the contractor provide QA/QC personnel.
- The owner required that all the project work be identified on checklists that could:
 - a. Be signed off by the contractor
 - b. Provide owner hold and witness points
 - c. Be signed off by QA/QC personnel.
- The owner identified what records would be required to be turned over as a result of implementing the project quality plan.

Of the fifteen quality elements, portions of each (except for Quality Audits) were contained in the contractor's QA/QC program. The benefits that were realized as a result of these actions were:

- The contractor supplied the needed human resources
- Every interface that the owner needed was retained
- Every document that the owner needed was retained
- A system to identify, and rectify potential problems was established prior to the first problem becoming an issue.

3.2.5 QA/QC in Equipment Procurement

The purchase of major capital equipment by a grantee is another process where the application of the fifteen quality elements is appropriate. The grantee's quality management system should provide for procedures for purchasing. The PM or project engineer in charge of the purchasing effort would be responsible for determining which quality elements and procedures should be applied to their project.

Alternatives for purchasing vary from requirements for the supplier to have a complete fifteen-element QA/QC program to requirements for a program limited to final inspection and testing. In either case, the grantee will have to provide QA oversight to assure that the supplier programs are consistent with the project quality objectives and effective in meeting grantee expectations. Section 3.5 of this chapter provides some guidance for the selection of quality elements that might be appropriate in a supplier quality program.

An adequate supplier QA/QC program is important, however, the responsibility for QA oversight is also critical. The role of QA oversight on complex procurement projects requires highly knowledgeable staff. Where such staff is not available, a grantee should consider hiring a consultant to assist in the QA oversight activity.

3.3 Independent Assurance Program

3.3.1 Description

Section 3.2.1 addresses having a QA/QC program with a construction management consultant and Section 3.2.2 addresses having a QA/QC program with in-house construction management. A third alternative is to have an independent contractor responsible for the QA/QC program. This alternative was proposed in Section 3.2.4, QA/QC for Small Projects. It is also useful when the grantee undertakes multiple projects simultaneously, such that the grantee's QA/QC staff is unable to adequately cover all of the project quality oversight requirements. It is also useful, when the construction management consultant does not possess a strong QA/QC function.

In the case where there is a construction management consultant or there is a design-build-operate contractor, the responsibility for hiring the independent, QA/QC firm may rest with them.

When there is in-house construction management, the responsibility for hiring the independent, outside firm should rest with the grantee's existing QA/QC function, or with the Project Manager when no QA/QC function exists. When the QA/QC performs the hiring, the outside firm should report directly to the existing QA/QC function, with dotted line or matrix responsibility to the Project Manager. When the Project Manager performs the hiring, the outside firm should report to the Project Manager, but provide written reports to grantee senior management.

It is important to note, that in either case, responsibility for project QA/QC still rests with grantee senior management, quality management, and project management, as necessary. The grantee cannot abdicate responsibility for satisfying all of the project QA/QC requirements.

3.3.2 Advantages and Disadvantages

Advantages for such an approach include:

- Additional resources will allow the existing grantee QA/QC function to cover all of their projects without spreading their resources so thin as to become ineffective.
- With additional resources, the existing grantee QA/QC function can effectively play a leadership role on all projects, while still accomplishing the day-to-day quality activities.
- An independent, outside firm can immediately provide experienced, professional personnel without having to undergo a learning curve. The grantee can review and accept or refuse these personnel on a case-by-case basis.
- The outside firm personnel can provide resources that can be dedicated to one or more specific projects.
- The outside firm provides an independent approach to QA/QC.

Disadvantages and associated mitigation for such an approach include:

- There will be some learning at the start of the project by the outside firm; so it is advisable to bring them into the project in the planning stage.
- Depending on the program management structure, allegiance on the part of the outside firm may become an issue, depending on who directly pays the salaries of the personnel. Roles, responsibilities, reporting, and allegiance must be clearly defined prior to hiring the outside firm and included in the firm's contract.
- Depending on whether the hired firm is local or distant, on-site availability may become an issue; but at a minimum, dedicated on-site support should be negotiated with the outside firm.

3.3.3 Methods of Control

As was earlier stated, the grantee cannot abdicate responsibility for satisfying all of the project QA/QC requirements. Therefore, it is necessary to implement methods of control to assure that the requirements are being met. Recommended methods include:

- Development and approval of mutually agreeable, well defined contract requirements that include clearly defined roles, responsibilities, and reporting.
- Frequent status reports and review meetings with the outside firm.
- Contract language highlighting that the outside firm must act in an independent professional manner and further contract language that provides for an immediate termination option by the grantee in the event of an irresolvable conflict.

3.4 QA/QC in Design-Build Projects

Unlike conventional project delivery methods (i.e., Design-Bid-Build), the Design-Build (DB) project development approach combines both responsibilities of design and construction under the auspices of a single entity – the Design-Build Contractor. With such an arrangement comes

modification to the roles and responsibilities of the parties involved, which will undoubtedly affect many aspects of the project at hand. The design-build concept utilizes the combined expertise of both the design and construction industry to promote innovative designs, speed project delivery, and reduce cost. The owner or grantee is often required to relinquish detailed oversight to obtain complete benefit of this project delivery system. Naturally, this transfer of responsibility generates great concern over whether the design-build team will adequately address QA/QC. This section focuses on how QA/QC is addressed under the Design-Build approach.

3.4.1 Unique Characteristics and Elements of Design-Build Projects

Design-Build project delivery has many unique characteristics. Several of these are listed below:

- Includes variation to virtually all project development tasks
- Combines many task contracts into more limited number of contracts
- Combines design, construction and installation functions
- Increases emphasis on procurement documents
- Redefines relationships among all contracting parties
- Reallocates risk among project development organizations.

There are several variations of Design-Build project delivery. Some of which are outlined below:

- Super Turnkey: Combines all the elements of design-build (Civil, Systems), and includes financing mechanisms. This variation can also allow for ownership of completed project.
- DBOM (Design-Build-Operate-Maintain): Under this type, the DB contractor is also responsible for operating and maintaining the system after its completion. The period of operation and maintenance is stipulated in the contract agreement, after which this responsibility is transferred to the owner.

3.4.2 Design-Build Contract Preparation – QA/QC Implications

In order to assure the success of QA/QC programs in design-build project delivery, owner agencies need to consider several key practices:

- Clearly define requirements of the QA/QC Program in the contract documents.
- Commit to a higher level of owner agency oversight activities in order to assure effectiveness of the QA/QC Program. Where agency in-house expertise is limited, the use of independent specialized consultants can prove beneficial to the effectiveness of the program.
- Require additional levels of reporting and/or detail by the DB contractor team.
- Clearly define roles and responsibilities of parties involved early in the bid documents.
- Maintain a proactive and systematic quality program that encompasses all the project lifecycle stages.

3.4.3 Roles and Responsibilities of the Owner and the Design-Build Contractor

QA/QC program effectiveness hinges on clear allocation of roles and responsibilities to the involved parties. Ideally, the best results are achieved when QA/QC roles and responsibilities are defined clearly in the contract documents; and more importantly, are agreed upon by the parties at the outset. Under design-build project delivery, the owner may elect to shift some of the QA/QC roles and responsibilities to the design-build contractor. In such cases, it is recommended that the owner agency conduct audits and testing at every stage of the QA/QC process, and retain ownership of the resident database. In less ideal cases, owner agencies have elected to retain the Quality Assurance (QA) role only, with the design-build contractor performing the Quality Control (QC) activities. Crucial to the success of this arrangement is the design-build contractor's level of experience and the owner agency's in-house oversight capabilities. Typically, design-build projects provide the DB contractors with added responsibility for program implementation. There are some perceived disadvantages to the shift in responsibilities from the owner's perspective. As was previously stated, a major concern in the design-build environment has been the potential for an agency conflict of interest when the DB contractor performs its own QA/QC over the project. Although this is a legitimate concern, it can be adequately addressed through careful stipulations and requirements delineated in the contract documents. As indicated earlier, the owner agency could place more QA/QC responsibility on the DB contractor while retaining a more stringent oversight role

For example, under the Bay Area Rapid Transit (BART) San Francisco Airport Extension project, the owner agency elected to transfer additional QA/QC functions to the design-build contractor. However, the owner retained responsibility to conduct quality surveillance to ensure incorporation of design intent into the construction process.

In the San Juan Tren Urbano project, the Puerto Rico Highway and Transportation Authority (PRHTA) assigned QA/QC responsibilities to the Systems and Test Track Turnkey (STTT) contractor and Alignment Segment Contractors (ASCs) while retaining an oversight level of control for owner monitoring. The STTT contractor was required to submit a QA/QC program plan for the entire project (including all segment contractors) to the owner for approval. This plan was reviewed and updated on a regular basis, and not less than semi-annually. Note that the STTT and ASC contractors were each responsible for the quality of their respective work. STTT had oversight responsibility for the integration requirements of all segment work, but did not have direct supervision for ASC work. The owner had the authority to audit and inspect contractor quality programs at any time.

In the Baltimore Central Light Rail Line (CLRL) Phase II Extensions project, Maryland Mass Transit Administration (MDMTA) provided the design-build contractor with responsibility for QA/QC requirements, including audits and inspections of all materials and facilities not supplied by the owner. The owner originally planned to provide a minimal effort of monitoring, while retaining the option to provide inspection deemed necessary to assure implementation of the contractor's QA/QC program and thereby assure the quality of the design-build contractor's work. This type of QA/QC function implementation was new to both the owner and the contractor. This process was adapted from the US Army Corps of Engineers' approach to QA/QC review process in design-build projects.

The MDMTA required the bidders to certify that they would conform to their QA/QC plan requirements instead of developing their own during the procurement process. In addition, MDMTA required review and approval of the control process and staffing plan. However, the transfer of virtually all of the QA/QC program responsibilities to the contractor, as per other federal design-build experiences at that time, created unintended limitations on the ability of MDMTA to adequately oversee the project. This may have had an unintended result of allowing decreased consideration of the QA/QC plan during the procurement process. The CLRL Extensions project demonstrated initial constraints over roles and responsibilities between the owner and the contractor, especially in regard to the contractor's role indirect reporting of the construction management functions. Additional effort was required by MDMTA to get the contractor to implement the defined program within the design-build project team and maintain adequate oversight once the project was underway. The MDMTA has maintained a larger role in the quality assurance aspects and document control since this initial design-build contract.

Figure 3-5 illustrates the organizational structure employed by MDMTA during the execution of the Baltimore CLRL Phase II Extensions project. Examples of how QA/QC fits within the program management organizational structure under design-build is shown in Figure 3-6. Figure 3-7 illustrates examples of variations under design-bid-build vs. design-build.

Figure 3-5 – Design-Build Project Organization Structure for The Baltimore CLRL Phase II Project

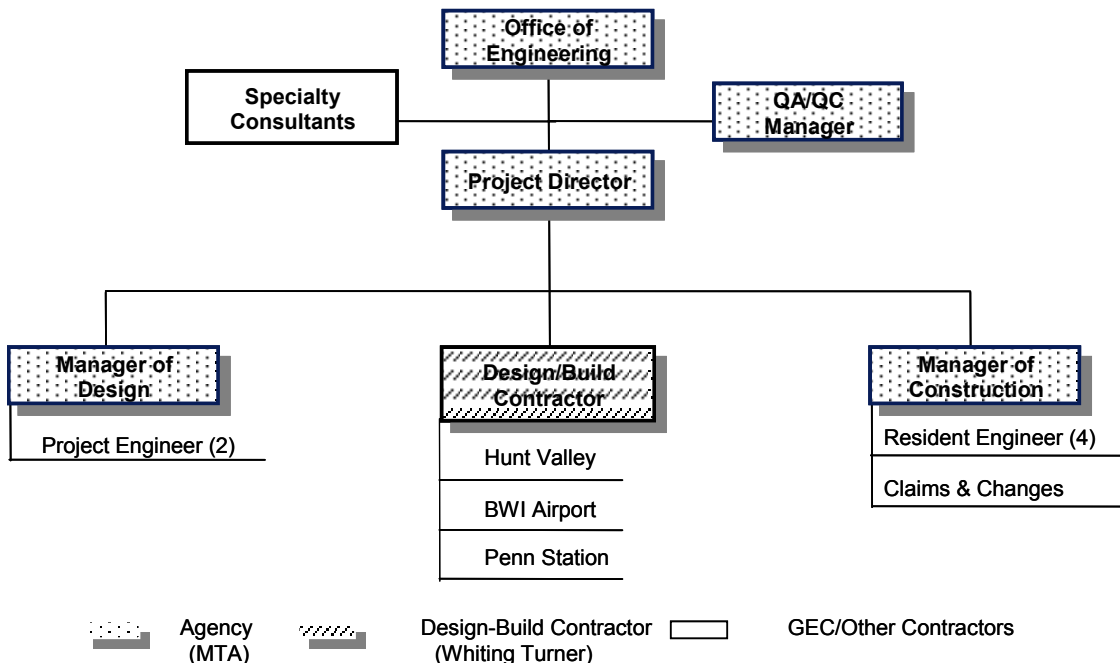


Figure 3-6 – Program Management Organizational Structure Under Design-Build Project Delivery

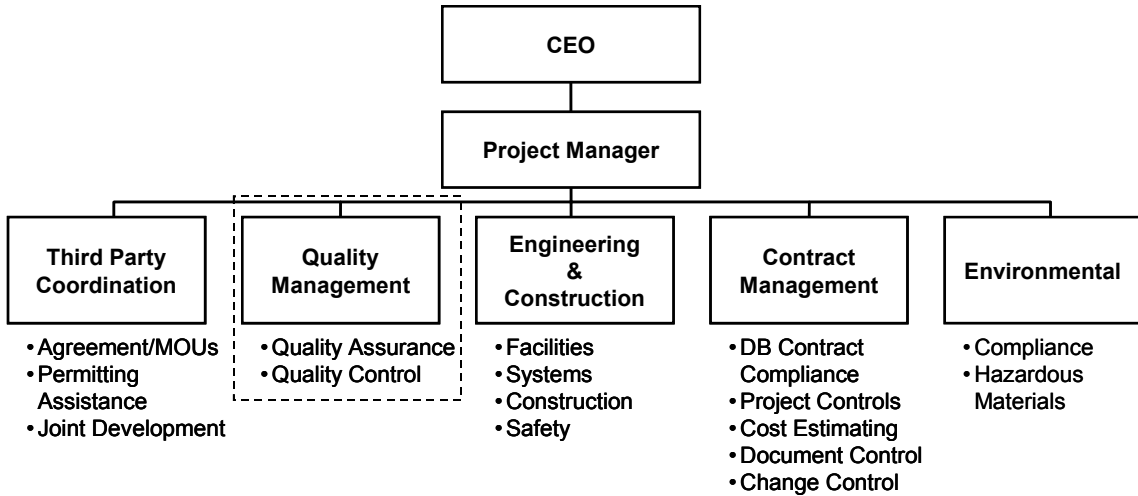
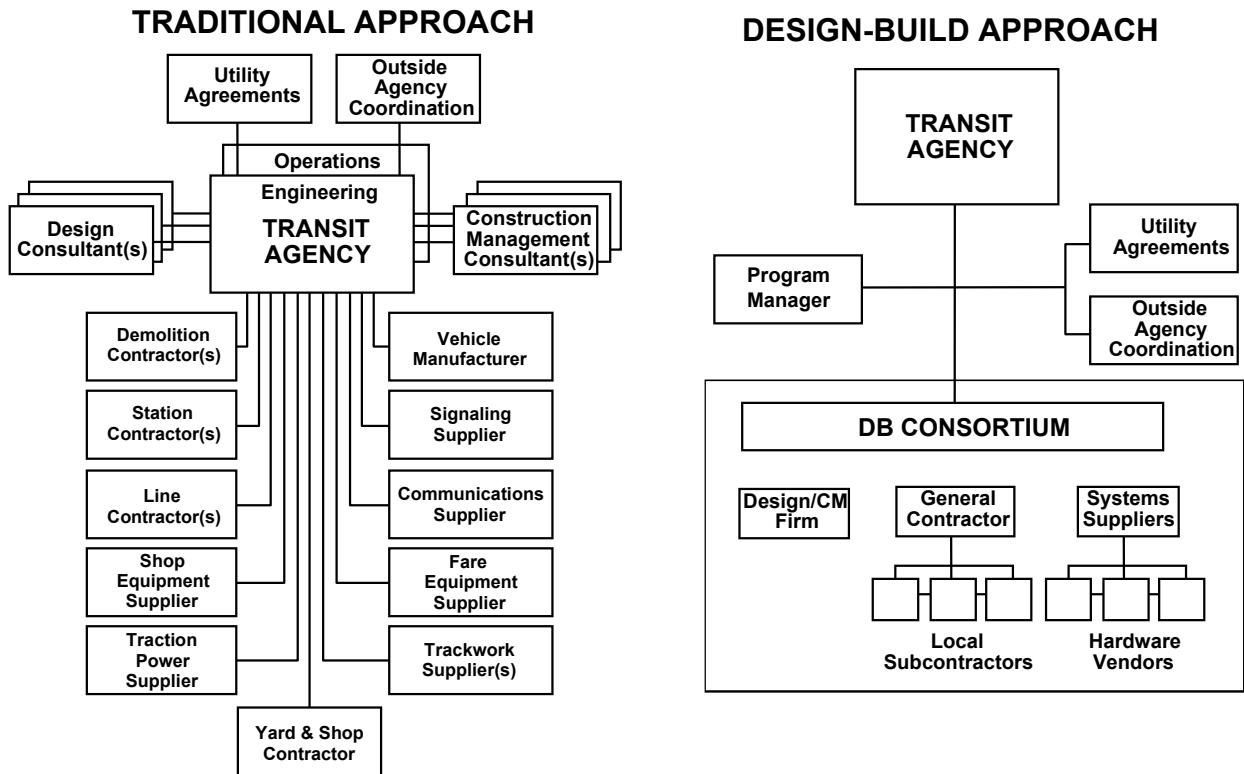


Figure 3-7 – Design-Bid-Build vs. Design-Build Project Organization Structure



These real life examples illustrate that shifting of responsibility for QA/QC under the design-build method requires clear definition of roles for both the owner and contractor. The owner and contractor must carefully define the QA/QC program, including roles and responsibilities, within the bid documents so those participants are clear as to their requirements. As with other areas of project management control, it is helpful for owners to monitor the QA/QC program. The owner may have to provide additional monitoring than would be anticipated in the design-build contract to ensure that the contractor has a full understanding of requirements for quality management and corrective actions.

3.4.4 Grantee Oversight

Oversight and monitoring is a key element of project management and successful QA/QC program. Moreover, oversight activities allow for closer engagement between the grantee and the FTA that provides a proactive process by which problems are identified and resolved in a timely manner.

In 1986 Congress, realizing the importance of project monitoring and oversight, authorized the establishment of the Project Management Oversight (PMO) Program to address the quality, cost, and scheduling problems that characterized several federally funded transit projects in the 1980s. The thrust of the PMO program is to ensure that grantees – State and local entities awarded FTA grants – have the procedures in place to successfully implement projects that comply with accepted engineering principles. The strategy followed to achieve this program's mission is straightforward. A grantee must develop and implement a Project Management Plan that addresses, for example, organization, quality, budget, and schedule requirements of the project. Once a plan is accepted, projects are monitored to see that the grantee follows the plan.

The PMO program allows the FTA to hire highly qualified industry experts for monitoring the progress of capital projects. These experts – Project Management Oversight Contractors (PMOCs) – serve as third-party inspectors that assist and report progress to the FTA. To be effective, oversight and monitoring activities must take place on a regular basis; however, as discussed earlier, these activities need to be balanced so as not to interfere with the progress of the project.

3.5 Test Lab Accreditation and QA/QC Personnel Qualifications

3.5.1 Test Lab Accreditation

Depending on the type of project and according to the *Quality Handbook for the Architectural, Engineering, and Construction Community*, test labs may be used for several types of testing, such as [Ref. 32]:

- Soil testing
- Aggregate testing
- Concrete testing
- Electrical testing
- Mechanical and welding testing

- Nondestructive examination operations
- Calibration of measuring and test equipment.

When test labs are required, projects should only use accredited laboratories. Accredited labs used by grantees may be local, national or international. In any case, the accreditation of the labs that perform various types of tests is the “formal recognition that a laboratory is competent to carry out specific tests or types of tests or calibrations.” [Ref. 43]

Accreditation is different from quality registration/certification, which recognizes that an organization is following a documented quality management system in accordance with the quality management system elements of standards, such as ISO 9000.

3.5.2 Accreditation Agencies

The National Institute of Standards and Technology (NIST) is a non-regulatory Federal agency with the U.S. Commerce Department’s Technology Administration. One of the many departments within NIST is Technology Services, which “provides U.S. industry, government, and the public with measurements, standards, and information services that promote innovation, increase competitiveness, and facilitate trade.” [Ref. 44] Within the Department of Technology Services is the Office of Standards Services (OSS), which “is the focal point for standards and conformity assessment activities in the Department of Commerce. The Office formulates and implements standards-related policies and procedures to enhance domestic commerce and international trade.” [Ref. 44]

OSS played a key role in the development of the National Cooperation of Laboratory Accreditation or NACLA, which is a nonprofit corporation established to coordinate laboratory accreditation activities within the US and to serve as the US link to the worldwide lab accreditation system. On September 29, 2000, NACLA recognized its first three accreditation bodies:

1. The American Association for Laboratory Accreditation (A2LA)
2. The International Council of Building Officials Evaluation Service (ICBO ES)
3. The National Voluntary Laboratory Accreditation Program (NVLAP).

The National Cooperation of Laboratory Accreditation and its associated members enter into Mutual Recognition Agreements with national and international accreditation associations so as to eliminate unnecessary duplication in the development and promulgation of accreditation efforts. As a result, once a facility is accredited by one agency, its accreditation is recognized by all national and international agencies with which agreements have been made. Grantees can consequently be assured that labs, which have been accredited by agencies recognized by NACLA, have all met the same rigid standards and are competent to carry out the tests in the areas for which they have received accreditation. In addition, other organizations have begun accrediting labs such as the American Association of State Highway and Transportation Officials (AASHTO).

3.5.2.1 American Association for Laboratory Accreditation (A2LA)

The American Association for Laboratory Accreditation or A2LA accredits laboratories in the following areas:

- Acoustics and vibration
- Biological
- Calibration
- Chemical
- Construction materials
- Electrical
- Environmental
- Geotechnical
- Inspection body
- Mechanical
- Nondestructive
- Thermal.

Additionally, A2LA services include specifically tailored programs that may be useful in the transit industry, including asbestos abatement, calibration, environmental lead, fasteners and metals. A2LA publishes a list of accredited laboratories that is also available on its website.

3.5.2.2 International Conference of Building Officials Evaluation Service (ICBO ES)

The International Conference of Building Officials Evaluation Service or ICBO ES accredits laboratories to perform tests on building materials and products, and quality control agencies to perform inspections at manufacturing locations. ICBO ES publishes a list of accredited laboratories that is also available on its website.

3.5.2.3 National Voluntary Laboratory Accreditation Program (NVLAP)

According to the National Institute of Standards and Technology (NIST), “NIST administers the National Voluntary Laboratory Accreditation Program (NVLAP). NVLAP is comprised of a series of Laboratory Accreditation Programs (LAPs) that are established on the basis of requests and demonstrated need. Each LAP includes specific calibration and/or test standards and related methods and protocols assembled to satisfy the unique needs for accreditation in a field of testing or calibration. NVLAP accredits public and private laboratories based on evaluation of their technical qualifications and competence to carry out specific calibrations or tests.” [Ref. 44] NVLAP publishes a list of accredited laboratories annually in a directory that includes name, address, contact person, phone and fax numbers, accreditation renewal date and scope of accreditation. This list is also available on the NIST website.

NVLAP fields of accreditation include:

<p>Calibration Laboratories</p> <ul style="list-style-type: none"> • Dimensional • Electromagnetics - DC/Low Frequency • Electromagnetics - RF/Microwave • Ionizing Radiation • Mechanical • Optical Radiation • Thermodynamics • Time and Frequency <p>Chemical Calibration</p> <ul style="list-style-type: none"> • Certifiers of Spectrophotometric NTRMs • Providers of Proficiency Testing <p>Dosimetry</p> <ul style="list-style-type: none"> • Ionizing Radiation Dosimetry <p>Electromagnetic Compatibility and Telecommunications</p> <ul style="list-style-type: none"> • Emissions, Immunity, MIL-STD-462, Safety, and Telecommunications 	<p>Environmental</p> <ul style="list-style-type: none"> • Asbestos Fiber Analysis (Polarized Light Microscope Test Method) • Asbestos Fiber Analysis (Transmission Electron Microscope Test Method) <p>Fasteners and Metals</p> <ul style="list-style-type: none"> • Fasteners and Metals <p>Information Technology Security Testing</p> <ul style="list-style-type: none"> • Common Criteria Testing • Cryptographic Module Testing <p>Product Testing</p> <ul style="list-style-type: none"> • Acoustical Testing Services • Carpet and Carpet Cushion • Commercial Products Testing • Construction Materials Testing • Efficiency of Electric Motors • Energy Efficient Lighting Products • Thermal Insulation • Wood Based Products
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3.5.3 QA/QC Personnel Qualifications

Section 3.2 provided various organizational suggestions that can be utilized on grantee projects. These structures identify the quality organization, quality management, and lines of communication. Personnel filling these positions should have the requisite education and experience required to accomplish a successful project quality program. It would be unrealistic to identify one set of requirements that would satisfy all of the needs of every organization or project. However, the following guidelines are recommended:

- Management/Supervisors – should possess some understanding of the general concepts and objectives established in these guidelines to assure that they are considered in major capital projects
- QA/QC Management/Supervisors – should possess experience managing professional personnel in similar circumstances or on similar projects. They should have experience with matrix organizations and managing multiple projects. They should have excellent communication skills and a working knowledge of QA/QC and quality management. They should possess certification as quality professionals for appropriate certifying bodies or have successfully completed training courses in the quality discipline

- Engineers – should have a Bachelors or Masters degree in the necessary fields of study (Civil, Electrical, Mechanical, etc., as appropriate) for the project; experience commensurate with the type of project and size of the quality department; and, depending on the project, one or more engineers should be a licensed Professional Engineer in the state where the project is taking place
- Inspectors – should have the appropriate education or experience commensurate with the job responsibilities. They should possess the necessary certifications required for assignments (e.g., American Welding Society (AWS), American Society for Testing and Materials (ASTM), American Concrete Institute (ACI), etc.)

3.6 Value Engineering Within The Project Lifecycle Context

3.6.1 Definition

Value engineering, or value analysis, as it is also called, is the systematic, continuous analysis of key processes or products, by one or all parties in the supply chain, to identify ways to simplify the design and subsequently, reduce the cost, while still providing the essential functionality of that product or process. Value engineering is also an essential component of the FTA guidelines for major capital projects, defined in the document entitled "Construction Management Guidelines" 1996 Update. Key elements of this definition are:

1. Value engineering can be applied to processes and projects, as well as products
2. It is an on-going effort that can and should be applied at any time during the entire lifecycle of the process, product, or project. It should not be a one-time activity
3. Key processes or products should be selected for analysis. Value engineering is both time consuming and costly and should be applied selectively
4. All parties in the supply chain, from grantee to consultant to contractor to suppliers should be involved in value analysis efforts
5. Essential functionality should not be sacrificed for cost savings resulting from value engineering
6. Value engineering as it relates to DB and Full Funding Grant Agreement (FFGA) requirements

Furthermore, FTA Circular 4220.1D, §7(g) encourages the use of value engineering clauses in construction contracts. This section states, “Grantees are encouraged to use value engineering clauses in contracts for construction projects of sufficient size to offer reasonable opportunities for cost reductions. Value engineering is a systematic and creative analysis of each contract item or task to assure that its essential function is provided at the lowest overall cost.” Grantees should conduct value engineering on their own vital processes and should encourage value engineering by those with whom they contract for projects, services, and products. This encouragement can come in the form of provisions and incentives in contract documents to support value engineering on the part of their consultants and contractors. Guidance for such clauses may be found in Part 48 of the Federal Acquisition Regulations (FAR), at FAR 52.248-3 *Value Engineering-Construction*. Further, grantees can and should participate on consultant and contractor value engineering teams to ensure that the results of these efforts are in the best

interest of the grantee. Finally, value engineering should be started as early as possible in a project's life cycle in order to maximize savings.

3.6.2 Benefits

The potential benefits of conducting value engineering or value analysis include:

- Simplified designs
- Lower product life cycle cost
- Improved project schedule performance
- Product standardization
- Increased customer acceptance/improved ridership
- Lower product obsolescence/improved availability of materials and components.

3.6.3 Implementation Process

1. Identify products/processes for consideration.
2. Establish cost and schedule targets.
3. Select team(s) to conduct the value engineering analysis or analyses.
4. Analyze product/process features – for products, dimensions, weight, components, materials, reliability, maintainability, functionality, and tolerances; for processes, steps/sequence, necessary approvals, schedule, tooling, etc.
5. Reengineer/redesign and prototype the product or process, as applicable.
6. Test the new product or process.
7. Provide feedback from the test results to the value engineering team.
8. Repeat steps 5 through 7, as necessary.
9. Make recommendations to management.
10. Implement approved changes.

3.7 Software Quality Assurance

Software plays an increasingly important role in every product and organization. The number of mission critical applications, those with a high cost of failure (e.g., Automatic Train Supervision (ATS) and Automatic Train Protection (ATP) software), or high cost to fix (e.g., communication equipment and other consumer products), have increased exponentially in recent years. Software for embedded systems more often than not fits a “mission critical” profile and with the forecast for embedded systems continuing to accelerate, the need for proactive quality assurance is higher than ever before.

The software developer or vendor should understand the value of having a formal software quality management system and should be committed to utilizing the best available standards, methods, practices, and dedicated resources to ensure all software meets a well-defined quality objective.

There are two key elements that make up a sound software quality management system: the Vendor's Quality System (VQS) and the Vendor's Software Development Process (VSDP).

The VQS consists of procedures assuring that quality is addressed and implemented in all aspects of project management and product development. These policies should be developed in accordance with ISO9000, Quality Management Systems. In addition, the VQS defines the quality management system requirements, policy stating vendor's belief in the requirement, the resources responsible for implementing the policy, and the standard operating procedures that describe how the vendor conforms to the software quality management system requirement.

The VSDP describes the detailed and comprehensive development process that translates the software quality management system requirements defined in the VQS. The VSDP includes project planning, project execution, product creation, and verification and validation, installation, and support functions. The VSDP identifies and defines the roles and responsibilities of project team members, project deliverables, and a monitoring mechanism based on measurements, analysis, and continuous improvement. Key audits and reviews are performed in order to track status and progress and to ensure that the project meets its requirements and milestones. The VSDP should be developed in accordance and be consistent with Institute of Electrical and Electronics Engineers (IEEE) Software Engineering Standards.

The Quality Assurance department, within the vendor's organization, performs configuration management, verification and validation, and quality assurance activities to ensure that the VQS is adhered to throughout the project development lifecycle. The VSDP ensures that the owner's/client's needs are fully understood and captured, and that project planning, development, and testing activities are documented prior to product creation. The VSDP should be flexible to allow tailoring to meet any solution that owners/clients require.

A software quality management system process needs to set expectations for the owner/client, project team members, and the vendor's organization and should support these expectations through the VQS and VSDP. The most important characteristic of the software quality management system is predictability; the vendor should be able to predict the budget, the schedule and the quality of deliverables. This translates to owner/client satisfaction since the project will be delivered on time, within budget, and with the best quality.

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CHAPTER 4

DEVELOPING A PROJECT QUALITY PLAN

The following sections describe the development process within the design-bid-build project delivery process. There are also variants between design-bid-build and design-build that are highlighted in Chapter 3. In all cases, the owner is responsible for assurance of the quality plan.

4.1 Goals and Objectives

The goal of a Quality Plan is to explicitly plan for the quality related activities needed to ensure that the project meets the requirements of the grantee and complies with regulatory requirements. The Quality Plan should be developed hand-in-hand with the PMP for the project. It is a living document in that it may need to be revised as the project progresses from the Project Planning Phase through Preliminary Engineering (PE), Final Design, Construction/Procurement, and Testing and Start-up.

4.2 Responsibilities

The PM is responsible for the Quality Plan. Ultimately, the PM must determine which procedures should be applied to the project. Where there is a Director of Quality Assurance or equivalent position, that person should also have to approve the plan.

4.3 Approach

Where a grantee has detailed procedures for carrying out the elements of the quality policy, the development of a Quality Plan for a project is straightforward. The PM can adopt particular procedures as appropriate during the different project phases of Project Planning, PE and Final Design, Procurement/Construction, and Testing and Start-up. The Quality Plan should provide an overview of the entire quality program for the project, and should provide enough detail either through incorporation of or reference to written procedures.

Where written procedures have not been adopted by the grantee, they will have to be developed specifically for the Quality Plan. Thus, if a grantee expects to be involved in multiple capital projects using FTA funding, the grantee should consider the formal development of written procedures.

The Quality Plan should be written to provide project management with easy access to the quality requirements. When the plan references procedures or standards, those items should be readily available as part of the plan.

4.4 Technical Requirements During Each Project Phase

While it is possible that one Quality Plan, applicable throughout the project, could be written at the end of the Planning Phase, the more likely situation is one where the Quality Plan evolves as

the project progresses. This is so because the organizations may change and the level of quality assistance required by contractors can vary. Also the procedures, forms, reports, etc., initially proposed for a QA/QC program may not be used or are changed during the course of the project. These changes should be reflected in the Quality Plan if they improve the final documentation and quality of the work.

There are exceptions to the traditional phased approach to a project. In design-build situations, one contractor could be responsible for several project phases. Therefore, the QA/QC program requirements should be completely specified at the time of the project bid and design-build contractor selection.

The following sections describe the type of detail that is desirable in a Quality Plan during the relevant project phases. The description is for the desired detail for a complex project where all of the quality system elements should be included at some time during the project. Less detail may be appropriate for simpler projects (See Chapter 2, Section 2.3).

4.4.1 Project Planning

Project Planning can include the bus maintenance facility planning process, rail modernization planning, and the Alternatives Analysis (AA) process for major capital investments for which FTA has established detailed procedures. Responsibility for bus maintenance facility planning and rail modernization planning typically rests with the operating agency. For AA planning, the responsibility may be spread among several agencies. The lead agency need only have the charter, authority, and capability to perform the planning and receive the grants required to accomplish the AA.

For major capital projects, a PMP should be initiated during the Project Planning Phase and completed and accepted before entering into Final Design. The project owner should develop the PMP, which may be different from the organization doing the Project Plan. Generally, the PMP must be submitted during the project grant review process and as part of FTA's grant application review. A Quality Plan is required as part of the PMP.

At this early phase, much is still unknown about the project. The participants may not be known, so that the Quality Plan cannot name organizations and persons. Timing, budgets, construction techniques, and so forth have yet to be decided. Initially, therefore, the Quality Plan should consist of a general description of the fifteen basic quality elements as applicable to the grantee and the project. The quality policy and appropriate existing procedures should be included in the Quality Plan.

Development of the Quality Plan is important at this phase to set an overall expectation and direction for quality for the project, and to clearly spell out quality requirements for procurement of the design consultants. Table 4-1 indicates the quality system elements for which design related detail might be appropriate at this initial phase.

There may not be a quality requirement for submittal of a Quality Plan for projects which are not major, and which do not have a PMP requirement. However, the development of a Quality Plan

can be beneficial for project management and project control purposes. Again, at this phase, the major planning effort should be focused on the quality requirements for the design activity.

4.4.2 Preliminary Engineering and Final Design

The Preliminary Engineering Phase is initiated at the conclusion of Project Planning. In PE the design is developed enough to provide a more accurate estimate of project costs and impacts. The resultant technical and financial information forms the basis for subsequent funding and implementation decisions. During PE, the merits of all sound configurations and designs are investigated. In addition, environmental requirements are completed, including preparation of a Final Environmental Impact Statement, and in some cases, a supplemental Draft Environmental Impact Statement.

The Final Design Phase is the last project development phase prior to construction. During this phase, the design consultant and/or in-house design staff prepares the plans, specifications, and bid documents required for awarding the individual facility construction and equipment fabrication/installation contracts.

Management of PE and Final Design is the responsibility of the grantee who must ensure that knowledgeable personnel are available to perform the required services.

Two basic alternatives exist for organizing the PE effort. The chosen alternative may be continued into Final Design or a different alternative can be established at that point. The two alternatives are 1) the grantee staff performs all design, or 2) consultants have the primary responsibility for design. There are also organizational alternatives in-between these extremes that mix the use of grantee staff and consultant staff. For larger projects, either the owner or a general design consultant can supervise and manage the work of firms retained to design sections of the project.

As design consultants are chosen and the design management organization is put into place, the PMP should be updated to reflect these actions. The Quality Plan should be updated to reflect each new organization of quality activity, and it should be updated to reflect more closely the planned quality activities during the Final Design Phase. The plan should begin to answer more specifically the questions of who is responsible and when in time actions should occur.

More important, the Quality Plan should be updated to reflect the quality requirements for the next phase in the process. Since an important product of the design phase is construction contract documents for construction contractors, decisions about quality requirements for construction and manufacturing need to be planned and included in the contract documents. Table 4-1 indicates the detailed descriptions that might be appropriate at this phase in the project Quality Plan.

4.4.3 Construction and Equipment Procurement

During the Construction and Equipment Procurement Phase, suppliers, contractors, and/or agency force account employees construct the fixed facilities, fabricate/install equipment, and

integrate them into a functioning system. During this phase, the Quality Plan should be developed in sufficient detail to guide the grantee in appropriate QA, QC, and quality oversight procedures.

During this phase, the first task is to procure the required contractors. These include the CMC, the construction contractors, and/or the equipment manufacturers. Where procurement regulations allow, contractors should be prequalified. Evidence of an acceptable quality program should be part of the prequalification process.

Where the specifications for the various contracted project tasks require the contractor to assume responsibilities for specific quality activities, the contractor should prepare written documentation of its quality program. This program should be reviewed and approved for adequacy by the grantee's Project Manager and the Director of Quality Assurance, or equivalent position.

Key quality elements that need to be specified in detail in the Quality Plan and, where appropriate, in contract documents, are procedures for nonconformance and corrective action during manufacturing and/or construction. In particular, the process for stopping work should be spelled out. Persons authorized to issue stop-work orders, procedures for doing so, approvals required, and restrictions need to be clearly understood by the contractors as well as the grantee. The grantee's role in providing quality oversight for the project should be described, and any audit activities should be planned. Table 4-1 indicates the type of information that would be useful at this phase.

4.4.4 Testing and Start-up

The Testing and Start-up Phase is the bridge between the Construction and Equipment Procurement Phase and the beginning of revenue service. The purpose of this phase is to accept the newly constructed or modernized facility, and/ or the newly procured equipment. This phase also includes integration testing of operating system prior to beginning or resuming revenue service. This phase overlaps with Construction and Equipment Procurement Phase, since some testing is performed in accordance with contract requirements during the earlier phase.

The Quality Plan should be modified prior to the beginning of the Testing and Start-up Phase to include detailed procedures for those tests required for the transfer of facilities and equipment from the constructing organization to the operating organization. Although contractually required testing will have been done as part of Construction and Equipment Procurement, other testing may be required by the owner/operating organization to accept the facilities and equipment. Acceptance criteria, however, must be specified at the end of the Final Design Phase and included in the construction contract documents.

Assurance of the testing program at this point is the responsibility of the owner. A test management team, as part of the project staff, should manage testing. A test engineer should manage the program with assistance from consultants and agency staff, as appropriate.

An exception to this situation would be when the contractor constructing the new system will also be responsible for operating the system for a period of time. In this case, all system integration testing would be performed as part of the contract with the constructing/operating organization. The tests must therefore be detailed in the Final Design Phase.

Preparation for revenue service start-up also includes the training of personnel to operate and maintain the facilities. Prior to service start-up the grantee should simulate service to test whether all system elements are functional and perform as designed. Start-up operations should verify the competence of the personnel and ensure a smooth and safe transition into operations.

The Quality Plan for the project should also reflect the need for ongoing maintenance contracts, as well as grantee/operator actions required to keep the contractual warranties in force. Table 4-1 shows the details to be included in the Quality Plan at the beginning of the Testing and Start-up Phase.

Given the existence of a detailed project Quality Plan and given that the plan is carefully executed, each of the project phases from Project Planning through Testing and Start-up should meet the quality specifications of the grantee, and provide excellent service. This, ultimately, is the objective of the quality program.

Tables 4-1 – Details of the Quality Plan at Various Project Phases

Quality Program Element	Project Phase			
	Project Planning	Pre. Engineering/Final Design	Construction/Procurement	Testing/Start-Up
1. Management Responsibility	Describe the quality responsibilities of the project team, and the persons/organization responsible for quality for the grantee. Identify specific personnel where possible.	Describe the quality responsibilities of the project team, and the persons/organization responsible for quality for the design consultant. Identify specific personnel where possible.	Describe the quality responsibilities of the grantee project team, and the persons/organization responsible for quality for the grantee and for construction management consultants, construction contractors, and equipment manufacturing contractors. Identify specific personnel where possible. Identify grantee staff responsible for quality oversight activities.	Describe the quality responsibilities of the project team, and the persons/organization responsible for quality for the grantee and for construction management consultants, and equipment manufacturing contractors. Identify specific personnel responsible for acceptance, demonstration, and integration testing. Identify grantee test engineer responsible for the testing program.
2. Documented Quality Management System	Incorporate by reference any written procedures for quality applicable to the project. Design-related procedures are particularly relevant. Note that applicable existing procedures can be referenced for any of the quality program elements.	Incorporate by reference any written procedures for quality applicable to the project. Construction and/or equipment manufacturing related procedures are particularly relevant.	Incorporate by reference any written procedures for the Quality Plan applicable to the project. Construction and/or equipment manufacturing related procedures are particularly relevant.	Incorporate by reference any written procedures for the Quality Plan applicable to the project. Testing related procedures are particularly relevant.
3. Design Control	Specify requirements for review & sign-off for design from departments, such as Construction and Operations, and other relevant agencies. Specify required design reviews during the PE and Final Design Phase. Specify any contract quality requirements for PE or Final Design consultants. Describe the procedures to be followed for design changes, including signoff and documentation.	Describe the procedures to be followed for design or specification changes or waivers of requirements during construction. Signoff of the responsible design consultant is desirable as well as signoff by those originally responsible for the design approvals. Requirements for "as-built" documents should be stated.	Describe the procedures to be followed for design or specification changes or waivers of requirements during construction. Signoff of the responsible design consultant is desirable as well as signoff by those originally responsible for the design approvals. Requirements for "as-built" documents should be stated.	Describe the procedures to be followed for fixing problems that are uncovered during final testing. Configuration management practices should be identified and followed.

Tables 4-1 – Details of the Quality Plan at Various Project Phases

Quality Program Element	Project Phase			Testing/Start-Up
	Project Planning	Pre. Engineering/Final Design	Construction/Procurement	
4. Document Control	A procedure for the control of project documents should be specified. This procedure may be modified as contractors and consultants join the project.	A procedure for the control of project documents should be described. This procedure should incorporate the design consultants for the project. This procedure may be modified as construction contractors and construction management consultants join the project.	A procedure for the control of project documents should be described as relates to the various construction contractors and consultants for the project. Contractor obligations should be specified and should be included in the contract documents.	A procedure for the control of documentation from the testing program should be described.
5. Purchasing	Describe procedures to obtain a list of qualified contractors for the design service. Provide a statement of general requirements, including quality requirements, and any past, demonstrated capability and performance requirements. Describe the process to ensure that purchasing documents are reviewed and approved by a designated authority prior to release.	Describe procedures to obtain a list of qualified contractors for the desired service. Provide a statement of general requirements, including quality requirements, and any past, demonstrated capability and performance requirements. Describe the process to ensure that purchasing documents are reviewed and approved by a designated authority prior to release.	Describe requirements for purchasing control to be placed upon construction contractors or equipment manufacturing contractors for the project. Describe purchasing and receiving control procedures to be followed by the grantee.	In addition to the requirements for testing of materials defined in the purchasing contract documents, the Quality Plan should specify random testing by the grantee of products for which fabricators submit material certificates or certificates of compliance. Testing should also be conducted when the validity of the materials/products or documentation are questionable.
6. Product Identification and Traceability	N/A	Describe requirements for product identification and traceability to be placed in contract documents, where appropriate, for equipment manufacturers or others supplying products for the project. Describe where these requirements are appropriate.	Describe requirements for product identification and traceability that should be included, where appropriate, in contract documents.	Describe the requirements for product identification and traceability for products and materials turned over to the owner at the project conclusion.
7. Process Control	N/A	Describe requirements for process control and procedures for special processes to be placed in contract documents, where appropriate, for contractors. Describe where these requirements are appropriate.	Describe requirements for process control and procedures for special processes, which should be included, where appropriate, in contract documents. These procedures should specify any sequencing of work requirements.	Describe plans for maintenance of the facility and equipment, especially as required for warranty purposes.

Tables 4-1 – Details of the Quality Plan at Various Project Phases

Quality Program Element	Project Phase			
	Project Planning	Pre. Engineering/Final Design	Construction/Procurement	Testing/Start-Up
8. Inspection & Testing	N/A	Describe requirements for inspection and testing to be placed in contract documents, where appropriate, for contractors. Inspection and testing can include in-process inspection and testing, final inspection and testing, and receiving inspection. Specifications should indicate the types of tests required and the standards to be met. Describe where these requirements are appropriate.	Describe requirements for inspection and testing for each contract, as appropriate. Inspection and testing can include in-process inspection and testing, final inspection and testing, and receiving inspection. State the types of tests required and the standards to be met.	Describe plans for acceptance testing, demonstration testing, and integration testing of the system and equipment. Acceptance tests verify that performance of all delivered equipment is in conformance with specifications. Demonstration tests demonstrate the reliability of the system equipment. System integration testing demonstrates the ability of various subsystems and facilities to work together as a system and for the new or modernized system to function with an existing system. Tests that affect system safety should be reviewed independently in a safety review to ensure that potential hazards are identified and resolved.
9. Inspection, Measuring & Test Equipment	N/A	Describe requirements for calibration and maintenance of inspection, measuring, and test equipment to be placed in contract documents, where appropriate, for contractors. Describe where these requirements are appropriate.	Describe requirements, as appropriate, for calibration and maintenance of inspection, measuring, and test equipment for each contract.	Describe requirements, as appropriate, for calibration and maintenance of inspection, measuring, and test equipment as required for final testing.
10. Inspection & Test Status	N/A	Describe requirements to be placed in contract documents, where appropriate, for contractors to identify the inspection and test status of work during production and installation. Describe where these requirements are appropriate.	Describe requirements, as appropriate, for contractors to identify the inspection and test status of work during production and installation.	Describe requirements, as appropriate, to identify the inspection and test status of work during final testing.

Tables 4-1 – Details of the Quality Plan at Various Project Phases

Quality Program Element	Project Phase			
	Project Planning	Pre. Engineering/Final Design	Construction/Procurement	Testing/Start-Up
11. Nonconformance	Procedures for handling nonconforming work should be described, and potential design contractors should be made aware of these procedures.	Grantee procedures for handling nonconforming work should be described, and these procedures should be included in contract documents to clarify future expectations.	Grantee procedures for handling nonconforming work should be specified in detail. All contractors should be made aware of the procedures. Procedures include defining responsibilities, stating conditions that would cause work to stop, and providing documentation. Specify the requirements for the contractor to have their own procedures.	Procedures for handling nonconforming work should be maintained during final testing.
12. Corrective Action	Procedures for handling corrective action should be described, and potential design contractors should be made aware of these procedures.	Grantee procedures for corrective action should be described, and these procedures should be included in contract documents to clarify future expectations.	Procedures for talking corrective action should be specified in detail. Each contractor should be made aware of the procedures. Specify any requirements for the contractor to have their own procedures.	Procedures for taking corrective action should be maintained during final testing.
13. Quality Records	Procedures should be specified for establishing and maintaining quality records. Requirements for contractors and subcontractors should be specified, and made part of bid specifications and contracts. An internal audit should be described with the initial focus on the design process at this phase in the project.	Procedures should be specified for establishing and maintaining quality records. Requirements for contractors and subcontractors should be specified, and made part of contract documents.	Procedures should be specified for establishing and maintaining quality records. Requirements for contractors and subcontractors should be specified, and made part of the contract documents.	Procedures should be specified for maintaining quality records for a specified period after project completion.
14. Quality Audits	An internal audit should be described with the initial focus on the design process at this phase in the project.	An internal quality audit system should be planned and implemented for the design activities during PE and Final Design. Requirements for contractors to cooperate with quality audits should be stated, and included where appropriate, in contract documents.	An internal audit should be planned and implemented for the construction and equipment manufacturing activities.	A final audit should be planned and implemented to ensure that project quality records are complete and in satisfactory condition.
15. Training	Specify any training required for personnel.	Specify any training required for personnel.	Specify any training required for personnel.	Specify training required for grantee operating and maintenance to ensure a smooth transition to operations.

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APPENDIX A

SELECTIONS FROM TRANSIT QUALITY PROGRAMS

This appendix presents selections from a number of transit quality programs in use around the United States. The selections may use different titles than the quality elements in these guidelines and their content may be slightly different. Nevertheless, these selections largely represent the elements suggested in this guidance.

Although these are excellent examples of policies, procedures, and formats from other transit capital programs, they are not presented here so that they may be merely copied. Rather, each organization should tailor their Quality Plan to fit their own structure and requirements. Personnel at the transit agencies that have provided these examples may be contacted and used as references when preparing a Quality Plan. Additional references that can and should be contacted include agencies of similar size or agencies that are working on similar sized programs. Additionally, the FTA regional office is an excellent resource for information and assistance.

Attached are the following:

Element 1: *Management Responsibility*

From the New York City Transit Authority, Department of Capital Program Management, Quality Management System Manual.

Element 2: *Documented Quality System*

From the Washington Metropolitan Transit Authority, 5000 Series Vehicle Procurement Program, Quality Assurance Plan.

Element 3: *Design Control*

From the New York City Transit Authority, Department of Capital Program Management, Quality Management System Manual; including Project Management Guideline No. 301 and corresponding Project Management Procedure No. 301, Design Management.

Element 4: *Document Control*

From the Chicago Transit Authority, Capital Improvement Program, Quality Assurance Manual.

Element 5: *Purchasing*

From the Chicago Transit Authority, Capital Improvement Program, Quality Assurance Manual.

Element 6: *Product Identification and Traceability*

From the Washington Metropolitan Transit Authority, 5000 Series Vehicle Procurement Program, Quality Assurance Plan.

Element 7: *Process Control*

From the New York City Transit Authority, Department of Capital Program Management, Quality Management System Manual.

Element 8: *Inspection and Testing*

From the Washington Metropolitan Transit Authority, 5000 Series Vehicle Procurement Program, Quality Assurance Plan.

Element 9: *Inspection, Measuring, and Test Equipment*

From the Washington Metropolitan Transit Authority, 5000 Series Vehicle Procurement Program, Quality Assurance Plan.

Element 10: *Inspection and Test Status*

From the Washington Metropolitan Transit Authority, 5000 Series Vehicle Procurement Program, Quality Assurance Plan.

Element 11: *Nonconformance*

From the Chicago Transit Authority, Capital Improvement Program, Quality Assurance Manual; including Project Management Procedure, PMP-6009, Nonconformance Reports and Corrective Action.

Element 12: *Corrective Action*

From the Chicago Transit Authority, Capital Improvement Program, Quality Assurance Manual; including Project Management Procedure, PMP-6009, Nonconformance Reports and Corrective Action.

Element 13: *Quality Records*

From the Chicago Transit Authority, Capital Improvement Program, Quality Assurance Manual; including Project Management Procedure, PMP-6002, Quality Records – Quality Assurance Department.

Element 14: *Quality Audits*

From the New York City Transit Authority, Department of Capital Program Management, Quality Management System Manual; including Project Management Guideline No. 118 and corresponding Project Management Procedure No. 118, Quality Assurance Audits.

Element 15: *Training*

From the New York City Transit Authority, Department of Capital Program Management, Quality Management System Manual.

Element 1: *Management Responsibility*

From the New York City Transit Authority, Department of Capital
Program Management, Quality Management System Manual.

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Section 2

MANAGEMENT RESPONSIBILITY

2.1 MISSION

The mission of the NYCT Department of Capital Program Management (CPM) is to rebuild and improve the NYC Transit System by planning, designing and building excellent capital projects.

We will accomplish this mission by:

- developing and empowering employees
- exceeding expectations on safety, environmental excellence, quality, budget and schedule
- providing consistently superior customer service
- optimizing and integrating new technology
- stressing continuous improvement

2.2 QUALITY GOAL

To achieve an organizational understanding of - and commitment to - Quality.

2.3 QUALITY PLANNING

2.3.1 Quality Objectives

CPM develops and disseminates departmental quality objectives measurable and consistent with the quality policy, including the commitment to continual improvement. Objectives are reviewed annually and revised as needed.

Senior Management develops individual Quality Objectives as part of their Management Performance Review.

2.3.2 Quality Planning

Quality Planning activities, conducted by CPM's top management include considerations such as:

- needs and expectations of the customers
- performance of products and processes
- resources needed
- lessons learned
- risk identification and analysis
- responsibility and authority for execution of improvement plans
- contingency plans

2.4 RESPONSIBILITY, AUTHORITY AND COMMITMENT

The responsibility for and commitment to the established Quality Policy begins with top management. Management should ensure that the Quality Policy shown in Section 1 is understood, implemented and maintained throughout all appropriate levels of the organization. Top management in CPM is defined as the Senior Vice President and his Direct Reports.

2.4.1 President

The President of the NYCT has delegated the responsibility for establishing and implementing a Quality Management System for Capital Program projects to the Senior Vice President and Chief Engineer, Capital Program Management.

2.4.2 Senior Vice President And Chief Engineer, Capital Program Management

The Senior Vice President and Chief Engineer, Capital Program Management is the NYCT Officer responsible for the direction, administration and management of the Department of Capital Program Management.

2.4.3 Management Commitment

CPM top management is committed to the development and improvement of the Quality Management System. This commitment is demonstrated by:

- communicating to the organization the importance of meeting customer as well as regulatory and legal requirements
- establishing the Quality Policy and Quality Objectives
- conducting management reviews
- ensuring the availability of necessary resources

2.4.4 Management Reviews

The SVP annually reviews the Quality Management System with his/her direct reports to ensure its suitability, adequacy and effectiveness. The reviews also evaluate the need for changes to the Quality Management System, including Quality Policy and Quality Objectives. Review

inputs include current performance and improvement opportunities related to:

- results of audits
- customer feedback
- process performance and product conformance
- status of preventive and corrective action
- follow-up actions from earlier management reviews
- recommendations for improvement
- changes that could effect the Quality Management System

Review outputs include actions related to:

- improvement of the effectiveness of the Quality Management System and its processes
- improvement of product related to customer requirements
- resource needs

2.4.5 Customer Focus

CPM top management is responsible for ensuring that customer needs and expectations are determined, converted into requirements and fulfilled with the aim of achieving customer satisfaction.

2.5 **ADMINISTRATION**

2.5.1 CPM functions under a program management structure. CPM's organizational structure consists of customer-focused business units called Program Areas. Engineering Services, Planning and Budget, Management Services and Quality and Safety Management divisions provide resources and support for the Program Areas. Projects are assigned to a Program Area based on the nature of the work. The Program Manager is in charge of a Program Area and is responsible for the planning, design and construction of all projects assigned to the Program Area. Successful completion of project activities, from planning through final acceptance and contract closeout, is the joint responsibility of CPM Program Managers and their operating department counterparts.

2.5.2 Management Representative

The SVP and Chief Engineer has appointed the Chief, Quality and Safety Management as the ISO 9001 management representative. The Chief has the responsibility and authority to:

- ensure that processes of the Quality Management System are established and maintained
- report to the SVP and his direct reports on the performance of the Quality Management System, including needs for improvement
- promote awareness of customer requirements throughout the organization

The responsibility of the management representative includes liaison with external parties on matters relating to the Quality Management System

2.5.3 Internal Communications

CPM ensures communications between its different levels and functions regarding the processes of the Quality Management System and their effectiveness in a number of ways. Communication tools include SVP directives, All Hands Meetings, staff meetings, CPM Newsletters, bulletins boards, project objectives reports, etc. Communication with our suppliers is on-going throughout design and construction and includes project kick-off meetings, progress meetings, TA Factor and NYACE meetings and periodic work shops conducted by the Program Areas.

2.5.4 Quality During Design

Quality in the constructed project begins in the design phase.

It is the responsibility of the entire Project Design Team to assure that contract drawings and specifications meet appropriate standards and customer and regulatory requirements and provide clear direction for construction of the project. Verification of the design against customer requirements contained in the Scope of Work is performed by the Project Design Team throughout the design phase.

Overall responsibility for design and construction rests primarily with the Program Manager, with assistance from Chief Discipline Engineers/Architects in the form of staff and technical expertise.

The Design Manager, reporting directly to the Program Manager, is responsible for all required design activities. The Design Manager must ensure design conformance with the Scope of Work, an acceptable project cost, technical coordination between the disciplines, and timely completion. The project's prospective Construction Manager is required to provide construction-related support to the Project Design Team.

Design staff matrixed to a Program Area receive project direction from the Design Manager. Matrixed design staff will turn to their Engineering Services disciplines when in need of technical guidance and direction and will keep their discipline informed with respect to project progress. Engineering Services has a mentoring, oversight, training and consulting responsibility.

The Quality Representative matrixed to a Program Area participates on all Project Design Teams. This Quality Representative reviews and comments on design distributions and provides guidance and assistance to the Project Design Team concerning quality issues and procedures. Quality Management audits the design process to assure that established requirements are being met. This audit function provides for validation of the department's QA process and, in conjunction with lessons learned activities, leads to the implementation of continuous improvements and corrective actions on a department-wide basis.

2.5.5 Quality During Construction

Construction work is generally performed by third-party contractors who have the primary responsibility for quality and safe construction of the constructed facility.

CPM construction contracts require that the contractor establish, implement and maintain an effective Contractor Quality Program, approved by the NYCT Construction Manager, to manage, control, document and assure that their work complies with the requirements of the contract documents.

This program consists of plans, procedures, and the organization necessary to assure adequate control (inspection) and assurance of quality for materials, workmanship, fabrication and operations covering both on-site and off-site construction work. Contractors are required to perform their own audits to assure compliance with the requirements of their quality program and must assign an approved quality engineer/manager whose function is to manage all quality matters relating to the project.

The ultimate responsibility for assuring that the contractor fulfills all obligations, including quality and safety, rests with the Program Manager.

The Construction Manager, reporting directly to the Program Manager, is responsible for assuring that contractors comply with all requirements of their Contractor Quality Program, Safety Management Program, contract documents and all applicable laws and regulations.

Verification of construction against the approved design documents is performed throughout the construction phase. Engineering Services personnel matrixed to the Program Areas, and working under the direction of the Construction Manager, perform oversight of construction activities, and assure, on a day-to-day basis, that the contractor is in compliance with construction documents, including quality and safety requirements. This oversight takes the form of: checking contractor supplied documentation; witnessing contractor operations, inspections and tests; performing independent inspections and tests to verify contractor results; or any combination of these activities.

On those construction projects not contracted out, work is performed by NYCT in-house forces, under the administration of a CPM Construction Manager. This work is done in accordance with the design documents and established CPM quality requirements.

Quality Representatives are matrixed to Program Areas to assist in the implementation of quality and safety throughout the construction process. They receive day-to-day direction from the Program Managers. Quality and Safety Directors have a mentoring, oversight, training and consulting responsibility.

Quality Management performs audits of contractor and project management activities during construction to assure that established requirements are being met. Audits are performed by personnel outside of the Program Area on a sampling basis and the projects/activities to be audited are selected based on an analysis of project scope, complexity, dollar value and prior audit history. The audit function provides for documentation and validation of the department's QA process. Pareto and trend analyses of data obtained by the audit functions and a customer satisfaction measurement process to determine customer perception of these CPM services and performance, are used to identify deficiencies and to implement corrective/ preventive actions for continuous improvement of processes and practices throughout CPM.

- 2.5.6 The procedures established for accomplishing the activities required to assure quality of the constructed project are found in the Quality Manual, Project Management Procedures, Project Management Guidelines, Design Guidelines, Senior Vice President Directives and internal CPM procedures.

Element 2: *Documented Quality System*

From the Washington Metropolitan Transit Authority,
5000 Series Vehicle Procurement Program, Quality Assurance Plan.

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2.0 DOCUMENTED QUALITY SYSTEM

2.1 Purpose

This section establishes the Authority's Quality Assurance and Quality Control requirements, responsibilities, and procedures for Element 2, "Documented Quality System", of the Federal Transit Administration's Guidelines for Quality Assurance and Quality Control.

2.2 Scope

It is the policy of the Authority to ensure continued adherence to the standard practices and policies of the Authority by undertaking periodic reviews, revisions, and redistribution of the Quality Assurance Plan. The Quality Assurance and Quality Control Plan applies to all quality activities performed under this contract.

2.3 Policy

Methods of accomplishing activities affecting quality are described in the Project Management Procedures. These procedures also define the documentation to be produced as verification of satisfactory accomplishment of the activity.

2.4 Responsibilities

The Authority is responsible for Quality Assurance to ensure the inclusion of all requirements and acceptance criteria covering quality matters in technical documents, drawings, specifications, directives, inspection, testing requirements, etc., for the Project.

Activities affecting quality are documented by the parties responsible for the activities, generally as defined by the PM, and approved by the Project Quality Assurance Manager. The responsible individuals or organizations will issue necessary directives or procedures to assure that pertinent activities are documented. Additional procedures will be incorporated, when and if required, with the approval of the Project Quality Assurance Manager. Procedures may be developed for use by groups or individuals as subsidiary or specialized needs dictate.

Documentation records testifying to the satisfactory execution of the required activities for the project will be readily available to authorized personnel and delivered to authorized personnel as directed. An integral part of this project is

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the list of instructions, procedures, drawings, specifications, inspection test reports, and quality assurance reports to be prepared, submitted, or made available for review or approval, in accordance with the individual contract requirements.

Contractor or consultant documents relating to quality will also be made available for review as described in this plan. These documents are to include provisions describing type, quality, and frequency of all submissions. Requirements shall be established in the individual contracts and/or specifications. Quality records will be accumulated and identified and will be available in the format provided in this Quality Assurance Plan and in the various applicable procedures associated with the project. Such records will not be removed from the project files.

2.4.1 Additional Responsibilities

2.4.1.1 The Deputy Program Manager reviews the Quality Assurance Plan at least annually and revises it, as required, with the approval of the WMATA Railcar Maintenance Quality Assurance Manager.

2.4.1.2 The Deputy Program Manager is responsible for issuing and controlling the Quality Assurance Plan.

2.3.1.3 Holders of controlled copies of the plan are required to keep them up-to-date and in good condition.

2.5 Revision Control

2.5.1 Each revision to the plan is issued with a revision sheet requiring an authorized signature and date of revision.

2.5.2 Revised procedures are authorized by the Project Quality Assurance Manager on the revision sheet.

2.5.3 If a revision to any section of the plan is made, the entire section is revised and re-issued under a new revision number.

2.5.4 The holder of the plan certifies receipt and removal of obsolete copies by signing and returning one copy of the distribution sheet to the Quality Assurance Department.

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2.5.5 A list of all Quality Assurance Plans in circulation is maintained in Quality Assurance files.

2.5.6 Serialized control copies of the plan are issued to specific persons. Only those plans are kept up to date.

2.5.7 Only controlled copies are valid for official use.

2.6 Procedures

During the course of the project, written procedures will be developed for the activities affecting quality in design, procurement, manufacturing, and construction, as applicable to the work performed. The procedures manuals that will support the quality initiatives for the program are:

- 2.6.1 Project Management Plan,
- 2.6.2 WMATA Quality Assurance/Quality Control Plan,
- 2.6.3 WMATA Operations Administrative Procedures,
- 2.6.4 Engineering Consultant Quality Assurance Plan (pending),
- 2.6.5 Contractor's Program Quality Assurance/Quality Control Plan,
- 2.6.6 5000 Series Specification (w/ Design Criteria and Standards), and
- 2.6.7 Engineering Consultant Quality Plan.

2.7 Inspection and Test Procedures

Inspection and Test Procedures will be developed and implemented by the Contractor in compliance with contract documents. These procedures will be submitted to the Authority as part of the Quality Plan submitted by the Contractor. The Contractor will be responsible for developing the Inspection and Test Plan (ITP) for all phases of the vehicle design and production. The Consultant will be responsible for developing the appropriate Test and Inspection Procedures for its portion of the work, including in-process inspection. The Authority will be responsible for Quality Assurance over the Consultant and/or Contractor(s) required by contract to develop Inspection and Test Procedures for their products or services.

The Authority will ensure enforcement of the following goals and objectives:

- 2.7.1 characteristics of items are verified at suitable stages during manufacturing and construction;

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2.7.2 critical and important design characteristics are defined in accordance with industry codes;

2.7.3 performance characteristics are defined;

2.7.4 results of performance testing are evaluated;

2.7.5 manufacturing methods and sequences are defined and tooling is specified;

2.7.6 each ITP:

- identifies inspection and test points within the manufacturing cycle
- contains a manufacturing plan flow chart
- identifies characteristics to be verified
- identifies the inspection and test points where calibrated and certified measuring equipment is required
- indicates mandatory inspections
- specifies which quality standards are applied to subContractor items
- defines how the processes are controlled
- specifies the inspection and test methods

2.7.7 the EC's responsibilities also include monitoring and maintaining the up-to-date status of the ITP during the Project.

2.8 Submittals

In conformance with the requirements of the Quality Assurance/Quality Control Program Plan, a complete listing of all deliverables required of the Contractor and its subContractors is included in the Specification under Section 1, Scope, Subsection 1.3.2, Contract Data Requirements List. The Authority and its Consultant are responsible for the review of all Contractor deliverables. Deliverables shall be revised and resubmitted if deemed to be "not approved".

Element 3: *Design Control*

From the New York City Transit Authority, Department of Capital Program Management, Quality Management System Manual; including Project Management Guideline No. 301 and corresponding Project Management Procedure No. 301, Design Management.

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Section 3

DESIGN CONTROL

3.1 QUALITY OBJECTIVE

Design activities shall be performed in accordance with approved procedures and appropriate Design Guidelines.

3.2 PROJECT DEVELOPMENT

3.2.1 Project Initiation

3.2.1.1 Operating departments identify and request each capital project by submitting a Capital Project Profile to Capital Planning and Budget.

3.2.1.2 Projects are assigned to Program Managers as soon as possible after they are identified to insure proper management during the initial pre-design phase of the project, and to provide continuity of management throughout the life of the project.

3.2.2 Scope Development

3.2.2.1 Scope development is the work necessary to expand the Capital Project Profile into a Preliminary Scope of Work. The initial version of the Preliminary Scope of Work is prepared before design commences. If the proposed project is accepted for Preliminary Engineering, the Preliminary Scope of Work serves as the starting point for the work of the Project Design Team. The Preliminary Scope of Work is updated throughout Preliminary Engineering and becomes the Final Scope of Work at the conclusion of Preliminary Engineering. The scope development process involves the review of available information, meetings with operating departments (Sponsors/Users/Maintainers) and other departments with interests in the project, field trips to inspect the project location, further definition of needs, discussions of whether the project is to be designed in-house or by consultant, and other activities necessary to assure that overall project and quality objectives and constraints are adhered to and that the requirements of the client are satisfied.

3.2.2.2 The Preliminary Scope of Work is updated throughout Preliminary Engineering to reflect CPM - Sponsor/User/Maintainer understanding of project requirements. To insure complete and cost-effective scopes of work, each new issue of the Preliminary Scope of Work must be approved in accordance with PMP 301.

3.3 DESIGN INPUTS, OUTPUTS AND REVIEWS

- 3.3.1 The approved scope of work identifying Sponsor/User/Maintainer department/division needs and requirements is used by the designer as input in designing the project. Design codes and standards, guidelines, standard and existing drawings, photographs, existing conditions and master specifications are also used as input in developing the project design.
- 3.3.2 Design Managers are responsible for the preparation of drawings, calculations and specifications, and other technical documents as outputs required to define and document the project design and any special methods of construction.
- 3.3.3 At suitable stages, systematic design reviews are conducted to:
- evaluate the ability to fulfill requirements
 - identify problems and propose follow-up actions

Participants in such reviews shall include representatives of functions concerned with the design being reviewed. The results of the review and subsequent follow-up actions shall be recorded.

3.4 DESIGN VERIFICATION AND VALIDATION

- 3.4.1 Calculations, drawings and specifications are checked by qualified personnel not normally associated with their preparation. The Project Design Team verifies the design against the Scope of Work.
- 3.4.2 Constructibility Reviews assure that the project includes the application of sound construction principles consistent with operating and maintenance requirements and accepted engineering practices for safe, efficient and economic construction.
- 3.4.3 Value Engineering Design Reviews assure cost effectiveness.
- 3.4.4 Design validations assure that the project conforms to the requirements of its intended use.

3.5 CONTROL OF DESIGN CHANGES

Design changes shall be identified, documented and controlled. This includes evaluation of the effect of the changes on constituent parts and delivered products. The changes shall be verified and validated, as appropriate and approved before implementation.

3.6 ACCEPTANCE CRITERIA

- 3.6.1 Contract specifications and drawings define inspection, testing and acceptance requirements for materials and equipment which the Contractor must follow and document in his Quality Program.

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1.0 PURPOSE

To provide guidelines to aid the Department of Capital Program Management in managing the design of capital projects.

2.0 SCOPE

This guideline is applicable to all Capital Program Management project designs, regardless of the mix of in-house and consultant design work.

3.0 GUIDELINES

3.1 Project Design Team

Members of the Project Design Team work together to develop the design and prepare the drawings and specifications required for advertisement, bid, award, and construction of a capital project. Team members report directly to the Design Manager on all project-related matters throughout design.

A typical Project Design Team includes the following membership (see Exhibit 1 for an organization chart).

1. Design Manager – As the team leader, the Design Manager is responsible for producing quality deliverables on schedule and within budget. S/he leads the Project Design Team in performing design work and/or overseeing the work of a design consultant. S/he plans and manages the resources necessary to produce a quality Design Solution (i.e. deliverable of the Preliminary Engineering stage) and Detailed Design (i.e. deliverable of the Final Design stage). The Design Manager must assure that the team is adequately equipped for its work. Thus the Design Manager's responsibilities include, but are not limited to:
 - A. Assuring that Engineering Force Account (EFA) funds are in place.
 - B. Working closely with CPM resource centers (i.e. Engineering Services Division, Estimating & Cost Control, Quality, Schedule Control, Signals & Systems) to assemble the Project Design Team.
 - C. Compiling and maintaining the Project Design Team membership list (i.e. names, locations, telephone numbers).
 - D. Working closely with the team's Architectural/Engineering Task Leaders (see below) in order to ensure that technical issues are

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resolved fully and promptly (i.e. arranging for additional expertise to be assigned or available to the Project Design Team as necessary).

- E. Coordinating work across disciplines.
 - F. Scheduling and conducting a review of conceptual designs with the Chief discipline Engineers and the Deputy Vice President, Engineering Services.
 - G. Serving as the Project Design Team’s representative to interested parties within CPM, the NYCTA, and the MTA, and particularly
 - keeping management informed of design progress and promptly bringing issues beyond the ability of the Project Design Team to resolve to the attention of appropriate management
 - bringing issues of significant capital and/or operating cost impact to the attention of the Chief Budget Officer, Capital Program.
 - H. Arranging for services and equipment needed by the Project Design Team (e.g. Access & Protection for site visits).
 - I. Assuring that CPM’s clients (Sponsor/User/Maintainer department/divisions) are satisfied throughout the design process.
 - J. Giving project presentation to Project Constructibility Advisory Review Board at Preliminary Engineering and Final Design for projects selected by the Deputy Vice President and Deputy Chief Engineer.
2. Sponsor Representative – As CPM’s client, the Sponsor Representative explains the functional/operational requirements for the project and keeps the Project Design Team informed of any changes in those requirements. This member is also responsible for keeping Sponsor management informed about progress of the design and major design decisions being made by the Project Design Team.
3. User/Maintainer Representative(s) – Representing other departments/divisions having interests in the project design, these members keep the Project Design Team informed of requirements for safety, functionality, maintainability, and customer service over and above those identified by the Sponsor. These members are also responsible for keeping User/Maintainer departmental/divisional management informed about progress of the design and major design decisions being made by the Project Design Team. “User” department/divisions include “collateral” sponsors and Operations

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Planning, which develops service plans and schedules for bus and train service.

4. System Safety Representative – Representing NYCTA’s Office of System Safety, this member provides expertise on and keeps the Project Design Team informed of system-wide safety issues of relevance to the project design.
5. Representative of project’s prospective Construction Manager – As the leader of CPM’s efforts during the construction phase of the project—should the project reach that phase—the Construction Manager: provides expertise on issues of constructibility and coordinates Constructibility Review; assisted by the Construction Scheduler, develops the construction schedule, project phasing and TA Labor occasions; provides expertise in estimating services required to administer the construction contract (construction phase EFA) and services required to support construction (TA Labor); provides input into and reviews contract documents (drawings and specifications) for award and construction-related issues; and is responsible for providing Special Conditions and Division 1 input of the contract-specifications document.
6. Procurement Representative – Representing NYCTA’s Procurement Subdivision, this member provides expertise on the various procurement processes suitable for the project’s construction contract.
7. Environmental Engineering Program Area Representative – As the environmental engineering professional most familiar with work of the Program Area, the Environmental Engineering Program Area Representative provides expertise on environmental impacts, hazardous materials and other environmental issues. Furnishes technical specifications for hazardous materials and other environmental concerns as required.
8. Quality Program Area Representative – As the quality assurance/control/management professional most familiar with all the work of the Program Area, the Quality Program Area Representative provides expertise on quality issues and processes.
9. Estimator – Assigned to the Program Area from Estimating & Cost Control, this member’s primary focus is on developing estimates for construction bid.

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10. Design Scheduler – Assigned to the Program Area from Schedule Control, this member’s primary focus is on developing and maintaining the design schedule.
11. Design Architects/Engineers – Assigned to the Project Design Team from Engineering Services Division (ESD) and Signals & Systems, each of these members focuses on technical design work in the engineering/architecture discipline (i.e. architecture, civil/structural engineering, electrical engineering, mechanical engineering, signal engineering, software engineering) of his/her expertise. Each disciplinary delegation is led by an Architectural/Engineering Task Leader.
12. Architectural/Engineering Task Leader – As the leader of his/her disciplinary delegation to the Project Design Team, the Architectural/Engineering Task Leader’s responsibilities include, but are not limited to:
 - A. Representing his/her discipline chief on the Project Design Team.
 - B. Leading the work of his/her discipline's Design Engineers/Architects on the Project Design Team.
 - C. Coordinating the work of his/her discipline’s Design Engineers/Architects with other members of the Project Design Team.
 - D. Promptly seeking guidance on unresolved technical issues and questions from his/her discipline management (e.g. Chief Discipline Engineer/Architect or Principal Engineer/Architect; Chief Software Officer).
13. Capital Planning and Budget Representative - Assigned to the Project Design Team from Capital Planning and Budget Division. This member’s primary focus is to monitor the evolving scope of work and its construction cost estimate (including construction phase EFA and TA Labor).

3.2 Preliminary Scope of Work

The Preliminary Scope of Work, first developed in the pre-design phase as part of the Project Master Plan (see PMP 320, Project Master Plan), serves as the starting point for the Project Design Team’s Preliminary Engineering work. A description of the functional requirements of a proposed project, it is continually updated throughout Preliminary Engineering and becomes the Final Scope of Work at the conclusion of Preliminary Engineering.

3.3 Design Kick-off Meeting

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Preliminary Engineering begins with the Design Kick-off Meeting. The Design Kick-off Meeting is held as soon as possible after issuance of the Preliminary Engineering Willingness to Assume Risk (WAR) Certificate. This is the Design Manager's opportunity to introduce the Project Design Team (and appropriate consultant personnel, in the case of consultant design) to major issues relating to the project: scope, purpose, estimated budget, estimated schedule, and plan for achieving design goals.

3.4 Preliminary Engineering

Preliminary Engineering is the initial design stage of a capital project, culminating in establishment and approval of the Design Solution. As the stage of the project when the most significant design decisions are made, it is essential that experienced design personnel (i.e. including Principal Engineers and even Chief Discipline Engineers) actively participate in Preliminary Engineering. It encompasses these activities: verification of the Sponsor/Users/Maintainers' functional requirements; definition of the project's program (i.e. determining spatial assignments necessary to meet functional and support requirements); conceptual designs; agreement on technical solutions to design problems; constructibility and value-engineering reviews; exploration of innovative contracting methods, design ideas, and construction approaches; preliminary engineering drawings; outline specifications; development of a Preliminary Engineering estimate and schedule. For projects that include software, see PMG 321, CPM Software Acquisition Process.

The degree to which a project's design must be carried out in developing a complete Design Solution depends on the type and size of the project. For some projects, 10% design may suffice and for others 40-50% or more design effort may be necessary. In all cases, close involvement of Sponsor/User/Maintainer representatives is required.

Since the Design Solution includes the Preliminary Engineering cost estimate and schedule, Preliminary Engineering is the time when the Project Design Team should settle all questions with significant potential to impact project cost and schedule. **Examples** of cost-sensitive considerations are:

- constructibility – the representative of the project's prospective Construction Manager serves on the Project Design Team in part to contribute his/her experience with similar projects, knowledge of various construction methods, and expertise in suggesting possible field conditions to be investigated and/or resolved
- phasing – the Construction Manager, assisted by the Construction Scheduler, serves on the Project Design Team in part to contribute

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his/her expertise in developing project phasing and in suggesting ways to minimize the need for services required to support construction (TA Labor); User Representatives (including the Operations Planning Representative) and the representative of the project’s prospective Construction Manager should actively participate in the development of the phasing and planning for use of TA Labor services

- presence of hazardous materials – the Environmental Engineering Program Area Representative serves on the Project Design Team in part to contribute his/her experience with similar projects and expertise in suggesting possible field conditions to be investigated
 - procurement strategy – the Procurement Representative serves on the Project Design Team largely to contribute his/her expertise in suggesting the best, most cost-effective type of contract to use for the project
 - quantities – the accuracy of a cost estimate depends on the completeness of the information provided to the Estimator. Whenever possible, drawings should specify quantities of required items; when quantities are not shown on drawings, the Project Design Team must provide the Estimator with other guidance on quantities required.
1. Project Plan – Preliminary Engineering begins with the Design Manager leading the Project Design Team in using the Preliminary Scope of Work developed during the Master Plan phase to plan the design effort. This “project plan” for design should include, but not be limited to:
- Work Breakdown Structure (WBS)
 - estimate of type and effort-level of design expertise required
 - preliminary drawing list
 - preliminary list of questions, issues, and alternatives to be explored during Preliminary Engineering
 - preliminary list of site investigations necessary and plan for obtaining TA Labor (e.g. Access & Protection, Flagging) needed to conduct such investigations
 - Preliminary Engineering Design Schedule, including timetable for design presentations to interested management parties (e.g. Program Manager, Sponsor/User/Maintainer management) to assure approvals by all relevant NYCTA department/divisions
 - preliminary timetable for obtaining all external permits and approvals necessary for constructing the project, i.e. from utilities, private property owners, and Federal, State, and City agencies (see PMG 108, Acquisition of Permits and Approvals)
 - identification of non-CPM expertise (e.g. procurement, legal, MTA inter-agency) required for projects with special circumstances.

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2. Design Solution – Guided by the Project Plan for Preliminary Engineering, the Design Manager leads the Project Design Team in developing the Design Solution. The Project Design Team produces a Design Solution review package consisting of:
- Design Solution project report, including conceptual design options and calculations (see DG 105, Design Submissions)
 - Final Scope of Work (see PMP 301, Design Management)
 - conceptual design sketches/drawings, reflecting the Design Solution
 - outline specifications; for projects that include software, see PMG 321, CPM Software Acquisition Process
 - project phasing
 - estimate of TA Labor occasions
 - construction schedule (duration)
 - Preliminary Engineering estimate (including bid, EFA, and TA Labor costs).

3.5 Preliminary Engineering Review

The Design Manager holds a formal review meeting for all interested parties (i.e. approvers and/or their representatives) once the Design Solution review package is ready for approval. All substantive discussion should have occurred and all disputed issues settled during the regular working sessions of the Project Design Team.

The Design Solution review package is distributed in advance of the meeting. The review meeting affords approvers (or their representatives) a final opportunity to ask the Project Design Team questions before approving the Design Solution. The Design Solution must be approved by:

- the Design Manager
- the project’s prospective Construction Manager
- the Program Manager
- Chief Discipline Engineers/Architect and Chief Software Officer, as appropriate
- heads of all appropriate Sponsor/User/Maintainer department/divisions
- NYCTA's Office of System Safety.

3.6 Final Design

During Final Design, the Design Manager leads the Project Design Team in preparing the Detailed Design, which undergoes at least one review and approval cycle as described below. Final Design culminates with approval of the Detailed Design.

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The Detailed Design review package consists of:

- drawings and specifications required for advertisement, bid, award, and construction of a capital project; for projects that include software, see PMG 321, CPM Software Acquisition Process
- final project phasing, as defined in the drawings and specifications
- final estimate of TA Labor occasions
- final construction schedule (duration)
- final construction cost estimate (including bid, EFA, and TA Labor costs).

3.7 Final Design Review

The Design Manager holds a formal review meeting for all interested parties (i.e. approvers and/or their representatives) once the Detailed Design review package is ready for approval. All substantive discussion should have occurred and all disputed issues settled during the regular working sessions of the Project Design Team.

The Detailed Design review package is distributed in advance of the meeting. The review meeting affords approvers (or their representatives) a final opportunity to ask the Project Design Team questions before approving the Detailed Design. The Detailed Design must be approved by:

- the project's prospective Construction Manager
- the Program Manager
- Chief Discipline Engineers/Architect and Chief Software Officer, as appropriate
- the Code Compliance Manager
- heads of all appropriate Sponsor/User/Maintainer department/divisions
- NYCTA's Office of System Safety
- the Design Manager
- the Deputy Vice President for Engineering Services.

NOTES:

1. The Detailed Design is not considered complete until the contract-drawing cover sheet has been signed by the Deputy Vice President for Engineering Services.
2. The contract-specifications document must be approved by NYCTA's Law Department.

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3.8 Consultant Design

NYCTA may contract a project's Preliminary Engineering, Final Design, or its entire design to a design consultant. The Design Manager leads the Project Design Team in close and constant review of all consultant work, as well as administration of the consultant agreement (see PMG 305, Handling Consultant's and Contractor's Submissions and Requests). This review must assure that the consultant produces a quality design, including reliable cost estimates and schedules when required.

In the case of a consultant performing a project's Preliminary Engineering or its entire design, the Design Manager is responsible for providing a Preliminary Scope of Work thorough enough to form the basis of a meaningful specification for the consultant agreement. The Design Manager leads the Project Design Team's oversight of the design consultant in the development of the Preliminary Scope of Work into the Final Scope of Work as part of the Preliminary Engineering stage. This is in addition to leading the review and administration required for consultant design work in general.

4.0 REFERENCES

- 4.1 PMP 206, WAR Certificates
- 4.2 PMP 301, Design Management
- 4.3 PMP 316, Value Engineering
- 4.4 PMP 319, Constructibility Reviews
- 4.5 PMP 320, Project Master Plan
- 4.6 PMP 326, CPM Manpower Planning – Engineering Force Account (EFA)
- 4.7 PMP 327, TA Labor Estimate Preparation
- 4.8 PMG 108, Acquisition of Permits and Approvals
- 4.9 PMG 305, Handling Consultant's and Contractor's Submissions and Requests
- 4.10 PMG 321, CPM Software Acquisition Process

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4.11 Policy/Instruction 3.11, Development and Implementation of Design Standards

4.12 DG 102, Contract Specifications

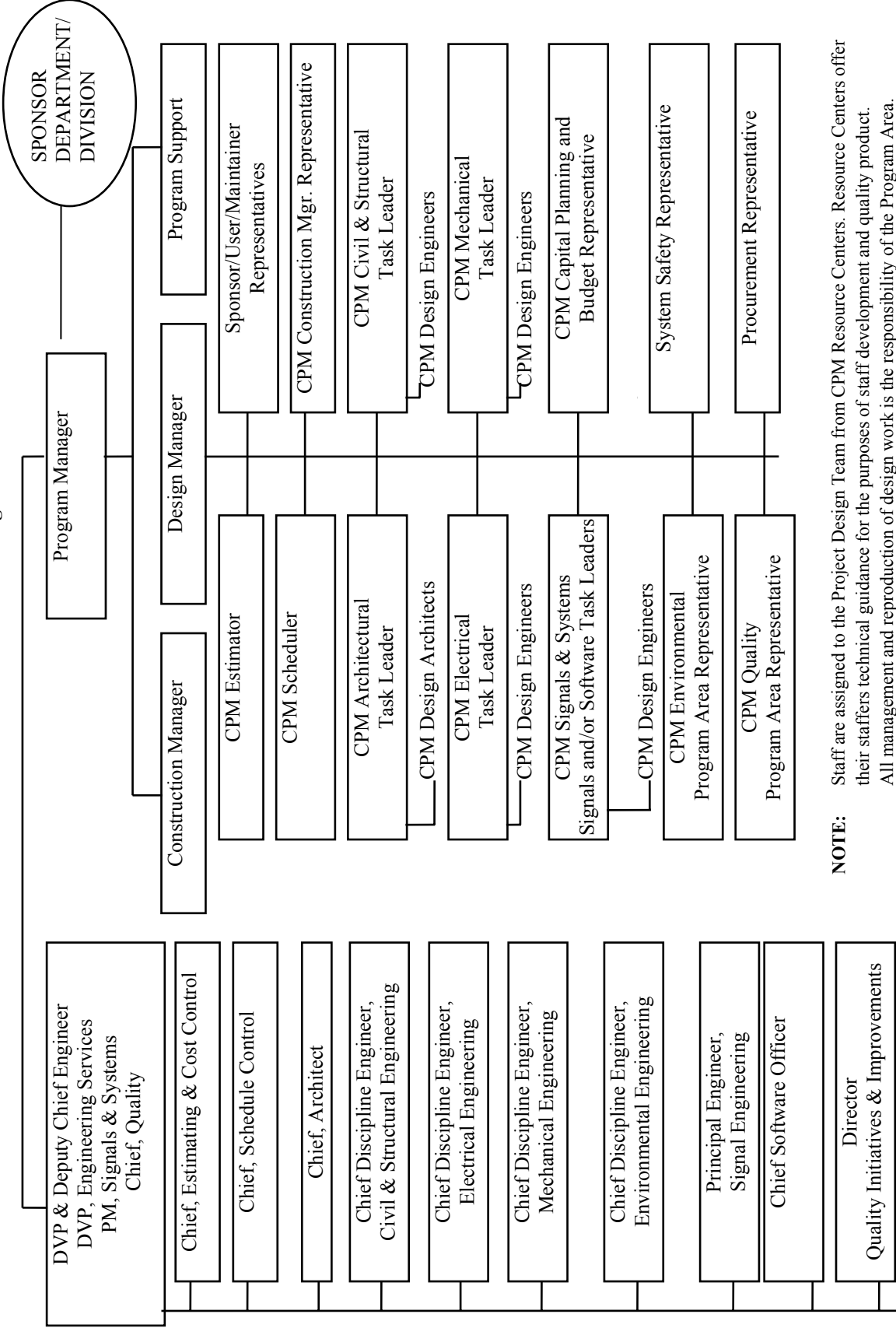
4.13 DG 105, Design Submissions

4.14 DG 107, Design Drawings

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**ORGANIZATION OF TYPICAL PROJECT DESIGN TEAM
Program Area**

CPM Resource Centers



NOTE: Staff are assigned to the Project Design Team from CPM Resource Centers. Resource Centers offer their staffers technical guidance for the purposes of staff development and quality product. All management and reproduction of design work is the responsibility of the Program Area.

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1.0 PURPOSE

To establish and document how the Department of Capital Program Management manages design of capital projects.

2.0 RESPONSIBILITIES

2.1 The Program Manager is responsible for:

1. All project-related work within the jurisdiction of his/her Program Area. Work begins with the pre-design Project Master Plan (see Exhibit 1) and concludes with contract closeout. It includes all design work, whether performed by in-house staff or by design consultants overseen by in-house staff. Program Managers are expected to lead their Program Areas in pursuing innovative contracting methods (e.g. bidding techniques, incentive payments), design ideas, and construction approaches (e.g., service shutdowns).
2. Planning the overall design effort in order to achieve goals for contract awards.
3. Negotiating with CPM resource centers (i.e., Engineering Services Division, Estimating & Cost Control, Quality Assurance, Schedule Control, Signals & Systems) for professional/technical staff and specialties such as geotechnical, hydrology, etc., required for the design effort. Each design staffer is matrixed from resource center to Program Area for a designated period of time. During the designated period, the Program Area may change any such staffer's mix of design project assignments. Assuring that CPM resource centers provide any special expertise to implement unusual or special requirements which may arise during the design effort.
4. Preparing a Project Management Plan in accordance with 49CFR Part 633 and submitting it to the Federal Transit Administration, when required to do so by the Senior Vice President & Chief Engineer.
5. Assigning a Design Manager to each project in design.

2.2 The Design Manager is responsible for:

1. Resource planning and management for all aspects of a project's design, including in-house and consultant design work. Design work occurs in two stages, Preliminary Engineering and Final Design, and involves selecting among alternative approaches to budget/contract issues as well as technical problems.

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- A. Assuring that funds are available for the project through the engineering force account (EFA). An MTA Willingness to Assume Risk (WAR) Certificate must be requested for Preliminary Engineering work. If the project is accepted for inclusion in the Capital Program (see below, 3.1), a WAR Certificate must be requested for Final Design work. (See PMP 206, WAR Certificates.)
 - B. Assembling the Project Design Team from staff matrixed by CPM resource centers to the Program Area. The Design Manager consults with resource-center management to ensure that appropriate professional/technical personnel and specialties, such as geotechnical, hydrology, etc., are assigned to the Project Design Team. Assures that specialty experts are assigned to the Project Design Team when unusual or special requirements arise during the design effort. A Project Design Team is assembled for each project in design, regardless of the mix of in-house and consultant design work.
 - C. Managing the schedule and workload of the Project Design Team to assure production of quality deliverables within the design timetable and EFA budget. The Design Manager effects implementation of coordination across disciplines through chiefs, principals and task leaders. As manager of the team, the Design Manager is responsible for compiling and maintaining the Project Design Team membership list (i.e., names, locations, telephone numbers).
2. Managing the Project Design Team in the case of in-house design. The Design Manager leads the Project Design Team to produce a quality Design Solution and Detailed Design, including reliable cost estimates and schedules. In the case of entirely in-house design, the Project Design Team performs all work necessary for Preliminary Engineering and Final Design. During the Preliminary Engineering stage, the Project Design Team first clarifies the project's functional requirements and then develops the design solution. For projects that include software, see PMG 321, CPM Software Acquisition Process. During the Final Design stage, the Project Design Team develops drawings and specifications for construction of the project.
 3. Giving project presentation to Project Constructibility Advisory Review Board at Preliminary Engineering and/or Final Design for projects if selected by the Deputy Vice President and Deputy Chief Engineer.
 4. Managing the Project Design Team in the case of a consultant performing only Final Design.

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- A. Leading the Project Design Team to produce a quality Design Solution to be used as the basis for selecting the design consultant.
 - B. Leading the Project Design Team's review of all work prepared by the design consultant. This review must assure that the consultant produces a quality Detailed Design, including reliable cost estimates and schedules.
 - C. Leading the Project Design Team's administration of the design consultant contract.
5. Managing the Project Design Team in the case of consultant design.
- A. Leading the Project Design Team's review of all work prepared by the design consultant. This review must assure that the consultant produces a quality Design Solution and Detailed Design, including reliable cost estimates and schedules.
 - B. Leading the Project Design Team's administration of the design consultant contract.
6. Assuring that CPM's clients (Sponsor/User/Maintainer department/divisions) are satisfied throughout the design process.
- 2.3 The CPM resource centers (i.e., Engineering Services Division and Signals & Systems), acting through the Chief Discipline Engineers/Architect and Principal Engineers/Architects and the Chief Software Officer, are responsible for:
- 1. Staffing the Program Area with qualified Design Engineers/Architects, and specialty experts, including Engineering/Architecture Task Leaders. These CPM resource centers assist the Design Manager in selecting appropriate technical/professional personnel and specialty experts for assignment to the Project Design Team.
 - 2. Establishing and updating technical standards and guidelines.
 - 3. Establishing and maintaining disciplinary centers of expertise. The Chief Discipline Engineers/Architect, their Principal Engineers/Architects, and the Chief Software Officer are available for mentoring and consultation on technical issues.
 - 4. Technical quality of design performed by staff assigned to a program area.
- 2.4 Each Engineering/Architecture Task Leader is responsible for:
- 1. Representing his/her resource-center chief on the Project Design Team.

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2. Supervising the work of his/her discipline's Design Engineers/Architects on the Project Design Team.
 3. Coordinating the work of his/her discipline's Design Engineers/Architects with other members of the Project Design Team.
 4. Promptly seeking guidance on unresolved technical issues and questions from his/her resource-center management (i.e. Chief Discipline Engineer/Architect or Principal Engineer/Architect; Chief Software Officer; etc.).
- 2.5 Under the direction of the Design Manager, the Project Design Team is responsible for:
1. Planning the design effort.
 2. Obtaining all external permits and approvals necessary, i.e. from utilities, private property owners, and Federal, State, and City agencies (see PMG 108, Acquisition of Permits and Approvals). Obtaining all NYCTA approvals required (see below, 3.1 and 3.2).
 3. Producing quality deliverables in each stage of design (Design Solution in Preliminary Engineering and Detailed Design in Final Design. Methods used for accomplishing these tasks include, but are not limited to:
 - conducting site investigations
 - holding working sessions
 - soliciting and responding to comments from all interested parties and documenting closure of comments.
 - conducting technical, value-engineering, and constructibility/phasing reviews
 - bringing issues of significant capital and/or operating cost impact to the attention of the Chief Budget Officer, Capital Program
 - bringing issues beyond the ability of the Project Design Team to resolve to the attention of appropriate management within CPM, NYCTA, or the MTA.

In addition to Design Engineers/Architects, the Project Design Team includes representatives of:

- Sponsor/User/Maintainer department/divisions
- the project's prospective Construction Manager (Resident Engineer)
- Environmental Engineering
- Estimating & Cost Control
- Quality Assurance
- Schedule Control
- Capital Planning and Budget
- NYCTA's Office of System Safety

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- NYCTA's Procurement Subdivision.

Attendance/participation of all project design team functional representatives is not mandatory during all steps of the design process. The Design Manager will assure that the appropriate representatives attend meetings and/or participate in the design processes that affect their respective departments/divisions.

Once the Project Design Team is assembled, the Design Manager compiles and maintains a membership list as part of the project file.

3.0 DESIGN PROCESS

3.1 Preliminary Engineering

Preliminary Engineering is the initial design stage of a capital project, culminating in establishment and approval of the Design Solution. It encompasses these activities: verification of the Sponsor/Users/Maintainers' functional requirements; definition of the project's program (i.e. determining spatial assignments necessary to meet functional and support requirements); conceptual designs; agreement on technical solutions to design problems; constructibility and value-engineering reviews; exploration of innovative contracting methods, design ideas, and construction approaches; preliminary engineering drawings; outline specifications; for projects that include software, System Requirements Specification; development of a preliminary engineering cost estimate and schedule.

The starting point for Preliminary Engineering is the Preliminary Scope of Work. This document is a non-technical functional description that: defines the project and its product for Sponsor/Users/Maintainers, the MTA, and the public; serves as the basis for design planning and verification; and yields an estimate useable for capital budgeting purposes.

The Preliminary Scope of Work is updated throughout Preliminary Engineering to reflect CPM-Sponsor/User/Maintainer understanding of project requirements. If the Scope of Work changes during Preliminary Engineering, the new Scope of Work must be approved by:

- the Design Manager
- the Program Manager
- the Chief Budget Officer, Capital Program
- heads of all appropriate Sponsor/User/Maintainer department/divisions.

The scope of work is considered final at the conclusion of Preliminary Engineering. The Final Scope of Work is one element of the Design Solution and is included in the Design Solution review package.

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The Design Solution review package consists of:

- Design Solution project report, including conceptual design options. (see DG 105, Design Submissions)
- Final Scope of Work
- preliminary engineering drawings, reflecting the Design Solution
- outline specifications; for projects that include software, System Requirements Specification.
- project phasing
- estimate of TA Labor occasions
- construction schedule (duration)
- preliminary engineering cost estimate (including bid, EFA, and TA Labor costs).

A quality Design Solution is consistent with:

- Sponsor/User/Maintainer requirements
- NYCTA design and maintenance guidelines
- cost and scheduling constraints
- NYCTA and industry technical standards
- Federal, State, City, and utility codes, regulations, and/or requirements.

The Design Solution must be approved by:

- the Design Manager
- the project's prospective Construction Manager
- the Program Manager
- Chief Discipline Engineers/Architect and Chief Software Officer, as appropriate
- heads of all appropriate Sponsor/User/Maintainer department/divisions
- NYCTA's Office of System Safety.

Only a project whose Design Solution review package has been approved can become a candidate for inclusion in the Capital Program. However, approval of the Design Solution does not guarantee the project's inclusion.

3.2 Final Design

Projects accepted for inclusion in the Capital Program enter the Final Design stage. During Final Design the Project Design Team prepares the Detailed Design, which undergoes at least one review and approval cycle as described below. Final Design culminates with approval of the Detailed Design.

The Detailed Design review package consists of:

- drawings and specifications required for advertisement, bid, award, and construction of a capital project; for projects that include software: System Requirements Specification; System and Software

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Requirements Documents; Independent Verification and Validation Plan; Configuration Management Plan; Risk Assessment; Support Plan; Development Acceptance Test Master Plan; User Acceptance Test Master Plan.

- final project phasing, as defined in the drawings and specifications
- final estimate of TA Labor occasions
- final construction schedule (duration)
- final construction cost estimate (including bid, EFA, and TA Labor costs).

A quality Detailed Design is consistent with the Design Solution. Changes to the Design Solution are permissible only if carefully evaluated and recommended by the Project Design Team and approved by the Program Manager.

The Detailed Design must be approved by:

- the project's prospective Construction Manager
- the Program Manager
- Chief Discipline Engineers/Architect and Chief Software Officer, as appropriate
- the Code Compliance Manager
- heads of all appropriate Sponsor/User/Maintainer department/divisions
- NYCTA's Office of System Safety
- the Design Manager
- the Deputy Vice President for Engineering Services.

NOTES:

1. The Detailed Design is not considered complete until the contract - drawing cover sheet has been signed by the Deputy Vice President for Engineering Services.
2. NYCTA's Law Department will review the contract-specifications document and provide presumptive approval to advertise the contract.

3.3 ADDENDA

Addenda to the contract may be required to clarify the questions from the bidders on the Detailed Design during the bid stage as determined by the Design Manager. Such change, if it is major in the opinion of the Design Manager, shall be approved by the Program Manager.

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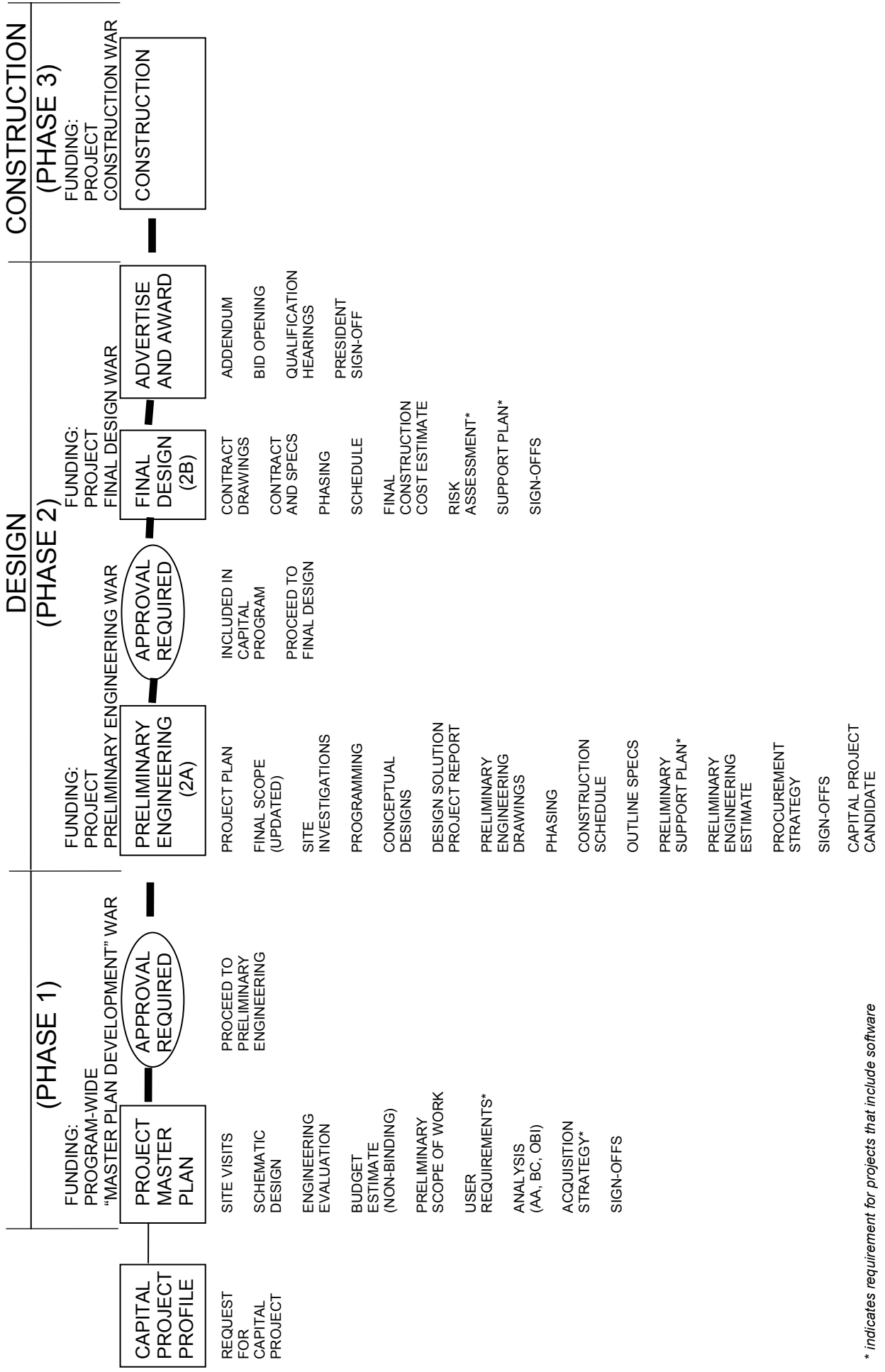
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4.0 REFERENCES

- 4.1 PMP 206, WAR Certificates
- 4.2 PMP 316, Value Engineering
- 4.3 PMP 319, Constructibility Reviews
- 4.4 PMP 320, Project Master Plan
- 4.5 PMP 326, CPM Manpower Planning – Engineering Force Account (EFA)
- 4.6 PMP 327, TA Labor Estimate Preparation
- 4.7 PMG 321, CPM Software Acquisition Process
- 4.8 PMG 108, Acquisition of Permits and Approvals
- 4.9 PMG 301, Design Management
- 4.10 PMG 305, Handling Consultant’s and Contractor’s Submissions and Requests
- 4.11 Policy/Instruction 3.11, Development and Implementation of Design Standards
- 4.12 DG 102, Contract Specifications
- 4.13 DG 105, Design Submissions
- 4.14 DG 107, Design Drawings
- 4.15 DG 103 Design Calculations
- 4.16 PMP 109 Consultant Contract Changes

Approved: _____ Signature on file
Mysore L. Nagaraja, P.E.
Senior Vice President and Chief Engineer
Capital Program Management

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* indicates requirement for projects that include software

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Element 4: *Document Control*

From the Chicago Transit Authority, Capital
Improvement Program, Quality Assurance Manual.

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SECTION 4 – QUALITY PROGRAM ELEMENTS

4.4 Document Control

Procedures shall be established and maintained for control of project documents and data. Document control measures shall ensure that all relevant documents are current and available to all users.

Control of project documents shall include the review of documents by authorized personnel, distribution and storage of those documents, elimination of obsolete documents, and control of changes to the documents. Whenever possible, changes to controlled documents and data shall be reviewed by the same authorized personnel who reviewed and approved the original documents.

Any superseded documents retained for the record shall be clearly identified as such.

SECTION 5 – CIP PROJECT LIFE-CYCLE PHASES

5.4 Construction Phase

The following subsections describe the quality assurance activities usually associated with the construction phase of capital project.

5.4.5 Document Control

Documentation relating to all project activity is prepared and maintained by the consultant and/or Construction Administration. Such documentation provides an accurate and current account of all project activities and information which contributes to the understanding of the project. Records are reviewed by appropriate personnel to assure that quality standards are maintained. Procedures for documentation and record maintenance include the following areas:

- Quality records
- Purchasing records
- Contract specifications and drawings
- Change orders, bulletins, proceed orders, requests for information
- Technical reports (e.g., soils, concrete, environmental reports)
- Photographs
- Daily logs
- Shop logs
- Field sketches and working drawings
- As-built drawings
- Schedules
- Material acceptance records

- Contract waiver reports
- Test, inspection, and acceptance records
- Noncompliance records
- Deviation and nonconformance reports
- Warranties and guarantees

These and other records relating to contractual, cost, technical, and quality assurance aspects of a project are filed and archived according to procedures which provide accessibility, long-term availability, and review for compliance with contractual obligations.

Element 5: *Purchasing*

From the Chicago Transit Authority, Capital
Improvement Program, Quality Assurance Manual.

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SECTION 4 - QUALITY PROGRAM ELEMENTS

4.5 Purchasing

Procedures shall be established and maintained to ensure that purchased services or products conform to specified requirements. Purchasing requirements shall apply to all contractors and suppliers, including consultants, construction contractors, and manufacturers. The quality requirements placed on the supplier or contractor shall depend upon the nature of the service or product.

The contract or purchasing requirements shall clearly specify the expectations of the purchaser, including relevant standards; drawings; specifications; process requirements; inspection instructions; and approval criteria for materials, processes, and product. The purchasing documents shall be reviewed and approved by a designated authority for adequacy of specified requirements prior to release.

SECTION 5 - CIP PROJECT LIFE-CYCLE PHASES

5.3 Procurement Phase

The following subsections describe the quality assurance activities usually associated with the procurement phase of a capital project.

5.3.1 Procurement Responsibility

The Purchasing Department has exclusive responsibility for the procurement activities of the capital program. These activities include, but are not limited to, the following:

- Consultant services for design, construction management, testing, and survey
- Contractor services for construction of new facilities and equipment or maintenance/renewal of existing ones
- Procurement of vehicles and equipment, including buses, rapid transit cars, associated capital maintenance items, non-revenue vehicles, office automation equipment, communications equipment, and miscellaneous equipment
- Real estate acquisition
- Material
- Legal/professional services

5.3.2 **Procedural Requirements**

The procurement activities of the Authority are subject to, but not limited to, the following documents established by Materials and Information Management:

- **Regulations Governing Purchasing and Sales Transactions Manual** – This manual sets forth the standards used for processing third-party contracts. The manual describes the activities required, whether sealed bid or negotiated contracts, and designated requirements based on the dollar value of the contract and funding sources.
- **Contract Procedures Manual** – This manual applies to capital contracts having a value of \$10,000 or more. This manual covers engineering and construction contracts; the purchase of vehicles, rapid transit cars, buses, and associated capital maintenance items; office automation equipment; communications equipment; and various other types of equipment.
- **Administrative Procedure (AP) 145** – This procedure applies to the procurement of architectural and engineering services. This qualifications-based process is initiated by a request for Letters of Interest and Qualification (LIQ). Responses to the LIQ are received from architectural and engineering firms interested in providing professional services for the project identified in the solicitation.
- **Administrative Procedure (AP) 146** – This procedure applies to the procurement of professional services other than from architectural or engineering firms. The Request for Proposal (RFP) process is detailed in this procedure, including advertisement requirements and RFP response procedures.
- **Administrative Procedure (AP) 202** – This procedure is followed when the acquisition of real estate is required for the operation/expansion of Authority facilities.

5.3.3 **Procurement Quality Control**

The Quality Assurance Department in Materials and Information Management is divided into the following areas of responsibility:

- **Quality Inspection** – Inspects purchased parts and materials to verify conformance to specified criteria. Tracks and evaluates vendor quality history and works with other departmental areas to improve vendor quality performance. Quality Inspection is also responsible for performing value analysis studies of materials and parts furnished from sole-source vendors and for interfacing with vendors, Purchasing, and using departments on matters relating to the quality of purchased parts and materials.
- **Document Management** – Ensures that contract documents are properly prepared and tracked during each phase of contract processing. Additionally, this

group maintains records of contract information including DBE requirements, insurance requirements, Buy America requirements, and funding agency correspondence. The group also maintains contract files, informational sources, micrographics, and the records center.

- **Vendor Performance** – Primarily responsible for follow-up work of various types of vendor liaison activity, such as keeping control over all unfilled orders and releases in order to ensure the delivery of adequate supplies and services. Additionally, this group follows through for performance and tracks expediting and delivery compliance, vendor applications, and DBE data.
- **Specification Engineering** – Responsible for establishing a level of quality for materials, supplies, equipment, and/or services required by the Authority. The exception to this is items designed and specified by the Bus Engineering and Technical Services Department and Engineering.
- **Contract Administration** – Responsible for post-award contract administration. Duties include auditing of invoices for both capital and operating purchase requisitions and negotiating adjustments with vendors as necessary; administering and processing contract change orders and evaluating change order request for compliance to regulatory requirements; directing the administration of contract close-out; and notifying appropriate personnel regarding status of remaining funds.

The Bus Engineering and Technical Services Department performs inspection and test services for new and rebuilt buses, non-revenue vehicles, shop equipment, replacement parts, and maintenance supplies. Additionally, this unit develops standard procedures to document work practices, implements these standards, and seeks alternate sources for materials to reduce costs.

In relation to new bus purchases, quality inspections begin with the sub-supplier component products. The component designs and quality of manufacture are inspected and evaluated. Depending on the size of the order being purchased, a prototype, pilot vehicle, or similar vehicle is inspected. A systematic and detailed inspection of the vehicle is conducted using established procedures. During production, on-line inspections are performed. It is to be noted, however, that the manufacturer is primarily responsible for vehicle quality control. Inspections by Authority staff are performed to oversee and monitor the manufacturer's quality control program, workmanship, and specification compliance. After delivery, in-house inspections are conducted to ensure quality and compliance prior to vehicle acceptance.

The Rail Engineering and Technical Services Department performs quality inspections of new and rehabilitated rail cars, including subsystems and components, to ensure compliance with specifications and other criteria. These inspections monitor and evaluate the overall quality of repair, servicing, and maintenance work performed by outside contractors, Rail Vehicle Heavy Maintenance, and Terminal Maintenance personnel. These inspections independently assess, evaluate, and report the level of compliance with operational requirements of the maintenance program, manuals, services bulletins, practices, and procedures.

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Element 6: *Product Identification and Traceability*

From the Washington Metropolitan Transit Authority,
5000 Series Vehicle Procurement Program, Quality Assurance Plan.

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5000 SERIES PROCUREMENT PROGRAM QUALITY ASSURANCE PLAN

TITLE: PRODUCT IDENTIFICATION AND TRACEABILITY		
ISSUE DATE: 01/10/00	PREPARED BY: R. Stoetzer	APPROVED BY: R. Stoetzer

6.0 PRODUCT IDENTIFICATION AND TRACEABILITY

6.1 Purpose

This section establishes the 5000 Series Procurement Program approach to fulfilling the requirements set forth in Element 6, "Product Identification and Traceability", of the Federal Transit Administrations Guidelines for Quality Assurance and Quality Control.

The purpose of product identification and traceability is to ensure the control of materials, parts, components, equipment, and products, and the identification and traceability of these materials to prevent the use of incorrect or defective items. They must also ensure that only correct and acceptable items are used or installed.

6.2 Scope

These requirements apply to all materials, parts, components, equipment, and products, including partially fabricated or assembled components, produced for incorporation into the project.

6.3 Policy

It is the policy of the Authority that all procurement specifications and associated items will, as applicable, contain requirements for control of materials, i.e., product identification and traceability. Each Contractor and supplier will be required to establish quality control procedures to assure proper control of the identification and traceability process.

6.4 Responsibilities

The Contractor (the car builder) and all subcontractors and suppliers [through the Contractor], are responsible for establishing and maintaining such controls as necessary to assure that improper materials are not built into or installed in the vehicles.

The Authority, with the assistance of the EC, will conduct such audits and oversight of the Contractor, subcontractors, and suppliers as necessary to maintain a reasonable assurance that the Contractor/subcontractor/supplier processes are maintained and effectively carried out on a continuing basis.

5000 SERIES PROCUREMENT PROGRAM QUALITY ASSURANCE PLAN

TITLE: PRODUCT IDENTIFICATION AND TRACEABILITY

ISSUE DATE: 01/10/00

PREPARED BY: R. Stoetzer

APPROVED BY: R. Stoetzer

The Authority's PM will ensure that requirements for control of products and identification and traceability are contained in the contract documents and procurement specifications, and for monitoring Contractor's, subcontractor's, or supplier's procedures.

The Authority and its EC will perform periodic audits of material control, product identification, and traceability records from the Contractor, subcontractor, and supplier.

6.5 Responsibilities

The requirements for maintaining effective material identification and traceability controls have been included in the prime contract and require the Contractor to impose similar requirements on its subcontractors and suppliers. Authority review of subcontract documents verified the pass-through of the requirements to the subcontractors. The Authority will conduct periodic audits at the Contractor's facility and at major subcontractor facilities to ensure that:

- 6.5.1 Purchased parts are identified, by positive markings and/or certifications receipt inspections with segregated storage containing identification data for controlled issue, and checked when received;
- 6.5.2 Procedures exist and are in effect to assure that proper materials are drawn and installed in accordance with the approved design, including oversight by the manufacturer's Quality Assurance staff;
- 6.5.3 Parts/materials that are received without satisfactory identification, that have lost that identification in process, or that are otherwise untraceable are segregated and not used unless re-identified/re-certified under the aegis of the QA staff; and
- 6.5.4 Traceability of manufactured items is maintained through unique serialization to the minimum requirements of the contract specification for ultimate entry into the Car History Books.

The EC will establish audit criteria for reviewing the effectivity of material identification and traceability as part of the overall Quality Assurance audit program.

Element 7: *Process Control*

From the New York City Transit Authority, Department of Capital
Program Management, Quality Management System Manual.

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Section 4

PROCESS CONTROL

4.1 QUALITY OBJECTIVE

Construction processes shall be performed in a controlled manner and logical sequence by qualified personnel using established procedures to meet industry and contractual requirements.

4.2 PROCESS CONTROL

This section establishes requirements and control of the construction processes such as, but not limited to, paving, concrete placement, electrical and mechanical system installation, trade work, structural steel erection, structural rehabilitation, and special processes, like welding, bolting, galvanizing, non-destructive and destructive testing.

4.3 MANAGEMENT OF CONSTRUCTION PROCESS

4.3.1 Quality of the constructed facility is the combined responsibility of the construction Contractor and NYCT. The mutual objective is an end product conforming to contract quality requirements and fit for NYCT use. The contract documents include requirements for a Contractor's Quality Program. The Program Manager implements control activities which assure that the contract requirements are met.

4.3.2 Contractor Responsibility

4.3.2.1 To assure compliance with contract provisions, plans and specifications, contractors are responsible for all of the activities required to manage, control and document their work. The contractor must assign a properly trained and qualified construction management team to the project. The team shall have sufficient management resources and ability and the necessary support staff to assure NYCT that this project will be properly coordinated and managed and will be completed on schedule.

The contractor team member requirements vary from contract to contract and are established when the specification is being developed. At a minimum, each project will require a full-time or part-time Project Manager, a designated full-time Safety Engineer and /or Safety Supervisor, and a Quality Manager or full-time Quality Engineer, depending on the dollar value of the contract and the type of work being performed.

4.3.2.2 Contractor's Quality Program

The Contractor is responsible for establishing, implementing and maintaining a Quality Program to manage, control, document and assure that the work complies with the requirements of the contract documents. The program shall be in accordance with Section 1J of the Contract Specifications.

The Quality Program shall consist of plans, procedures, work instructions and the organization necessary to perform inspections and assure adequate control of the quality of materials, equipment, workmanship, fabrication, installation and operations covering both onsite and offsite work by the contractor, including its subcontractors, suppliers, technical laboratories and consultants.

4.3.3 CPM Program Management

The department has established a program management organization which provides for qualified, trained individuals to assure that all construction materials, methods, workmanship and end products meet the technical and quality requirements of the contract.

Departmental procedures and guidelines provide for and prescribe source and field inspection activities, cost and schedule control, interface with user (accepting) departments, document preparation, submittal and review of "as built" drawings and manuals, processing of contract changes, document filing and retention, evaluation of contractor performance and contract closeout and acceptance. Collectively, these procedures and guidelines document that the quality of work is consistent with project objectives and use.

Element 8: *Inspection and Testing*

From the Washington Metropolitan Transit Authority,
5000 Series Vehicle Procurement Program, Quality Assurance Plan.

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5000 SERIES PROCUREMENT PROGRAM QUALITY ASSURANCE PLAN

TITLE: INSPECTION AND TESTING

ISSUE DATE: 01/10/00

PREPARED BY: R. Stoetzer

APPROVED BY: R. Stoetzer

8.0 INSPECTION AND TESTING

8.1 Purpose

This section establishes the 5000 Series Procurement Program approach to fulfilling the requirements set forth in Element 8, "Inspection and Testing", of the Federal Transit Administration's Guidelines for Quality Assurance and Quality Control. It addresses the planning and controlling of inspection and test activities to assure contractor compliance with the established design criteria and contract requirements.

8.2 Scope

The inspection and testing requirements outlined herein apply to the design, procurement, manufacture, installation, testing, and acceptance of the 5000 Series rail cars, the systems, equipment, and materials installed thereon, as well as to the spare parts, technical documentation, and training procured as part of the base contract.

8.3 Policy

Activities affecting quality are to be inspected and documented by experienced personnel who are independent of those performing the work. Inspections and tests will be performed in accordance with approved documents to determine that items meet the established requirements.

Requirements for Contractor and subcontractor inspection and testing programs, identification of responsibilities, and qualification for inspection and testing personnel are set forth in the Contract and Specifications.

8.4 Responsibilities

In accordance with contract documents, the Contractor will submit a written Quality Plan, containing plans for inspection and testing which is under its control. Inspection and testing plans will include specific descriptions, procedures, frequency, criteria for acceptance or rejection, and requirements for records and documentation.

The Authority will provide oversight for this Element of the Quality Assurance Plan. Quality Control Plans and procedures are reviewed by Program Office representatives, including the EC, for compliance with the contract requirements. In addition, the EC will oversee the execution of the Contractor's quality assurance functions by audit, on-site observation, and independent inspections and witnessing of tests performed by the Contractor.

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ISSUE DATE: 01/10/00

PREPARED BY: R. Stoetzer

APPROVED BY: R. Stoetzer

The EC will provide on-site quality control inspection services and personnel at the Contractor's facilities to ensure compliance with the contract specification for tests and inspection and the approved QA program plan. The EC will perform surveillance and periodic audits of inspection and test records of the Contractor and (at least) the major subcontractors.

8.5 Audit of Inspection Practices

The EC will conduct initial audits and such additional periodic audits as indicated necessary based on observed results of the Contractor's general inspection procedures in accordance with the following guidelines:

8.5.1 Incoming/Receipt Inspections:

All purchased items received should be subjected to incoming inspections to ensure that only approved materials, equipment and supplies are delivered to the project site, and that such Certificates of Compliance attesting to the quality of material, equipment, and supplies as may be required by contract, purchase order, or standard practice are present. On-site inspector representatives maintain surveillance over the Contractors receipt inspection performance.

8.5.2 Source Inspections:

The Contractor's Quality Assurance Departments determine when source inspection at supplier/subcontractor plant(s) is required. Such determinations are normally based on complexity of the subcontracted items, economic benefit, assessment of the subcontractor's QA program, and results of receipt inspections. This activity is subjected to periodic audit by the EC.

8.5.3 First Article Inspections (FAI):

First Article Inspections are conducted on the first production unit of all major components/systems, prior to its delivery to ensure compliance with contract requirements, including engineering tests and physical examinations. The FAIs provide opportunities for the inspection team to observe and assess the vendor's manufacturing and quality control processes. Program office staff, along with the EC, routinely attends FAIs of all major/complex equipment.

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8.5.4 In-Process Inspections:

In-Process Inspection is essential to all manufacturing and assembly operations and is the prime responsibility of the Contractor. Authority staff and/or the EC conduct routine inspections at the Contractor's plants for the purpose of observing the Contractor's inspection performance and establishing the acceptability of products to be delivered for acceptance.

8.5.5 Final Acceptance Inspection:

When the Contractor(s) believes that a given feature, segment, or end product is completed and ready for acceptance, they notify the Authority that work is complete and ready for acceptance. The Authority and/or the consultant's inspection teams make a final inspection to verify that all required work has been completed and that the presented work/product is compliant with the specification. Any items noted to be deficient will be identified on a punchlist and submitted to the Contractor for rework or completion. When the Contractor believes the punchlist items have been resolved the "Acceptance Inspection" process will be repeated.

8.6 Testing Procedures

The general testing procedures to be followed shall include:

8.6.1 Material testing shall be conducted to verify that materials proposed for use are in compliance with the contract requirements. It is the responsibility of the Contractor to perform or have performed all required tests (by approved testing laboratories if required) and to provide certified test results as required by contract.

8.6.2 In-place control and validation testing of materials shall be performed if necessary to verify that such materials conform to those previously approved through testing as described above and that they have been installed properly in accordance with the contract documents.

8.6.3 Functional testing of each system will be conducted to demonstrate satisfactory operation prior to acceptance.

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8.6.4 Qualification tests are conducted as part of design development on individual systems and/or components of major complexity and operational significance. These tests are generally conducted at the Contractor's plant or at subcontractor laboratory facilities. Vehicle qualification tests are conducted on the pilot married pair of cars upon delivery of the Authority. The Authority and the EC witness all major qualification tests. The minimum test requirements are identified in the 5000 Series Specification.

8.6.5 Acceptance tests are conducted at subcontractor factories, primarily for the benefit of the Contractor to prevent the installation of defective equipment or materials. Vehicle and vehicle system acceptance tests are generally conducted on a married-pair basis upon delivery to the Authority. The Contractor is responsible for conducting the tests and demonstrating that the cars are in acceptable condition. The Authority, with the assistance of the Engineering Consultant, observes the tests demonstrated, reviews the results, and approves their acceptability as applicable.

8.7 Material Handling & Storage

Incoming materials supplied by subcontractors are inspected on receipt by the Contractor's Quality Assurance staff for damage, completeness, and compliance. Supporting documentation is verified to ensure material is handled and stored in accordance with the Contractor's/supplier's normal storage and handling procedures including the secure segregation of non-conforming items. Storage conditions of materials and equipment pending use or installation are periodically verified adequate to prevent unacceptable deterioration from improper exposure. Authority on-site inspectors observe, audit, and spot check the Contractor's performance in this function.

Element 9: *Inspection, Measuring, and Test Equipment*

From the Washington Metropolitan Transit Authority,
5000 Series Vehicle Procurement Program, Quality Assurance Plan.

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5000 SERIES PROCUREMENT PROGRAM QUALITY ASSURANCE PLAN

TITLE: INSPECTION, MEASURING AND TEST EQUIPMENT		
ISSUE DATE: 01/10/00	PREPARED BY: R. Stoetzer	APPROVED BY: R. Stoetzer

9.0 INSPECTION, MEASURING AND TEST EQUIPMENT

9.1 Purpose

This section establishes the 5000 Series Procurement Program approach to fulfilling the requirements set forth in Element 9, "Inspection, Measuring and Test Equipment", of the Federal Transit Administration's Guidelines for Quality Assurance and Quality Control. It describes the responsibilities and procedures for controlling quality of equipment used in inspection, sampling, measuring and testing.

9.2 Scope

These requirements apply to all inspection, sampling, measuring, and testing equipment used from initial qualification through final acceptance testing to determining the quality of materials, parts, components, and equipment which are fabricated into and/or installed on the 5000 Series rail cars.

9.3 Policy

All equipment used in quality control work will be identified, calibrated, and maintained in proper working order. Provisions will be made for periodic re-calibration. Such equipment must meet the standards of accuracy for the measurements and tests required.

9.4 Responsibilities

The Program Office, with the support of the EC, will provide oversight for this Element of the Quality Assurance Plan. The EC's inspection staff, on site at the car builder's factory, at the car assembly plant, and at the Authority's facilities, will periodically check to ensure measuring and test equipment are properly calibrated. It is the responsibility of the Contractor's and its subcontractor's Quality Assurance Personnel to verify that only calibrated or verified accurate measuring and test equipment are utilized on this project. Through on-site observation and periodic formal audits, the EC ensures that the Contractor carries out his responsibilities on a continuing basis.

The Authority, in company with the EC, performs surveillance and periodic audits of the Contractor's and its subcontractor's records to verify that all measuring of test equipment are being controlled in accordance with the written procedures.

5000 SERIES PROCUREMENT PROGRAM QUALITY ASSURANCE PLAN

TITLE: INSPECTION, MEASURING AND TEST EQUIPMENT		
ISSUE DATE: 01/10/00	PREPARED BY: R. Stoetzer	APPROVED BY: R. Stoetzer

9.5 Procedures

The general procedures to be followed for controlling the quality of measuring and test equipment include:

- 9.5.1 All test procedures must include requirements for using currently calibrated test and measuring devices. Contractors and suppliers must provide or be prepared to provide calibration documents at the time of each test witnessed by the Authority and/or the EC's staff.
- 9.5.2 Instruments must be verified with calibration standards traceable to the National Institute of Standards and Technology (NIST) or an approved equivalent.
- 9.5.3 Each instrument is identified by a serial number and a calibration sticker to indicate the date of the last calibration and the date due calibration.
- 9.5.4 The calibration and verification history for each instrument is kept on file by the Contractor's or supplier's QA Department and is available upon request.
- 9.5.5 Instruments found to be out of calibration are identified as defective and segregated.
- 9.5.6 If an instrument is found to be out of calibration during the inspection process, all characteristics measured with such instrument shall be re-verified.
- 9.5.7 The environmental conditions as well as the handling, preservation and storage of instrumentation must be controlled when calibrations, inspections, measurements, and tests are being carried out.
- 9.5.8 The calibration program includes periodic re-calibration of test instruments using a documented recall process and calibration intervals.
- 9.5.9 All WMATA and EC staff witnessing tests routinely observe calibration stickers and records at the time of testing to ensure test instruments overdue calibration are not used for inspections.

Element 10: *Inspection and Test Status*

From the Washington Metropolitan Transit Authority,
5000 Series Vehicle Procurement Program, Quality Assurance Plan.

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TITLE: INSPECTION AND TEST STATUS

ISSUE DATE: 01/10/00

PREPARED BY: R. Stoetzer

APPROVED BY: R. Stoetzer

10.0 INSPECTION AND TEST STATUS

10.1 Purpose

This section establishes the 5000 Series Procurement Program approach to fulfilling the requirements set forth in Element 10, "Inspection and Test Status", of the Federal Transit Administration's Guidelines for Quality Assurance and Quality Control.

10.2 Scope

These requirements apply to all inspections and tests of materials, parts, components, and equipment that are fabricated into and/or installed on the 5000 Series rail cars.

10.3 Policy

Appropriate control procedures are to be established and adhered to for identifying the full scope of necessary testing and inspection and adequately monitoring the inspection and test status of work during production and installation to ensure that only work, materials, and equipment which passed the required inspections and tests are incorporated into the end product.

10.4 Responsibilities

The Program Office, with the support of the EC, provides oversight for this quality requirement. This responsibility includes ensuring that the Contractor and its subcontractors establish appropriate quality controls and quality assurance procedures for inspection and test of the work to assure that all materials and equipment are subjected to the required and proper quality checks prior to acceptance by the Authority.

10.5 Procedures

10.5.1 In accordance with the 5000 Series procurement contract specification, the Contractor's procedures for Inspection and Testing Status are submitted to the Authority for review and approval.

Additionally, the Contractor is required to submit test and inspection program plans covering design development/system and equipment qualification tests, factory acceptance tests, and

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<p>vehicle qualification and acceptance test programs. The minimum required submittals are established in the Contract Specification and listed in the contract data requirements list (CDRL). The Authority exercises approval rights over these plans and procedures.</p>	
10.5.2	<p>Inspection and Test Status for Manufactured Products</p> <p>10.5.2.1 The Contractor's, and its subcontractor's, Quality Assurance Department is primarily responsible for determining the inspection status of an item. The EC's QC Personnel, acting as on-site representatives of the Authority, verify the inspection status.</p> <p>10.5.2.2 The inspection status is signed by tagging the items and/or by the inspection and/or test reports.</p> <p>10.5.2.3 Status indicators must be used to identify the company and the inspector.</p> <p>10.5.2.4 Acceptance of finished parts is signified by an acceptance tag.</p> <p>10.5.2.5 The Authority, with the assistance of the EC, observes all design development and qualification tests, exercises audit control over critical factory acceptance tests, and maintains accurate historic records of all vehicle qualification and performance acceptance tests and inspections.</p>

Element 11: *Nonconformance*

From the Chicago Transit Authority, Capital Improvement Program,
Quality Assurance Manual.

See Element 12, Corrective Action, for a copy of CTA Project Management
Procedure, PMP-6009, Nonconformance Reports and Corrective Action.

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SECTION 4 – QUALITY PROGRAM ELEMENTS

4.11 Nonconformance

Procedures shall be established and maintained to control nonconforming work to preclude its inadvertent use or installation. This control shall provide for identification, documentation, evaluation, segregation (where practical), disposition of nonconforming product, and notification to the functions involved.

The review responsibility and authority for the disposition of nonconforming work shall be defined in documented procedures. Disposition of nonconforming work shall be documented.

Repaired and/or reworked product shall be reinspected in accordance with documented procedures. A determination to accept nonconforming work as is or with repair shall have the concurrence of the engineer of record.

SECTION 5 – CIP PROJECT LIFE-CYCLE PHASES

5.4 Construction Phase

The following subsections describe the quality assurance activities usually associated with the construction phase of the capital project.

5.4.7 Nonconformance

Workmanship, processes, materials, procedures, or an end product that does not meet the quality requirements is immediately noted and identified for corrective action. The contractor is notified of nonconforming contract obligations and after receipt of such notice, must immediately take corrective action in accordance with the Authority's procedures and the contractor's quality plan. If the noncompliance is significant and/or it is not resolved in a timely manner, further action will be taken, up to and including the issuance of a stop work order.

Procedures provide remedies for deviations from contract requirements as long as functional, cost, and quality standards are not compromised. Items which require repair or replacement are reinspected and must meet original specifications unless otherwise approved in accordance with Authority procedures.

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Element 12: *Corrective Action*

From the Chicago Transit Authority, Capital Improvement Program, Quality Assurance Manual; including Project Management Procedure, PMP-6009, Nonconformance Reports and Corrective Action.

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SECTION 4 - QUALITY PROGRAM ELEMENTS

4.12 Corrective Action

Corrective action procedures shall be established and maintained. These shall include procedures for investigating the cause of nonconforming work and taking corrective actions to prevent recurrence, analyzing processes to detect and eliminate potential causes of nonconforming work, initiating preventive actions to deal with problems to a level corresponding to the risks encountered, ensuring that corrective actions are implemented and evaluating their effectiveness, and implementing and recording changes in procedures resulting from corrective action.

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The above-named procedure is hereby approved:

 Manager, Quality Assurance Date

 Vice President, Engineering Date

 Vice President, Maintenance Date

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NONCONFORMANCE REPORTS AND CORRECTIVE ACTION

1.0 PURPOSE

- 1.1 The purpose of this procedure is to describe the methods for reporting and controlling nonconforming items from the point of identification through corrective action and verification.

2.0 SCOPE

- 2.1 This procedure applies to activities performed under CTA's Capital Improvement Program (CIP), including force account capital construction.

3.0 REFERENCES

- 3.1 Chicago Transit Authority, Capital Improvement Program Quality Assurance Manual
- 3.2 FTA-MA-06-0189-92-1, dated March 1992, United States Department of Transportation, Federal Transit Administration, Quality Assurance and Quality Control Guidelines
- 3.3 PMP-6002, Quality Records - Quality Assurance Department
- 3.4 PMP-6004, Quality Assurance Surveillance

4.0 DEFINITIONS

- 4.1 Disposition - A statement describing the manner in which a deficiency or nonconformance is to be resolved. Nonconforming items or activities shall be dispositioned in one of the following ways:

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Accept-As-Is - Allows the use of an item that does not meet all requirements when it is determined by engineering evaluation that the item will satisfy its intended use. It is the same as "Use-As-Is."

Reject - The item is unsuitable for its intended purpose and economically or physically incapable of being reworked or repaired.

Repair - Work required which will result in making an item acceptable for its intended use, as determined by an engineering evaluation, even though it is not restored to a condition which meets all specification requirements.

Rework - The deficiency can be brought into conformance with all specification requirements through remachining, reassembling, reprocessing, reinstallation, or completion of the required operations.

- 4.2** Engineer of Record - For the purpose of this procedure, the engineer responsible for performing an engineering evaluation of the proposed disposition for a nonconforming condition. This individual may be a member of the consultant's organization, the CTA Project Manager, or an engineer assigned by the Project Manager.
- 4.3** Nonconformance - The non-fulfillment of specified requirements which affects form, fit, or function and which renders the quality of an item unacceptable or indeterminate in regard to meeting all relevant project requirements.
- 4.4** Oversight - Comprehensive monitoring and examining for effectiveness any activities or processes affecting quality.
- 4.5** Stop Work Order (SWO) - Notification that a nonconforming item or condition is of such significance that affected activities may not continue until corrective action is accomplished and resumption of work is approved in writing. The scope of the SWO shall be clearly defined. When an SWO is issued, all affected work shall be halted until the SWO is closed. Work may continue on activities not affected by the SWO.

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4.6 Surveillance - Act of monitoring or observing to verify whether an item or activity conforms to specified requirements.

5.0 PROCEDURE

5.1 General

- 5.1.1 Nonconformances identified during the performance of surveillances by the Quality Assurance Department or other quality oversight activities shall be documented on a Nonconformance Report (NCR) (see attached Form 6009.01 and Form 6009.03). Instructions for completing the form are given in Exhibit A.
- 5.1.2 The individual responsible for CTA construction oversight activities on a project shall be responsible for implementing control of nonconforming items through the use of NCRs in accordance with this procedure. That individual may be either a CTA employee or a consultant.
- 5.1.3 Nonconforming items shall be segregated or otherwise labeled and controlled to prevent their inadvertent use or installation.
- 5.1.4 Each NCR shall be identified by a unique, sequential number in the format YY-NNN where YY designates the year of issue and NNN is a sequential number. The sequential number shall increment from year to year, identifying the total number of NCRs generated. It shall not return to "001" at the start of each new calendar year.
- 5.1.5 NCRs shall be logged in a Nonconformance Report Log (see attached Form 6009.02) or a similar computerized log maintained by the Manager, Quality Assurance. The originator of an NCR shall contact the Manager, Quality Assurance, for the next sequential NCR number.
- 5.1.6 The Manager, Quality Assurance, shall be included in the distribution of all NCRs.

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- 5.1.7 In case of a dispute over the validity of an NCR, or over the effectiveness of corrective action, an engineering evaluation shall be performed and documented.
- 5.1.8 An engineering evaluation shall be performed and documented for any disposition of "Accept-As-Is" or "Repair."
- 5.1.9 Disposition and corrective action shall not be undertaken without authorization by CTA. Proper authorization is documented by signatures in blocks 14, 15, and 16 of the Nonconformance Report form.

5.2 Generation of NCRs

- 5.2.1 The originator of the NCR shall complete the "Nonconformance" section of the NCR form, blocks 1 through 7.
- 5.2.2 The originator of the NCR shall make copies of the NCR form and distribute the copies and the original form as follows:
 - 1) Original NCR to the organization or individual responsible for resolving the nonconforming condition, identified in block 2 of the NCR form. (Engineering, Construction, Maintenance, or other organizations or activities affected by the nonconforming condition shall also be notified.)
 - 2) One copy to the Manager, Quality Assurance.
 - 3) One copy for the originator's file.
- 5.2.3 Within 10 working days, the organization or individual responsible for resolving the nonconforming condition shall complete the "Disposition" section of the NCR form, blocks 8 through 13.

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- 5.2.4 The organization or individual responsible for resolving the nonconformance shall return the NCR form to the CTA Manager, Quality Assurance.
- 5.2.5 The Manager, Quality Assurance, shall determine the responsible CTA Engineering/Construction/Maintenance Manager and forward the original NCR form to that individual for review and concurrence.
- 5.2.6 The responsible manager shall review the proposed corrective actions and actions to prevent recurrence.
 - 5.2.6.1 If the proposed actions are acceptable, the responsible manager shall sign and date block 14 of the NCR form and proceed to step 5.2.7.
 - 5.2.6.2 If the proposed actions are not acceptable, the responsible manager shall return the unsigned NCR form to the responsible organization with a separate written explanation, with a copy to the Manager, Quality Assurance. (Return to step 5.2.3.)
- 5.2.7 The responsible manager shall transmit the signed NCR form to the engineer of record, with a copy to the Manager, Quality Assurance.
- 5.2.8 The engineer of record shall review the NCR and perform and document an engineering evaluation if required.
 - 5.2.8.1 An engineering evaluation is mandatory for NCR dispositions of "Accept-As-Is" or "Repair."
 - 5.2.8.2 If the evaluation finds that the proposed actions are satisfactory, the engineer of record shall attach a copy of the evaluation, sign and date block 15 of the NCR form, and proceed to step 5.2.9.1.

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- 5.2.8.3** If the evaluation finds that the proposed actions are unsatisfactory, the engineer of record shall attach a copy of the evaluation to the unsigned NCR form and proceed to step 5.2.9.2.
- 5.2.8.4** For dispositions of "Reject" or "Rework," the engineer of record shall mark block 15 "N/A" (not applicable), sign and date the block, and proceed to step 5.2.9.1.
- 5.2.9** The engineer of record shall forward the NCR as follows:

 - 5.2.9.1** If the evaluation finds that the proposed actions are satisfactory (step 5.2.8.2), or if no evaluation was required (step 5.2.8.4), the engineer of record shall forward the NCR form to the Manager, Quality Assurance.
 - 5.2.9.2** If the evaluation finds that the proposed actions are unsatisfactory (step 5.2.8.3), the engineer of record shall return the unsigned NCR form to the responsible manager, with a copy to the Manager, Quality Assurance. The responsible manager shall notify the originator and the responsible organization that the proposed actions are not satisfactory. (Return to step 5.2.3.)
- 5.2.10** The Manager, Quality Assurance, shall review the process and the proposed corrective actions and completion date.

 - 5.2.10.1** If the process has been followed correctly and the proposed corrective actions and completion date are acceptable, the Manager, Quality Assurance, shall sign and date block 16 of the NCR form to indicate acceptance of the process and concurrence with corrective actions and completion date and proceed to step 5.2.11.

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5.2.10.2 If the process, proposed corrective actions, or completion date are not acceptable, the Manager, Quality Assurance, shall return the unsigned NCR to the responsible manager with a separate written explanation, with a copy to the engineer of record. The responsible manager shall notify the originator and the responsible organization that the proposed disposition, corrective action, and/or completion date are not acceptable. (Return to step 5.2.3.)

5.2.11 The Manager, Quality Assurance, shall update the Nonconformance Report Log and forward the signed NCR form to the responsible manager.

5.2.12 The responsible manager shall notify the responsible organization that it has approval to proceed with the proposed corrective actions and actions to prevent recurrence.

5.2.12.1 The responsible manager shall forward the original NCR form to the originator.

5.2.12.2 The responsible manager shall forward a copy of the NCR form to the responsible organization.

5.3 **Closure**

5.3.1 The responsible organization shall notify CTA when the corrective actions and actions to prevent recurrence have been implemented.

5.3.2 The originator shall verify correction of the nonconformance. Verification shall include reinspection of reworked or repaired work.

5.3.2.1 If the corrective actions and actions to prevent recurrence have been completed and the nonconforming condition has been corrected, the originator shall record verification in block 17 of the NCR form, sign and date the block, and proceed to step 5.3.3.

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5.3.2.2 If the nonconforming condition has not been corrected, or if the corrective actions or actions to prevent recurrence have not been completed properly, the originator shall not sign the NCR form but shall notify the responsible organization that implementation is unsatisfactory. (Return to step 5.3.1.)

5.3.3 The originator shall forward the original NCR form to the Manager, Quality Assurance.

5.3.4 The Manager, Quality Assurance, shall review the NCR and sign and date block 18 signifying acceptance of the resolution process and closure of the NCR.

5.3.5 The Manager, Quality Assurance, shall indicate required distribution for the closed NCR and make distribution. As a minimum, distribution shall include:

- 1) Manager, Quality Assurance (original -- record copy)
- 2) Vice President, Engineering (for NCRs related to design or construction)
- 3) Vice President, Maintenance (for NCRs related to force account capital construction work)
- 4) Responsible Manager (Engineering/Construction/Maintenance) from step 5.2.5
- 5) Originator
- 6) Engineer of record
- 7) Responsible organization
- 8) Document Control

5.3.6 The Manager, Quality Assurance, shall update the Nonconformance Report Log.

5.3.7 The Manager, Quality Assurance, shall be responsible for ensuring revision of any procedures necessitated by the corrective action process.

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5.4 Corrective Action Evaluation

The Manager, Quality Assurance, shall conduct an annual review of NCRs generated during the previous 12-month period, and related dispositions, to determine the effectiveness of corrective actions in precluding recurrences of nonconforming conditions.

5.5 Quality Assurance Records

NCRs, the Nonconformance Report Log, and related engineering evaluations are quality assurance records. They shall be maintained in accordance with PMP-6002 or other approved written procedures.

5.6 Trend Analysis

Information concerning NCRs and corrective actions shall be entered into the Audit/Surveillance Information System maintained by the Quality Assurance Department and otherwise made available for trend analysis as necessary.

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NONCONFORMANCE REPORTS AND CORRECTIVE ACTION

6.0 ATTACHMENTS

- 6.1 Nonconformance Report, Form 6009.01 (1 page)
- 6.2 Nonconformance Report Log, Form 6009.02 (1 page)
- 6.3 Nonconformance Report Continuation Sheet, Form 6009.03 (1 page)
- 6.4 Exhibit A: Nonconformance Report Instructions (3 pages)

7.0 PROVISIONS

- 7.1 The Manager, Quality Assurance shall have the independence and authority to direct the generation of an NCR to identify any activity or item not meeting specified requirements. The generation of an NCR may be independent of any other processes and may be utilized at any time.
- 7.2 The Manager, Quality Assurance, shall review each NCR to determine if the condition indicates a breakdown in the controls established to ensure effectiveness of the Quality Assurance Program and to ensure that corrective actions and their implementation resolve the problem. If a breakdown in the quality process is identified, the Manager, Quality Assurance shall take the steps necessary to restore the quality process.
- 7.3 The NCR form may be used as a Stop Work Order (SWO) at the discretion of the Manager, Quality Assurance, subject to approval by the Vice President, Engineering, and the responsible General Manager and Vice President. An NCR used to stop work shall state in the "Description of Nonconformance" section (block 4):

"STOP WORK ORDER. NO FURTHER WORK MAY BE PERFORMED
WITHOUT PROPER WRITTEN AUTHORIZATION.
SEE CONTINUATION SHEET, PAGE 2."

The activity or item covered by the Stop Work Order shall be clearly defined on the Nonconformance Report Continuation Sheet and signed by all of the appropriate

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NONCONFORMANCE REPORTS AND CORRECTIVE ACTION

authorities. Closure of the Stop Work Order shall require the same authorization signatures.

7.3.1 SWO Approval Authorities for Engineering and Construction Department

- Manager, Quality Assurance
- General Manager, Facilities Engineering (for SWOs related to facilities engineering)
- General Manager, Power and Way Engineering (for other SWOs related to engineering and design)
- General Manager, Construction (for SWOs related to construction)
- Vice President, Engineering

7.3.2 SWO Approval Authorities for Maintenance Department

- Manager, Quality Assurance
- Vice President, Engineering
- General Manager, Facilities Maintenance
- Vice President, Maintenance

7.4 Where responsibilities are assigned by position title, it is understood that those responsibilities may be delegated. The named position shall retain accountability for all assigned activities.

**CTA CAPITAL IMPROVEMENT PROGRAM
QUALITY ASSURANCE DEPARTMENT**

NONCONFORMANCE REPORT

PAGE 1 OF

NONCONFORMANCE

1. CONTRACT NO.

2. ORGANIZATION

3. NCR NO.

4. DESCRIPTION OF NONCONFORMANCE

5. APPLICABLE REQUIREMENTS

6. PREPARED BY/DATE

7. RESPONSE DUE DATE

DISPOSITION

8. CAUSE(S) OF NONCONFORMANCE

9. DISPOSITION

REJECT

REWORK

REPAIR

ACCEPT-AS-IS

10. CORRECTIVE ACTION(S)

11. ACTION(S) TO PREVENT RECURRENCE

12. DISPOSITION RESPONSE PREPARED BY/DATE

13. SCHEDULED COMPLETION DATE

14. CONCURRENCE BY/DATE

15. ENGINEERING EVALUATION APPROVAL/DATE
(FOR REPAIR AND ACCEPT-AS-IS DISPOSITIONS)

16. QUALITY ASSURANCE CONCURRENCE/DATE

CLOSURE

17. VERIFY NONCONFORMING CONDITION CORRECTED (CTA INSPECTION ACCEPTANCE/DATE)

18. QUALITY ASSURANCE CONCURRENCE/CLOSURE DATE

19. DISTRIBUTION

ATTACH CONTINUATION SHEETS AS NECESSARY.

FORM 6009.01 (12/96)

CTA CAPITAL IMPROVEMENT PROGRAM
 QUALITY ASSURANCE DEPARTMENT

NONCONFORMANCE REPORT LOG

PAGE _____ OF _____

NCR NO.	CONTRACT NO.	DESCRIPTION	ORIGINATOR	RESPONSIBLE ORGANIZATION	ISSUE DATE	RESPONSE DUE DATE	SCHEDULED COMPLETION	ENGINEERING EVAL. APPROVAL BY/DATE	VERIFIED BY/DATE	CLOSED DATE

NONCONFORMANCE REPORT CONTINUATION SHEET

PAGE _____ OF _____

1. CONTRACT NO.

2. ORGANIZATION

3. NCR NO.

IDENTIFY BY NUMBER THE PAGE 1 BLOCK BEING CONTINUED.

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NONCONFORMANCE REPORT INSTRUCTIONS

The Originator Completes Items 1 - 7:

1. Enter the contract number.
2. Enter the complete name of the organization responsible for the nonconformance. This may be a CTA organizational unit or a consultant or contractor.
3. Enter the NCR number obtained from the CTA Manager, Quality Assurance.
4. Describe the nonconformance.
5. Enter the requirement(s) violated with reference to the applicable procedure or specification section or paragraph, or other identifying information.
6. Signature of person preparing the NCR, and date.
7. Enter the date by which the responsible organization must respond to the NCR by completing the "Disposition" section of the form. This date should be 10 working days after the issue date. Transmit the NCR to the responsible organization.

The Responsible Organization Completes Items 8 - 13:

8. Explain why the requirement was violated.
9. Indicate the proposed disposition. (Dispositions of "repair" or "accept-as-is" require concurrence by the engineer of record.)
10. Describe the action taken or planned to be taken to correct the specific nonconforming item or condition.
11. Describe what action is planned to prevent recurrence of the same or similar nonconformances, with the focus on prevention, not correction. Include any required changes to procedures.
12. Signature of person preparing the response, and date.

The Responsible Organization Completes Items 8 - 13 (Cont.):

13. Enter date when corrective action is expected to be complete. Return the NCR to the CTA Manager, Quality Assurance. NOTE: The CTA Manager, Quality Assurance, shall determine the responsible CTA Engineering/Construction/Maintenance Manager and forward the NCR to that individual.

The Responsible Manager Completes Item 14:

14. Signature denoting concurrence with proposed corrective action and effective date, and date of signature. Transmit the NCR to the engineer of record, with a copy to the Manager, Quality Assurance. NOTE: If the proposed disposition and/or corrective action are not acceptable, the responsible manager shall return the unsigned NCR to the responsible organization with a separate written explanation, with a copy to the Manager, Quality Assurance.

The Engineer of Record Completes Item 15:

15. Signature of engineer of record documenting engineering evaluation and acceptance of proposed corrective action and completion date, and date of signature. Transmit the NCR to the Manager, Quality Assurance. NOTE: If the proposed disposition and/or corrective action are not acceptable, the engineer of record shall return the unsigned NCR to the responsible manager with a separate written explanation, with a copy to the Manager, Quality Assurance. The responsible manager shall notify the originator and the responsible organization that the proposed disposition and/or corrective action are not acceptable.

The Manager, Quality Assurance, Completes Item 16:

16. Signature by Manager, Quality Assurance, indicating review of the process and concurrence with corrective actions and completion date, and date of signature. Transmit the NCR to the responsible manager for notification to the originator and the responsible organization. The responsible manager shall forward the original NCR form to the originator and a copy of the form to the responsible organization. NOTE: If the proposed disposition, corrective action, and/or completion date are not acceptable, the Manager, Quality Assurance, shall return the unsigned NCR to the responsible manager with a separate written explanation, with a copy to the engineer of record. The responsible manager shall notify the originator and the responsible organization that the proposed disposition and/or corrective action are not acceptable.

The Originator Completes Item 17:

17. Signature accepting work, and date. Describe inspections, location, serial numbers, etc., as appropriate, to document field verification that the work is complete and acceptable. Attach or reference supporting documents (e.g., inspection reports, procedures, revised drawings) as appropriate. NOTE: If the work is not acceptable, the originator shall return the unsigned

NCR to the responsible organization with a separate written explanation, with a copy to the Manager, Quality Assurance.

The Manager, Quality Assurance, Completes Items 18 and 19:

18. Signature accepting the resolution process, and date.
19. Indicate distribution of the closed NCR as required, and distribute. As a minimum, the following distribution shall be made:
 - Manager, Quality Assurance (original)
 - Vice President, Engineering (for NCRs related to design or construction)
 - Vice President, Maintenance (for NCRs related to force account capital construction work)
 - Responsible Manager (Engineering/Construction/Maintenance)
 - Originator
 - Engineer of record
 - Responsible organization
 - Document Control

Element 13: *Quality Records*

From the Chicago Transit Authority, Capital Improvement Program,
Quality Assurance Manual; including Project Management Procedure,
PMP-6002, Quality Records – Quality Assurance Department.

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SECTION 4 – QUALITY PROGRAM ELEMENTS

4.13 Quality Records

Procedures shall be established and maintained for identification, production and collection, indexing, access, filing, storage, maintenance, and disposition of quality records.

Quality records shall be maintained by the area responsible for the work. Supplier, contractor, and subcontractor quality records shall be included where pertinent.

All quality records shall be stored and retained in such a way that they are readily retrievable in facilities that provide a suitable environment to prevent damage, deterioration, or loss. Retention times of quality records shall be established and recorded.

Quality records shall be legible and shall clearly identify the project or subject to which they apply.

Where specified by contract, quality records shall be made available to the purchaser or purchaser's representative.

SECTION 5 – CIP PROJECT LIFE-CYCLE PHASES

5.2 Design Phase

The following subsections describe the quality assurance activities usually associated with the design phase of a capital project.

5.2.5 Quality Records

The Project Manager assures that quality records are compiled and maintained. Written procedures provide for a project filing system and establish the guidelines for the retention of records.

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QUALITY RECORDS -- QUALITY ASSURANCE DEPARTMENT

The above-named procedure is hereby approved:

 Manager, Quality Assurance Date

 Vice President, Engineering Date

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QUALITY RECORDS -- QUALITY ASSURANCE DEPARTMENT

1.0 PURPOSE

The purpose of this procedure is to establish a system and assign responsibility for the identification, collection, filing, retrievability, and maintenance of quality assurance records generated by CTA's Quality Assurance Department.

2.0 SCOPE

This procedure applies to all documents classified as quality assurance records as identified on the Quality Assurance Records Index (see attached Form 6002.01). The identification, maintenance, and control of quality assurance records generated by organizational units external to the Quality Assurance Department shall be in accordance with this procedure or other approved documented procedures. The identification, maintenance, and control of quality-related documents generated by consultants or contractors shall be in accordance with the applicable contract.

3.0 REFERENCES

- 3.1 Chicago Transit Authority, Capital Improvement Program Quality Assurance Manual
- 3.2 FTA-MA-06-0189-92-1, dated March 1992, United States Department of Transportation, Federal Transit Administration, Quality Assurance and Quality Control Guidelines

4.0 DEFINITIONS

- 4.1 Quality assurance records - Records which furnish documentary evidence of the quality of items and/or activities affecting quality.

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QUALITY RECORDS -- QUALITY ASSURANCE DEPARTMENT

- 4.2 Quality Assurance Records Index - A document that identifies quality assurance records by type or classification and specifies required retention periods and records storage locations.
- 4.3 Records File Master List - A document that lists the records stored in the quality assurance records files. It is arranged to reflect the organizational structure of the records files. The list includes records files that have been purged from the system, when they were purged, and by whom.

5.0 PROCEDURE

5.1 General

- 5.1.1 Quality assurance records shall include all documents produced in implementing the CTA's Quality Assurance Program that furnish documentary evidence of the quality of items and/or activities affecting quality. These documents may be generated by the Quality Assurance Department during the implementation of quality-related procedures or by any other organization having responsibility under the CTA's CIP. This procedure applies to those records generated by the Quality Assurance Department.
- 5.1.2 The Manager, Quality Assurance, shall be responsible for identifying, collecting, controlling, and maintaining quality assurance records and for establishing records retention periods for those records generated by the Quality Assurance Department.
- 5.1.3 The Manager, Quality Assurance, shall interface with the generating department to make decisions about records generated external to the Quality Assurance Department.

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QUALITY RECORDS -- QUALITY ASSURANCE DEPARTMENT

5.2 Record Identification Number

5.2.1 The Manager, Quality Assurance, shall establish and maintain a system for identification numbering of quality assurance records. This system may apply unique numbers to individual documents (e.g., contractor quality plans) or group related documents together under a single identification number (e.g., daily inspection reports for a particular project), at the discretion of the Manager, Quality Assurance.

5.2.2 The numbering scheme shall include provisions for associating related records that carry unique numbers (e.g., individual audit files, supplier quality evaluations) that have been produced and indexed at various times.

5.3 Quality Assurance Records Index

The Manager, Quality Assurance, shall record quality assurance records on the Quality Assurance Records Index (see attached Form 6002.01) or a similar computerized form containing the same information. The index shall identify the type or classification of record, the associated record identification number, the location of the record, and its minimum retention period.

5.4 Records File Master List

The Manager, Quality Assurance, shall establish and maintain a Records File Master List (see attached Form 6002.02) or a similar computerized list of all quality assurance records. This list shall include the record identification number and a brief description of the record. Purged records shall be retained on the list, annotated with the date purged and initials of the person purging the file. The list shall reflect the structure of the records files to enhance retrievability of records and shall be updated as records files are added or deleted.

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QUALITY RECORDS -- QUALITY ASSURANCE DEPARTMENT

5.5 Identifiability of Quality Assurance Records

The Manager, Quality Assurance, shall ensure that all records are identifiable to the project, item, process, person, or event to which they pertain and that all records are complete, legible, dated, and identify the person who established the record.

5.6 Retrievability of Quality Assurance Records

The Manager, Quality Assurance, shall establish a documented system for indexing or grouping documents to facilitate their retrieval. Records should be grouped by project, process, and record type wherever possible.

5.7 Storage of Quality Assurance Records

Quality assurance records shall be stored in designated records files in clean, dry rooms appropriate for records storage. Filing cabinets containing quality assurance records shall be clearly labeled as to their contents. Quality records shall be maintained separately from working or in-process files.

5.8 Maintenance of Quality Assurance Records

5.8.1 Quality assurance records shall be retained for the minimum duration identified on the Quality Assurance Records Index.

5.8.2 The Manager, Quality Assurance, shall review the quality assurance records periodically to determine which records have exceeded their minimum retention period. Records whose retention period has expired may either be purged from the quality assurance records files or retained in the records files at the discretion of the Manager, Quality Assurance.

5.8.3 At the discretion of the Manager, Quality Assurance, lifetime records may be microfilmed or stored in secure, remote storage facilities.

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QUALITY RECORDS -- QUALITY ASSURANCE DEPARTMENT

5.9 Access to Quality Assurance Records

Direct access to the quality assurance records files shall be limited to authorized individuals. Access to the quality assurance records files shall be authorized by the Manager, Quality Assurance.

6.0 ATTACHMENTS

6.1 Quality Assurance Records Index, Form 6002.01 (1 page)

6.2 Records File Master List , Form 6002.02 (1 page)

7.0 PROVISIONS

7.1 Due to project assignment, work location, or other limiting conditions prohibiting daily access to the designated records storage location, quality assurance records may, at the discretion and with the approval of the Manager, Quality Assurance, be maintained at other than the designated location. Records maintained at other than the designated records storage location shall be subject to all the criteria of this procedure and shall be moved to the designated records storage location as soon as practical.

7.2 Organizational units external to the Quality Assurance Department may develop and implement separate documented procedures for identifying, collecting, filing, and maintaining quality assurance records provided that the procedures meet the requirements of FTA-MA-06-0189-92-1 and the CTA Capital Improvement Program Quality Assurance Manual. Any such procedure shall be subject to review and acceptance by the Manager, Quality Assurance.

7.3 The Manager, Quality Assurance, shall be notified of what files are maintained in accordance with provisions 7.1 and 7.2 above and where they are maintained. Logs of such files may be maintained separately; or they may be included on the Quality Assurance Records Index (Section 5.3) and the Records File Master List (Section 5.4) and appropriately identified.

QUALITY ASSURANCE RECORDS INDEX

PAGE _____ OF _____

RECORD TYPE OR CLASSIFICATION	RECORD IDENTIFICATION NO.	LOCATION	MINIMUM RETENTION PERIOD

CTA CAPITAL IMPROVEMENT PROGRAM
QUALITY ASSURANCE DEPARTMENT

RECORDS FILE MASTER LIST

PAGE OF

PURGED BY
(INITIALS/DATE)

RECORD IDENTIFICATION NUMBER AND DESCRIPTION

Element 14: *Quality Audits*

From the New York City Transit Authority, Department of Capital Program Management, Quality Management System Manual; including Project Management Guideline No. 118 and corresponding Project Management Procedure No. 118, Quality Assurance Audits.

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Section 14

QUALITY AUDITS

14.1 QUALITY OBJECTIVE

The effectiveness of the Quality Management System and its conformance with the ISO-9001 standard shall be verified through audit activities. The results of audits shall be transmitted to appropriate levels of management for corrective and preventive action.

14.2 AUDIT OBJECTIVES

In accordance with PMP No. 118, Quality Assurance Audits are performed:

- during the design, construction and close-out phases of a project
- to confirm that all NYCTA employees involved in the expenditure of capital funds are adhering to elements of the Quality Manual, PMPs/PMGs, Directives and Design Guidelines
- to verify contractor and consultant compliance with contract requirements, including Quality Program/Plan requirements
- by contractors and consultants in accordance with their approved Quality Programs/Plans

14.3 PLANNING

Quality Assurance is responsible for audit activities. Based on status and importance of activities, an annual Audit Program and schedule is developed and implemented by Quality Assurance.

14.4 EVALUATION OF QUALITY ASSURANCE METHODS

Audits are performed to develop information sufficient to evaluate the adequacy of quality assurance methods, procedures and instructions established to assure the control and verification of activities, documentation and products.

14.5 REPORTING AND CORRECTIVE ACTION

Following each audit, a debriefing or exit conference is conducted. Following this debriefing, the audit team leader prepares a written audit report and distributes it to appropriate project personnel involved in the audit for necessary action. Quality Assurance verifies that corrective and preventive actions taken are completed and

acceptable. In some cases, immediate corrective action may have to be taken by the contractor or Construction Manager.

14.6 MAINTENANCE OF QUALITY INFORMATION

Information on audits conducted is maintained in a Quality Assurance database. This information will be used to analyze trends in contractor, consultant and project management activities to determine the need for action to correct recurrent deficiencies. Reports on Quality Assurance audits and the results of trend analyses performed are provided as inputs to the management review meetings.

New York City Transit
Department of Capital Program Management
PROJECT MANAGEMENT GUIDELINE

Title QUALITY MANAGEMENT SYSTEM AUDITS SPONSOR: Candace Martone	Issued 12/1/01	Revision 5	Number 118	Page
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1.0 PURPOSE

To set forth guidelines for establishing, planning, implementing and documenting audits.

2.0 SCOPE

These guidelines apply to all NYCT and/or consultant design and construction administration; contractor (including subcontractors and suppliers) and/or force account capital construction; and equipment (excluding car and bus purchase, car overhaul, and other rolling stock contracts), power, signal, track, communication, architectural or similar contracts administered by all NYCT Departments.

3.0 GUIDELINES

3.1 Audit Objectives

Audits are generally planned, developed and initiated for one or more of the following reasons:

- to verify that an organization's quality management system continues to meet specified requirements and is being implemented
- to assess the effectiveness of established processes
- to evaluate quality management systems implemented by NYCT departments, contractors and consultants involved with Capital Program projects against established quality system standards
- to verify that regulatory requirements are being met

3.2 Audit Roles and Activities

Whether an audit is carried out by a team or an individual, the lead auditor is in overall charge and has authority to make decisions regarding the conduct of the audit. Depending upon the circumstances, the audit team may include experts with specialized background.

Auditors should be free from bias and influences which could affect objectivity and should act in an ethical manner at all times.

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Auditor qualifications, training and experience records shall be maintained and evaluated on a yearly basis in accordance with Quality Management Internal Guideline No. 4.

Auditor Activities:

- plan the audit and prepare working documents
- review documentation on existing quality management system activities to determine their adequacy
- verify and analyze evidence that is relevant and sufficient to permit the drawing of conclusions regarding the audited quality management system
- remain alert to any indications of evidence that can influence the audit results and possibly require more extensive auditing
- report critical nonconformities to the auditee immediately
- report any major obstacles encountered in performing the audit
- report on the audit results clearly, conclusively and without undue delay
- retain and safeguard documents pertaining to the audit, submit such documents as required, ensure that such documents remain confidential and treat privileged information with discretion

3.3 The Audit Process

As a basis for planning the audit, the auditor reviews the auditee's recorded description of the methods for meeting the quality system requirements (such as the documented quality management system manual/plan/program or equivalent).

An audit plan will be prepared by the lead auditor, and communicated to the auditee.

The audit plan will be designed to be flexible in order to permit changes in emphasis based on information gathered during the audit, and to permit effective use of resources. The plan includes:

- the audit objectives and scope
- identification of the individuals having significant direct responsibilities regarding the objectives and scope

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- identification of reference documents (such as the applicable quality system standard and the auditee’s documented quality management system)
- identification of audit team members
- the date and place where the audit is to be conducted and the expected time and duration for each major audit activity
- identification of the organizational units to be audited
- the schedule of meetings to be held with auditee management
- confidentiality requirements, if applicable
- audit report distribution and the expected date of issue

If the auditee objects to any provisions in the audit plan, such objections should immediately be made known to the lead auditor. They should be resolved between the lead auditor and the auditee.

Specific details of the audit plan may be communicated to the auditee prior to/throughout the audit if their premature disclosure does not compromise the verification of objective evidence.

The work documents required to facilitate the auditor’s investigations and to document and report results will usually include:

- checklists/worksheets used for evaluating quality system activities
- forms for documenting required Action Requests

Work documents should be designed so that they do not restrict additional audit activities or investigations which may become necessary as a result of information gathered during the audit.

Work documents involving confidential or proprietary information shall be suitably safeguarded by the auditing organization.

A pre-audit conference may be scheduled to:

- introduce the members of the audit team to the auditee’s senior management
- review the scope and the objectives of the audit

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- provide a short summary of the methods and procedures to be used to conduct the audit
- establish the official communication links between the audit team and the auditee
- confirm that the resources and facilities needed by the audit team are available
- confirm the time and date for the exit meeting and any interim meeting of the audit team and the auditee’s senior management
- clarify any unclear details of the audit plan

Throughout the audit, the auditee’s compliance with established requirements should be verified through interviews, examination of documents/records, and observation of activities and conditions in the areas of concern. Indications of nonconformities should be noted if they seem significant, even if not covered by checklists, and should be investigated. Information gathered through interviews should be tested by acquiring the same information from other independent sources, such as physical observation, measurements and records.

After all activities have been audited, the audit team should review their notes/worksheets to develop an overall summary of the audit results and determine what Action Requests are required. The audit team should then ensure that these are documented in a clear, concise manner and are supported by evidence. Action Requests should be identified in terms of the specific requirements of the standard or other related documents against which the audit has been conducted.

At the end of the audit, prior to preparing the audit report, the audit team should hold a meeting with the auditee and those responsible for the functions concerned. The lead auditor should present the audit team’s conclusions regarding the quality management system’s effectiveness in ensuring that quality objectives will be met. The main purpose of this meeting is to present a summary of the team's overall audit assessment and any required Action Requests so as to ensure that the auditee clearly understands the results of the audit and any additional actions required.

The process and an approximate time frame for issuance of the audit report and response by the auditee should be discussed.

Records of the closing meeting should be kept.

3.4 Audit Documentation

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The audit report is prepared under the direction of the lead auditor, who is responsible for its accuracy and completeness. It should be prepared and issued within 45 calendar days from the last day of the audit.

The audit report should reflect both the tone and content of the audit. It should contain the following items, as applicable:

- the purpose and scope of the audit
- identification of the audit team members; the specific organization audited and the auditee's representative(s); audit dates and locations; and areas/activities audited
- identification of the reference documents against which the audit was conducted (ie: quality system standard, the auditee's documented quality system, etc.)
- Overall summary of the audit results and the audit team's assessment of the project/activity compliance with requirements
- any required Action Requests, documented on an Action Request Report (Exhibit 1), as well as a description of any other observations made during the course of the audit
- the time period for submittal of a response to the Action Requests
- the audit report distribution list

Audit reports containing confidential or proprietary information shall be suitably safeguarded by the auditing organization.

The audit report is submitted to the Senior Director, Quality Systems for final review and signature and sent to the NYCT representative (ie: Program Area Construction Manager, Design Manager, etc.) responsible for the activity or project audited. If applicable, the NYCT representative shall forward a copy of the report to any affected outside organization (ie: general contractor, consultant, supplier, etc.) for information and/or action. Copies of the audit report shall also be sent to CPM's Senior Management.

The management of the activity or project audited will normally be required to respond to the Action Requests within 30 calendar days using the applicable Action Request Response form (Exhibit 2 or 3) in accordance with instructions provided. Circumstances may arise where responses require additional time or further clarification. Such instances will be resolved with the Quality Management Office and appropriately documented. Action Request Response statements are to be specific with respect to the cause of the noncompliance, as well as actions taken to correct the noncompliance and to preclude recurrence.

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The NYCT representative will follow-up on any Action Request Responses required from outside organizations.

3.5 Corrective Action Follow-Up

The auditee is responsible for determining and initiating corrective action needed to correct a noncompliance or to correct the cause of the noncompliance.

For Action Request Responses submitted by outside organizations, the NYCT representative will review the response/proposed action for acceptability prior to forwarding it on to the Quality Management Office. If the NYCT representative does not accept the response and returns it to the auditee for additional action, the Quality Management Office will be notified.

Upon submittal, the Quality Management Office shall review all Action Request Responses received. Any reasons for rejection will be provided to the appropriate NYCT representative.

Follow-up audits will be scheduled, when required, to verify the completion and effectiveness of the corrective action. Noncompliance with actions proposed/taken will be handled in the same manner as original Action Requests.

The Quality Management Office will send a memorandum to the appropriate NYCT representative advising them of the Action Requests which have been closed or which remain open.

3.6 Maintenance of Quality Information

Audit information will be maintained in a Quality Management database. This information will be used to analyze trends in contractor, consultant and project management activities to determine the need for action to correct/prevent recurrent deficiencies. Reports on Quality audit activities and the results of trend analyses performed will be provided to CPM Senior Management as part of the annual Management Review.

4.0 REFERENCE

4.1 PMP 118, Quality Management System Audits

4.2 Quality Management Internal Guideline No. 4, Auditor Qualifications

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NYCT DEPARTMENT OF CAPITAL PROGRAM MANAGEMENT		ACTION REQUEST (AR)		1. AUDIT NO. _____ 2. AR # ___ of ___	
3. INDIVIDUAL/DEPARTMENT CONTACTED		4. PSE NUMBER		5. AUDIT DATE(S)	
6. REFERENCE/REQUIREMENTS: 					
7. NONCOMPLIANCE NOTED: 					
8. RECOMMENDED ACTIONS: 					
9. AUDIT TEAM LEADER _____			10. RESPONSIBLE NYCT MANAGER _____		

PMG No. 118	Issued 12/1/01	Revision 5	Exhibit No. 2	Exhibit Page 1 of 2	PMG Page
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New York City Transit Department of Capital Program Management	ACTION REQUEST RESPONSE	11. AUDIT NO. _____ AR ____ of ____
12. DETERMINATION OF CAUSE		
<input type="checkbox"/> 1) Procedures Not Developed, Reviewed, Inadequate, and/or Approved <input type="checkbox"/> 2) Procedure Noncompliance and/or Not Implemented <input type="checkbox"/> 3) Workmanship Error Explanation of "Other":	<input type="checkbox"/> 4) Inadequate Indoctrination, Training and Qualification of Personnel <input type="checkbox"/> 5) Material Deficiency <input type="checkbox"/> 6) Inadequate or Missing Documentation <input type="checkbox"/> 7) Other (Explain below)	
13. ACTION TO CORRECT NONCOMPLIANCE		
14. ACTION TO PREVENT RECURRENCE		
15. COMPLIANCE DATE:		
16. _____ Date Submitted _____ Date		
17. _____ Date Approved _____ Date		
- BELOW THIS LINE FOR Q.M . USE ONLY -		
18. PROPOSED CORRECTIVE ACTIONS SATISFACTORY.....YES <input type="checkbox"/> NO <input type="checkbox"/>		
19. COMMENTS:		
20. VERIFICATION OF CORRECTIVE ACTION COMPLETION BY QM		
ACTION ACCEPTABLE.....YES or NO AR CLOSED.....YES or NO		
		21. _____ Date Follow-up Audit Leader
		22. _____ Date Sr. Director, Quality Systems

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INSTRUCTIONS FOR COMPLETION
OF ACTION REQUEST RESPONSE

EXHIBIT 2

<u>BLOCK #</u>	<u>INFORMATION TO BE PROVIDED</u>	<u>RESPONSIBILITY FOR PROVIDING INFORMATION</u>
11	Identification of Audit and Action Request #	Audit Team Leader
12	Identification of the cause of the noncompliance by checking the appropriate box; if "other," details must be provided	NYCT representative responsible for the activity or project audited
13	Identification of action taken, or to be taken, to correct the noncompliance	NYCT representative responsible for the activity or project audited
14	Identification of action taken, or to be taken, to prevent recurrence of the noncompliance on this and other/future projects	NYCT representative responsible for the activity or project audited
15	Date on which proposed actions will be implemented	NYCT representative responsible for the activity or project audited
16	Signature of person responsible for ensuring corrective actions (i.e.: NYCT Manager) and date signed	NYCT representative responsible for the activity or project audited
17	Signature of the supervisor/higher management of the person responsible for ensuring corrective actions (ie: Program Manager) and date signed	NYCT management responsible for the activity or project audited
18	Acceptance/rejection of corrective action response	Follow-up Audit Leader
19	Summary of the results of the follow-up audit/corrective action review	Follow-up Audit Leader
20	Acceptance/rejection of corrective action and status (open/closed) of the Action Request	Follow-up Audit Leader
21	Signature of Follow-up Audit Leader and date signed	Follow-up Audit Leader
22	Signature of Sr. Director, Quality Systems and date signed	Sr. Director, Quality Systems

PMG No. 118	Issued 12/1/01	Revision 5	Exhibit No. 3	Exhibit Page 1 of 2	PMG Page
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New York City Transit Authority Department of Capital Program Management	ACTION REQUEST RESPONSE CONTRACTOR/CONSULTANT AUDIT	11. AUDIT NO.: _____ AR # _____ of _____
12. DETERMINATION OF CAUSE		
<input type="checkbox"/> 1) Procedures Not Developed, Reviewed, Inadequate, and/or Approved <input type="checkbox"/> 2) Procedure Noncompliance and/or Not Implemented <input type="checkbox"/> 3) Workmanship Error	<input type="checkbox"/> 4) Inadequate Indoctrination, Training and Qualification of Personnel <input type="checkbox"/> 5) Material Deficiency <input type="checkbox"/> 6) Inadequate or Missing Documentation <input type="checkbox"/> 7) Other (Explain below)	
Explanation for "Other":		
13. ACTION TO CORRECT NONCOMPLIANCE		
14. ACTION TO PREVENT RECURRENCE		
15. CORRECTIVE ACTION COMPLETION DATE: _____		
16. _____ SIGNED (CONTRACTOR/CONSULTANT) DATE		
- BELOW THIS LINE FOR NYCT USE ONLY -		
17. PROPOSED CORRECTIVE ACTIONS SATISFACTORY.....YES <input type="checkbox"/> NO <input type="checkbox"/>		
18. COMMENTS:		
19. _____ NYCT Manager Date		
20 VERIFICATION OF CORRECTIVE ACTION COMPLETION BY QM		
ACTION ACCEPTABLE YES or NO		
AR CLOSED YES or NO		
21. COMMENTS:		
22. _____ Follow-up Audit Leader Date		
23. _____ Sr. Director, Quality Systems Date		

PMG No. 118	Issued 12/1/01	Revision 5	Exhibit No. 3	Exhibit Page 2 of 2	PMG Page
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INSTRUCTIONS FOR COMPLETION OF
ACTION REQUEST RESPONSE
CONTRACTOR/CONSULTANT AUDIT
EXHIBIT 3

<u>BLOCK #</u>	<u>INFORMATION TO BE PROVIDED</u>	<u>RESPONSIBILITY FOR PROVIDING INFORMATION</u>
11	Identification of Audit and Action Request #	Audit Team Leader
12	Identification of the cause of the noncompliance by checking the appropriate box; if "other," details must be provided	Contractor/Consultant Management
13	Identification of action taken, or to be taken, to correct the noncompliance	Contractor/Consultant Management
14	Identification of action taken, or to be taken, to prevent recurrence of the noncompliance on this and other/future projects	Contractor/Consultant Management
15	Date on which proposed actions will be completed	Contractor/Consultant Management
16	Signature of person responsible for ensuring corrective actions and date signed	Contractor/Consultant Management
17	Acceptance/rejection of proposed corrective actions	NYCT representative responsible for the activity or project audited
18	Any additional comments as may be required concerning proposed corrective actions	NYCT representative responsible for the activity or project audited
19	Signature of NYCT Manager (or other representative) responsible for the activity or project audited and date signed	NYCT Manager
20	Determination of acceptability of actions taken and status (open/closed) of the Action Request	Follow-up Audit Leader
21	Any additional comments as may be required concerning verification/acceptability of actions taken and status of the Action Request	Follow-up Audit Leader
22	Signature of Follow-up Audit Leader and date signed	Follow-up Audit Leader
23	Signature of Sr. Director, Quality Systems and date signed	Sr. Director, Quality Systems

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New York City Transit
 Department of Capital Program Management
 PROJECT MANAGEMENT PROCEDURE

Title	Issued	Revision	Number	Page
QUALITY MANAGEMENT SYSTEM AUDITS	12/1/01	3	118	
SPONSOR: Candace Martone				

1.0 PURPOSE

The purpose of this procedure is to establish responsibilities and requirements to assure the performance of effective quality audits of the NYCT Capital Program.

2.0 RESPONSIBILITIES AND REQUIREMENTS

2.1 Quality Audits will be conducted to ensure that the department's Quality Management System:

- conforms to planned processes and requirements established within the department, as well as to the ISO 9001 Quality Management Standard and
- is effectively implemented and maintained

2.2 The Quality Management Office is responsible for establishing and implementing an annual audit program to monitor NYCT and Contractor/Consultant adherence to applicable policies, procedures and contract documents. The Quality Audit program reflects the planned number and type of audits, as well as the areas within and outside NYCT to be audited. Audit candidates are selected based on the status and importance of activities, previous audit history, and changes in policies, processes, procedures and organizational structure.

2.3 The audit staff shall meet established DCPM qualifications as defined in Quality Management Internal Guideline # 4, and shall be independent of the areas to be audited.

2.4 The results of audits are transmitted to appropriate levels of DCPM management and the auditee's organization. The audit report shall include: the purpose and scope of the audit; identification of the audit team members, auditees, audit dates and locations, and areas/activities audited; overall summary of the audit results; description of any noncompliance with requirements; identification of any noncompliance requiring an Action Request for a documented corrective/preventive action plan; the time period for submittal of the response to any Action Requests; and the report distribution list. Follow-up audits will be performed to verify completion and effectiveness of required corrective action(s).

2.5 Quality audit records will be maintained and will include areas and procedures/requirements audited; audit results; follow-up actions; and status of all audits.

2.6 Auditees are responsible for:

New York City Transit
Department of Capital Program Management
PROJECT MANAGEMENT PROCEDURE

Title	Issued	Revision	Number	Page
QUALITY MANAGEMENT SYSTEM AUDITS	12/1/01	3	118	

- providing personnel/resources needed to facilitate the audit
- providing access to facilities and documentation
- cooperating with auditors in achieving audit objectives
- determining and initiating corrective action based on audit results
- providing timely response to Action Requests

2.7 When auditees are outside of the NYCT organization (ie: general contractors, subcontractors, suppliers, or consultants) the appropriate NYCT manager will work with the Quality Management Office to ensure that the auditee meets the above noted responsibilities.

3.0 REFERENCES

3.1 Project Management Guideline No. 118, Quality Management System Audits

3.2 Quality Management Internal Guideline # 4, Auditor Qualifications

Approved: _____
Signature on file
Mysore L. Nagaraja, P.E.
Senior Vice President and Chief Engineer
Capital Program Management

Element 15: *Training*

From the New York City Transit Authority, Department of Capital
Program Management, Quality Management System Manual.

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Section 15

RESOURCE MANAGEMENT

15.1 QUALITY OBJECTIVE

To create and implement plans for the development of resources based on our present and future needs and to ensure that the work environment supports the achievement of CPM's policies and objectives.

15.2 ASSIGNMENT OF PERSONNEL

CPM shall determine and provide, in a timely manner, the resources needed to implement and improve the process of the Quality Management System and to address customer satisfaction. Personnel assigned to responsibilities defined in the Quality Management System shall be competent on the basis of applicable education, training, skills and experience.

15.3 TRAINING, AWARENESS AND COMPETENCY

15.3.1 Each level of CPM management/supervision is responsible for identifying the competency and/or training needs of his or her direct reports, developing training plans to close any gaps, and measuring the effectiveness of training provided.

Competency of an individual is defined as having the necessary education, skills and ability to meet civil service position requirements and/or perform an assigned task. Measurements of training effectiveness can include:

- obtainment of Certifications, licenses, diplomas, etc.
- written examinations
- analysis of course evaluations
- on the job performance improvements

15.3.2 Training for personnel is coordinated and provided by the Director, Customer Service/Training, under the direction of the Senior Director, Management Services.

15.3.3 Awareness training of CPM personnel, consultants and contractors shall be conducted and address:

- requirements of the CPM Quality Policy
- relevance and importance of their activities and how they contribute to the achievement of the quality objectives
- importance of meeting customer as well as applicable regulatory and legal requirements

- 15.3.4 The Director, Customer Service/Training coordinates with the NYCT Division of Training and contracts with providers of training services outside NYCT to ensure that regularly scheduled and special requirement courses are available to CPM personnel. Catalogs of course offerings (internally, from NYCT, Division of Training and externally, from provider institutions) are maintained by the Director, Customer Service/Training. These materials are also provided to Program Area/Division Training Liaisons, and are available to individual CPM personnel upon request.
- 15.3.5 CPM personnel are registered for selected courses through their Program Area/Division Training Liaison, with authorization from the employee's immediate supervisor and, for external training, from the Program Manager, Division Head or the SVP and Chief Engineer.
- 15.3.6 Internal and external training program attendance is monitored by CPM Training Liaisons and the NYCT Division of Training.
- 15.3.7 Training in Track Safety is made available to Contractor personnel as required. Track training is provided by the NYCT, Division of Training, with registration coordinated through the Division Training Liaison. Training and coaching on Contract Specification Section 1J, "Contractor's Quality Program" is provided by Quality Management to both in-house and contractor personnel.

15.4 TRAINING AND DOCUMENTATION

Each level of CPM management/supervision is responsible for identifying the training needs for the level of employee beneath it. Projected training needs for matrixed and non-matrixed represented and other non-management personnel are documented by the appropriate Division Manager or their Supervising Manager, respectively, using the Career Performance Development plan or its equivalent.

15.5 EDUCATION, EXPERIENCE AND TRAINING

- 15.5.1 Record of employee's education, experience, training and qualifications is documented and maintained by NYCT, Divisions of Training and CPM. CPM has access to Division of Training records as needed.
- 15.5.2 Individual contractors maintain their own training records. Contractors have access to NYCT training records through CPM Division Training Liaisons as needed.

15.6 FACILITIES

CPM provides and maintains the necessary facilities (workspace, hardware/software, supplies, tools, etc.) in order to achieve conformity of our various products. Facility requirements, provided by the contractor for personnel working on construction projects are defined in the contract specification.

15.7 WORK ENVIRONMENT

CPM assures that all human and physical factors relating to the work environment are maintained, including safety rules and procedures and protective equipment.

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APPENDIX B

SELECTIONS FROM LONG ISLAND RAILROAD

Capital Program Procedures 315, “Project Quality Plan”

Signal Engineering Operations, “Quality System Procedure”

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**CAPITAL PROGRAM
PROCEDURE 315**

PROJECT QUALITY PLAN

REVISION NO.

1

DATE APPROVED

December 26, 2000

J. E. Ferrara
Chief Engineer – CPM



**LIRR CAPITAL PROGRAM
PROCEDURE 315
PROJECT QUALITY PLAN**

<u>ARTICLE</u>	<u>DESCRIPTION</u>	<u>PAGE</u>
1.0	<u>Purpose</u>	1
2.0	<u>General</u>	1
3.0	<u>Content</u>	1
4.0	<u>Preparation</u>	2
5.0	<u>Plan Adoption and Maintenance</u>	2

ATTACHMENTS

- ATT-1 Project Quality Plan Considerations**
- ATT-2 Project Quality Plan Concurrence Form**



LIRR CAPITAL PROGRAM PROCEDURE 315 PROJECT QUALITY PLAN

1.0 **Purpose**

To establish the requirements for preparation and maintenance of a Project Quality Plan (PQP).

2.0 **General**

- 2.1 The PM shall ensure that the PQP is developed prior to completion of the preliminary design.
- 2.2 The Quality Assurance (QA) Representative shall monitor and assess the project quality and advise the members of the project team at the Project Progress Meetings, as appropriate.

3.0 **Content**

The PQP shall delineate the following project-specific requirements:

- 3.1 The level of Quality for each design/construction element.
- 3.2 The processes to achieve the Quality (e.g., standards, specifications, etc.)
- 3.3 Allocation of responsibilities and resources during each stage of the project.
- 3.4 Method of verifying conformance to the requirements, as appropriate.
- 3.5 Inspection and testing, at appropriate stages (e.g., design, procurement, installation/construction).
- 3.6 Documents and records to be maintained to verify conformance.
- 3.7 The primary Capital Program procedures to be followed during the execution of the project.
- 3.8 A documented procedure for changes and modifications in the Quality Plan as the project proceeds.



LIRR CAPITAL PROGRAM PROCEDURE 315 PROJECT QUALITY PLAN

4.0 Preparation

Development of the PQP shall be compatible with the Project Management Plan, Project Plan, the Inspection and Test Program, awarded Contracts, Value Engineering Concepts, Constructibility Review Requirements, and available resources, as well as address the following, as appropriate:

- X Review and revision of the design criteria including selection of materials and equipment.
- X Preparation and review of design drawings and specifications as well as design calculations.
- X Development of acceptance criteria for inspections and tests including installation tolerances.
- X User needs and operational modifications.
- X Customer impact assessments.

Note: For additional details regarding the development of PQP, refer to ATT-1.

5.0 Plan Adoption and Maintenance

- 5.1 The PM shall obtain the concurrence of QA Department as well as each department affected by the Plan prior to approval by the Director - CPM and the Chief Engineer - CPM (see ATT-2).
- 5.2 The PQP shall be maintained throughout the project duration. Revisions shall be incorporated into the PQP as they are identified.
- 5.3 Approval of revisions shall be as per 5.1 above.
- 5.4 At a minimum, the approved PQP and each revision shall be distributed to each affected Department.



1. General

- a) Does the PQP define project quality objectives?
- b) Does it indicate specific records to be maintained such as:
 - X Licenses, Certifications, and other personnel qualifications;
 - X Results of inspections, examinations, measurements, and tests;
 - X Nonconformance reports and corrective action reports; and
 - X Material Certifications, Warranties, Guarantees, and Bonds?
- c) Are the requirements for monitoring and control of the project (with respect to material, equipment, and workmanship) clear and adequate?

2. Design Phase

- a) How were the project requirements defined? Are the requirements complete, reasonable and consistent?
- b) Has the project team been organized with clear delineation of responsibilities?
- c) Will in-house specialists, or outside consultants, perform value engineering studies, analyze traffic flow patterns, and perform Geotechnical evaluations (as applicable)?
- d) Should the project be implemented in phases or stages? Are the deliverables for each element clearly identified?
- e) Are the cited standards appropriate for the Work?
- f) Have minimum personnel qualifications been established?
- g) Are field surveys required?
- h) Will the design address Safety, Constructibility, Environmental Impacts, Operations and Real Estate and, who will review these aspects?
- i) What environmental factors such as Rain, Fog, Humidity, Solar Radiation, Salt/Corrosion, Dust, Vibration, Shock, Bounce (Vehicular) need special care and attention?
- j) Are acceptance criteria clearly defined and adequate?
- k) Are requirements with respect to submittals and their monitoring clear?



- l) Which working drawings are to be stamped by a Professional Engineer (PE)?
- m) Will design assumptions, calculations, and analyzes be checked? If yes, by whom?
- n) Will the drawings be coordinated among disciplines? If yes, by whom?
- o) Will the specifications and drawings be coordinated? If yes, by whom?

3. Implementation Phase

- a) Will any critical item(s) be purchased by the LIRR?
- b) Should there be special material processing such as plating, encapsulation, casting required? If yes, what type(s) and should inspection be required?
- c) Will a Vendor Inspection Plan be required? If yes, who will approve and monitor?
- d) Should inspection or field-testing of materials (concrete, paint, etc..) be required? If yes, by whom?
- e) Should the testing of systems be performed? If yes, by whom?
- f) Should in-process testing and monitoring be required? If yes, who will perform or monitor?
- g) Will testing by an outside Independent Testing Laboratory be required?
- h) Upon completion of work, should acceptance testing be required? If yes, by whom?
- i) What in-house support will be provided?
- j) Will certification of equipment operators, welders, etc., be required? If yes, what documentation or verification will be required?



PROJECT QUALITY PLAN CONCURRENCE FORM

315
ATT-2

Project No. _____ Project Title _____

Prepared By: _____
Project Manager - CPM _____ Date _____

Concurred By: _____
Manager - QA Surveillance _____ Date _____

Concurred By: _____
Department Head _____ Date _____

Department Head _____ Date _____

Department Head _____ Date _____

Department Head _____ Date _____

Approved By: _____
Director - CPM _____ Date _____

Chief Engineer - CPM _____ Date _____

Issue Date: _____ Revision No. _____

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SIGNAL ENGINEERING OPERATIONS

QUALITY SYSTEM PROCEDURE

QSP-02-02, Rev. 0 - 06/26/2001

Every User of Procedures which implement the Signal Quality System is responsible for ensuring that Work is performed in accordance with the latest approved procedure revision/change.

Revision No.	Change No.	Date Approved
0	-	06/06/2001

**PROCEDURE APPROVED BY: _____ ACP -
Communications/Signal**

1. PURPOSE

1.1 The purpose of this procedure is to define the method and instructions, and to assign responsibilities for the development of a Signal Project Quality Plan (PQPlan) for use as a management tool to ensure that designs, materials, and equipment, and the workmanship of fabrication, installation, and construction is in accordance with specified requirements.

2. SCOPE

2.1 The scope of this procedure covers the facilitation of scheduling, performing, and documenting the verification processes necessary for the project. Monitoring of the overall activities of Capital funded projects from design to final construction, shall be by Corporate Quality Assurance (CQA) conducting Quality Assurance Surveillances/Audits.

3. ESSENTIAL FUNCTIONS

3.1 Develop a detailed PQPlan specific to the requirements of the individual project, in accordance with this procedure.

3.2 Identify areas of responsibility to ensure the Quality activities in the PQPlan are performed and documented, and the records are maintained.

3.4 Prepare and process revisions to the PQPlan as may be required.

4. PROCEDURE

4.1 Project Quality Plan Content

4.1.1 The PQPlan shall describe how Quality requirements and Quality inspections will be applied to all designs, materials and equipment, as well as the workmanship of all fabrication, installation and construction efforts furnished under the project.

4.1.2 The PQPlan shall include a checklist for each discipline review and inspection that will be performed, and describe how the information will be documented and maintained.

4.1.2 The PQPlan shall clearly identify the parties who will have the responsibility to:

- manage all facets of the project, and
- perform the inspections and reviews.

4.1.3 The development of the PQPlan shall reflect input from all relevant LIRR departments in implementing the project. This shall include, but not be limited to, the User department, the CPM Department, and any LIRR departments who have personnel materially involved in design, procurement, installation, construction, or inspection and testing activities.

4.2 Project Quality Plan Preparation

4.2.1 The PM shall prepare a PQPlan in narrative form for each project.

4.2.2 The cover sheet of the PQPlan, **Attachment QSP02021**, shall indicate the project name, project number, date of PQPlan approval/issue, revision number, name and title of PM, and approval by the Chief Engineer and the DQA.

4.2.3 The PM shall develop checklists tailored to the specific needs of the project to organize information in preparing the PQPlan. This information shall identify the activities and functions required to control the project Quality as shown on the Checklist for Development of a Project Quality Plan, **Attachment QSP02022**.

4.2.4 The PM shall ensure that requirements are addressed for each project stage:

A. Project Description and Organization

B. Design Stage

C. Procurement Stage

D. Installation/Construction Stage

E. Maintenance Schedule

A. Project Description and Organization

- Name and number of project
- Purpose and scope of the project and the project quality plan
- Scope of work by location and discipline
- Location of work and inspections and tests to be performed
- Applicable standards and governing documents
- Assignment of personnel and detailed responsibilities
- Master list or control procedure for documents and data, including approval and revision levels
- Develop a project schedule

B. Design Stage

30% Design Process Flow Plan

Develop a 30% Design following the steps identified in the process flow plan and assign a control number to each related document:

30% DESIGN PROCESS		
No.	Process Steps	Applicable Documents/actions
1	Review Management Expectations/ Requirements for Proposed Project	ACO to Define Goals
2	Review existing conditions at Planned Locations	Design Construction , PM and Maintenance Representatives visit field locations
3	Develop preliminary 30% Scope and Design Criteria	Comply with SEOM & current preferences of Maintenance
4	Develop 30% Design Review Checklist	
5	Present Draft 30% Scope & Design criteria for review by Signal Department	
6	Issue a Final 30% Design Document (Signed by Authorized Personnel) Incorporating required changes	Form _____ Rev ____ Signed by authorized personnel
7	Note: A Request for Changes, affecting estimate, Scope of Work and/or schedule, to be submitted in writing, and approved by ACO Signals. Copy to PM	
8	Determine distribution of the 30% design document	
9	Ensure that Original Draft copy of 30 % Design has been made obsolete	
10	Issue the Final 30% Design to Signal Construction to initiate next step(s) in the Project Plan by obtaining approval/concurrence from Engineering disciplines for Signal Layout	

Develop a 30% Checklist that includes (as a minimum):

- Confirmation that drawings have been signed and dated by Designer and Checker
- Notes are properly indicated and worded correctly
- All locations have been identified and included

Scope of Work: Confirm the scope of work and maintain records of concurrence from all disciplines participating in the project, following the 30 % review. Signal Construction shall compile information from all the supporting Engineering Disciplines and provide Design Engineering the final Project Configuration and Scope of Work. This document shall be used by Design Engineering to complete the 90% design.

Develop a 60% Design: A 60 % Design review shall be conducted **only** when there is a major change in the (1) Scope of Work, (2) Schedule, and/or (3) Budget; as determined by the ACO Communications/Signal. When a 60% Design review is required, a formal evaluation as described in the 30% Design process shall be conducted and documented. All changes shall be approved/concurred by all disciplines associated with the project.

Development of 90% and 100% Design

90 % 100% DESIGN PROCESS		
No.	Steps in the Process	Applicable Documentation and/or Actions
1	Obtain data/information from Signal Construction	
2	Issue a Draft 90% Design	Designate Document Number
3	Issue request for review and changes	
4	Issue a Final 90% Design Document	Designate Rev. to original Draft Document
5	Issue 100% Design Document after an Independent Checking	Designate Document as 100%

Development of 90% and 100% Design Review Checklist

90% and 100% Design Review Checklist				
No.	Drawing and Material Attributes	Yes	No	N/A
1	All new cable alignment and the new hut/case locations are shown.			
2	Drawing shows numbers, branch, milepost, and circuit description.			
3	Drawing has been signed and dated by Designer and Draftsman/checker.			
4	Drawing shows materials requirements and the Item Number of Materials are indicated on the Plan.			
5	Drawing has revision blocks with revision description and dates.			
6	Revisions, where applicable, have approval signatures.			
7	All changes are bubbled “X” and “O” with assigned revision number.			
8	Notes are properly indicated and worded correctly.			
9	Material specifications have been prepared, approved, and sent to vendor for procurement and delivery.			
10	Physical properties have been indicated e.g., location stations, Mileposts, signal and switch locations, and all track grade and curves.			
11	All applicable routings are shown. All locations in the project are included. Copy of CASCOL Run attached, as applicable.			
12	100% Design Completed.			

Comments

Completed by: _____ Signature: _____ Date: _____

Name (Print)

Note: Selection of materials, parts, and equipment shall comply with safety and functionality requirements of the components and systems.

Specification Development, when required, that covers, as a minimum:

- Scope
- Definition of Terms
- Applicable Documents
- General Information
- Design Criteria
- Prewired Enclosures (as applicable)
- Materials & Construction
- Inspections & Tests
- Delivery & Shipment

C. Procurement Stage

- Material procurements shall be made only following 100% design approval.
- Quality design measures, as noted above, shall be appropriately included or referenced in the procurement document for purchasing of materials, equipment, and services.
- To determine the vendor/supplier capability to provide product that meets the LIRR needs:
 - Source verification of an effective quality system prior to selection of vendor/supplier,
 - Source inspection and testing prior to shipment, or
 - Inspection and testing of products upon delivery.

NOTE: Source evaluation, when conducted, shall consider the criteria of **Attachment QSP02023**, LIRR Procurement Guidelines.

- Documentation shall be provided by the vendor/supplier to attest that materials/products supplied satisfy quality and warranty requirements specified in Contract or Purchase Order documents.

D. Installation/Construction Stage

- Activities in the Installation/Construction process shall be identified on checklist(s) covering each Installation/Construction step, and a control number shall be assigned to each related document.
- Each checklist item shall be filled in by both qualified technicians after the item is completed, and by inspectors after the item is verified.
- Measuring, Inspection, and Test Equipment (MI&TE) shall be calibrated. Prior to each use, MI&TE shall be verified to be within the prescribed calibration interval and in good working condition.
- Inspection of activities affecting quality are performed to verify conformance with contract requirements and applicable documented instructions, procedures, drawings; and such inspections shall be performed in accordance with the Project requirements.
- Results of examinations, tests, inspections, etc., shall be documented on prescribed Inspection Reports (IRs), and include the following information as a minimum:
 - Date of inspection,

- Project number and title,
- Title of Force Account (F/A) discipline(s),
- A concise description of the inspection performed and of the inspection results,
- Reference of Nonconformance Reports, if applicable,
- Inspector signature,
- Inspection Criteria or reference to appropriate sections of technical specifications, drawings, or contract documents.
- Original Inspection Reports and associated documents shall be reviewed by the PM for the following:
 - Inspection data is complete and in compliance with governing documents,
 - Nonconforming conditions/items are documented on Nonconformance Reports,
 - No additional corrective action is required, and there are no open issues.

E. Maintenance Schedule

Following installation, construction, and cutover, the PM shall coordinate with the Manager FRA/LIRR, the preparation of a Maintenance Schedule. Records of actual maintenance activities and Inspections and Tests, shall be documented and retained in accordance with the applicable FRA requirement.

4.3 Project Quality Plan Approval

4.3.1 The PM, with assistance from the Corporate Quality Assurance Department and other Department Heads as required, shall review the PQPlan, make comments as necessary and either approve the plan and obtain the Chief Engineer and Director Quality Assurance signatures, or continue development of the PQPlan. Upon final approval of the PQPlan, the PM shall ensure that the PQPlan is understood and properly implemented by the project personnel.

4.3.2 If during the progress of a project it becomes necessary to revise the PQPlan due to scope, budget, and/or schedule changes, and/or refinements to design, fabrication, installation, or construction procedures, the review and approval cycle of the PQPlan shall follow the same routing as that of the original PQPlan.

4.3.3 Any revisions required to be made to the PQPlan as a result of changes that are not related to scope, budget or schedule, shall be incorporated into the PQPlan as they are identified.

5. ATTACHMENTS

5.1 **Attachment QSP02021**, Cover Sheet for a Project Quality Plan

5.2 **Attachment QSP02022**, Checklist for Development of a Project Quality Plan

5.3 **Attachment QSP02023**, LIRR Procurement Guidelines

**LIRR SIGNAL
PROJECT QUALITY PLAN
(PQPlan)**

Revision X

Project No.	Name:
Prepared By: (Project Manager)	Date
Concurred By: (ACO - Communications/Signal)	Date
Approved By: (Chief Engineer)	Date
Approved By: (Director - Quality Assurance)	Date

Checklist for Development of Project Quality Plan		
Item	Planning Activities/Functions	Completed (x)
1.	Introduction	
2.	Project Overview Name, Purpose, Number, Location of Work, Physical Layout, Description of Work, Standards and Governing Documents, Assignment of Personnel and Responsibilities, Flow Chart of Activities, Project Schedule, and Document Control Log	
3.	30% Design Steps in the process, Checklist, Submittals, Formal Review, Project Plan Layout (60% Design Review, if required)	
4.	Design Approval / Concurrence from Engineering Disciplines	
5.	90 % and 100 % Design and Specifications	
6.	Control of Purchased Products	
7.	Material/Signal Equipment by Location and required Inspections and Tests	
8.	Construction Signal Department & Engineering Disciplines	
9.	Inspection, Measuring, and Test Equipment	
10.	Cutover Inspections and Tests for Final Acceptance	
11.	Control of Nonconforming and Punchlist Items	
12.	Update/generate As-in-Service Drawings	
13.	Maintenance Schedule	
14.	Other (as appropriate)	

Project Manager _____ Date _____

LIRR Procurement Guidelines

1. FOREWORD

1.1 During the period of purchase order performance, a LIRR Engineering, Procurement, and/or Quality Assurance representative may visit the Supplier facility to monitor the items being manufactured for the LIRR. The representative(s) may assess both the product and the quality procedures to determine compliance with quality requirements. The LIRR will provide advance notification of such visits wherever possible to avoid disruption of schedules.

- The Quality Assurance requirements specified herein apply to equipment which is manufactured to a manufacturer's design as a proprietary item, or is classified as "off-the-shelf" equipment. The requirements do not supersede any of the provisions of the contract or applicable specifications and drawings considered a part of the contract.
- The equipment, including parts, accessories and spares shall be constructed to high quality manufacturing standards and workmanship practices within the state-of-the-art, design limitations and consistent with the intended use. Special emphasis shall be placed on manufacturing processing such as welding, brazing, riveting, plating, finishes and special coating, soldering, wiring, machine operations, deburring, freedom from sharp edges or other processes where uniform high quality cannot be assured by inspection of the end item.

2. PRODUCT VERIFICATION

2.1 In some cases, mutual interest can best be served by verification of product quality at the Supplier plant prior to delivery. Conditional acceptance made at the Supplier facility by an LIRR representative through product verification shall consist of the review of objective evidence of conformance or actual verification of measurements or tests performed. Although product verification is performed at that suppliers facility, final acceptance will be accomplished at the LIRR.

2.2 Receiving Inspection and Test Based upon adequate product control by the Supplier, the LIRR may use sampling plans to inspect and test received material. Acceptance and rejection may be based upon the use of the sampling plans. Defective material will be reported to the Supplier via a LIRR Nonconformance Report (NCR) whether or not the LIRR elects to return the material to the Supplier. Each LIRR NCR requires action and a prompt reply by the Supplier to ensure that subsequent shipments are satisfactory. The Supplier reply must include the following:

- Cause the deficiency of the Supplier Quality System that permitted defective material to be shipped.
- Corrective Action the action being implemented by the Supplier to preclude recurrence.
- Effectivity Date the date the corrective action will be fully implemented.

3. SUPPLIER QUALITY SYSTEM

3.1 The Supplier must have in place a series of operational controls, systems and guidelines which must be in place in order for them to manufacture and deliver a reliable and trouble free product.

The Supplier Quality System must provide for:

- Control of product quality
- Standards of Workmanship
- Inspection and test instructions/procedures
- Control and use of inspection stamps
- Quality Records Documentation and Retention for purchased material, in-process inspection and test, in addition to final inspection and test
- Maintain equipment calibrated at periodic intervals
- Use of approved sampling plans (when sampling instead of 100% inspection/test is applied)
- Control of nonconforming materials
- Corrective action for in-plant detected or customer reported product quality deficiencies
- Timely response to a LIRR NCR
- Handling and shipping to preclude damage
- Additional requirements as may be specified in the body of the purchase order or the Contract

3.1.1 Distributors/Contractors

Distributors and Contractors are required to have selected as sources for materials and products furnished to the LIRR only those sources determined to be qualified and capable of performance in accordance with the applicable specifications. The distributor Quality System shall include:

- Records showing that applicable specifications were imposed on the purchase order of his sources for materials and products being furnished to the LIRR.
- Provision for obtaining and retaining statements of quality from his sources for materials and products being furnished to the LIRR.
- Control of products and materials to ensure that the identity of materials and products being furnished can be demonstrated.
- Provision for obtaining from his sources upon request by the LIRR objective quality evidence for the items being furnished and a corrective action response for deficient items.

3.2 Statement of Quality and Objective Quality Evidence

3.2.1 Manufacturers

Suppliers are required to maintain and to make available for examination upon request objective evidence in the form of records or data attesting to the quality control applied to the product and the quality of the furnished product. The Supplier shall provide with each shipment, a Statement of Quality for the material.

3.2.2 Distributors

Distributors are required to furnish a Statement of Quality signed by an authorized agent of the Supplier.

3.2.3 Contractor/Consultant

Contractors/Consultants are required to furnish a Statement of Quality that the material and services supplied meet the terms and conditions of the Contract. Lists of subcontractors and vendors must be submitted to the LIRR by Contractors/Consultants. Any Subcontractors and Vendors must be approved by the LIRR. The LIRR Supplier Quality Requirements in addition to terms and conditions of the Contract may be binding on all Contractors/Consultants, Vendors and Subcontractors.

3.3 Purchase Orders

The LIRR P&MM Department issues purchase orders which specify the items required as well as other pertinent data. The specifications or drawings referenced on the purchase order may in turn reference other requirements. It is the Supplier responsibility to obtain and be cognizant of all specifications prior to commencement of his production cycle. The LIRR will supply required LIRR drawings and specifications.

3.4 Drawing and Specification Revision Level

When the revision level of drawings or specifications is not given on the face of the purchase order, the Supplier shall conform to the revision level specified on the LIRR Statement of Work. If neither indicate the revision level, the Project Manager shall ensure that the Supplier receives the correct information.

3.5 Purchase Order Changes

Purchase order changes shall be effected in accordance with the terms and conditions of LIRR procedures for the Procurement of Materials.

3.6 Workmanship Standards

The minimum standards of workmanship applicable to items furnished via LIRR purchase orders are described within this procedure. These standards are applicable except when the standards of workmanship are specified by other specifications listed in the purchase order or referenced in documents listed in the purchase order.

3.7 Supplier Services

The Supplier shall select as sources for parts, materials and processes applicable to the LIRR purchase order item(s), only those sources which he has determined to be qualified and in conformance to the applicable specification. The LIRR may, upon request, assist suppliers by suggesting the names of sources found to be satisfactory for plating, heat treating, welding, and other processes, products or services. The LIRR also reserves the right to disapprove sources which have not demonstrated satisfactory performance. The LIRR Quality Assurance will, upon request of a supplier, perform an assessment of a

source not currently approved and grant approval if satisfactory. Approvals are usually limited to specific products, processes, services and plant location, and it should not be assumed that approval extends to other products, processes, services or other divisions or plant locations.

3.8 LIRR Supplier Assessment

The LIRR reserves the right to visit the plant of the supplier or his sources to perform an assessment of the facilities and systems to determine satisfactory conformance to the applicable specifications. When field inspection is invoked or required, the Supplier shall provide notice when ready and make available to the field inspector and facilities and assistance as may be reasonably required in his conduct of product, process or service quality verification. With reasonable advance notice, the LIRR may require retest or re-measurement of any product found to be unsatisfactory when received or where correction cannot be obtained.

3.9 Unsatisfactory Performance

As a result of unsatisfactory performance by the Supplier, as determined by LIRR Inspection or Quality Assurance, the LIRR reserves the right to require any or all of the following as appropriate:

- Metallurgical analysis,
- Chemical analysis of process baths,
- Rectification of personnel,
- Recalibration of gages or equipment, and
- Any testing required by specification.

Unsatisfactory performance may also result in a reassessment and reconsideration of approval status. The requirements of paragraph 3.10 are applicable to distributors only to the extent that the distributor shall act for the LIRR to obtain the required information from their sources.

3.10 Specific Requirements for Categories of Parts, Assemblies, Castings, and Raw Materials

3.10.1 Small Electronic Assemblies, Boards and Components

- The part and its markings shall not be adversely affected during any process operation and cleaning (e.g., soldering, assembly and cleaning by solvents such as Ihibisol, Freon, etc.).
- Printed circuit boards exhibiting burns, separation of base material, discoloration, excessive measling or blistering which could effect equipment life or its serviceability are unacceptable.

3.10.2 Synthetic Rubber Products, Potting Compounds, Epoxies, and Age Sensitive Adhesives, Sealants and Compounds

- Material must be date coded to show the date at which the critical life is initiated and the useful life will be expended.

3.10.3 Castings, Sheet, Tubular, and Bar Stock, Solder, and other Bulk Metals and Alloys

- Evidence inspection/test or physical/chemical analysis must be submitted in duplicate with each shipment of material on this order.
- Material supplied under this purchase order must be identified in accordance with the specification for this material.

NOTE: The LIRR encourages the marking of materials in this category with classification, temper, etc. as appropriate even when not a specification requirement.

3.10.4 Welding Operations

- Where welding is employed, all rough edges shall be removed and the finish shall have a smooth, even appearance free from undercut, pits, voids and splashes. There shall be no evidence of open, off-center, porous, cracked or deformed welds. There shall be no damage to adjacent parts resulting from the welding.
- Where complex chassis are involved qualification of welder to perform such operations will be required by purchase order or specification reference. Other assemblies may require that the vendor maintain as a minimum an in-house welder training and certification program to ensure that welders are sufficiently skilled in performing the operations associated with the materials and configurations represented by the assembly.

3.10.5 Support

Wires should be properly dressed, neatly grouped and routed to prevent movement and damage from abrasion, heat or other detrimental conditions. Individual wire breakouts should have sufficient stock to preclude stress on connections. Wire bundles and parts should be supported so that soldered electrical connections are not subjected to mechanical stress. Wires and cables should be positioned or protected to avoid contact with rough or irregular surfaces and sharp edges. Wires in a continuous run between two terminals should not be spliced except as authorized by the design.

3.10.6 Protective Finish

Exposed metal surfaces, with the exception of corrosion resistant metals and track shall have a protective finish. The finish shall be free from imperfections such as scratches, chips, or other damage which detracts from the appearance or corrosion resistance.

NOTE: This provision is applicable to only electronic housings and assemblies.

3.10.7 Foreign Material

After fabrication, all chassis parts, components, and assemblies shall be clean and free of dirt, and grease; loose, splattered or excess solder or other foreign material.

3.10.8 Controls and Indicators

Control devices should provide for maximum operator control, accuracy and convenience. Important considerations include:

- Control Marking All letters, numbers and division marks must be clear and legible under normal lighting conditions.
- Control and Indicator Rotation Valves should increase with a clockwise rotation or movement, unless prohibited by design.
- Movement Controls should function smoothly and freely without binding. There shall be no excessive play or backlash which would contribute to inaccurate settings or poor equipment operation.
- Adjustment Control settings should be positioned at midrange for normal operation. Settings at upper or lower limits of the control shall be avoided. Controls located within the equipment enclosure shall be identified and be readily accessible for adjustment.
- Locking Provisions Controls shall maintain their settings under normal operating conditions. When controls are critical or are likely to change adjustment, locking provisions shall be incorporated.

3.10.9 Threaded Parts or Devices Screws, nuts and bolts shall show no evidence of cross threading, mutilation, detrimental or hazardous burns. Additionally, all screw type fasteners shall be tight. The word tight means the screw shall be firmly secured and that there shall be no relative movement possible between the attached parts.

3.10.10 Riveting

The riveting operation shall be carefully performed in order to assure that rivets are tight and satisfactorily headed with the rivet heads tightly seated against their bearing surface.

3.10.11 Calibration

Inspection, measuring and test equipment, used by the contractors in the inspection and test of the procured item, shall be calibrated at schedule intervals against certified standards, which have known, valid relationships to national standards, within the state-of-the-art limitations.

3.10.12 Identification (End Item)

Unless otherwise specified by LIRR purchase orders, each end-item shall be legibly and permanently identified with the manufacturer's name, model and serial number. Equipment not normally serialized shall be directly traceable to the manufacturer's identification system.

3.10.13 Safety Provisions

The design and construction of the equipment shall provide maximum safety for operating and servicing personnel:

Warning Notices

- When high voltages or other hazards are present, an appropriate legible warning notice shall be permanently attached to the equipment.

Grounding

- All chassis areas used as a ground shall be free of finishes having insulating characteristics. Ground connections shall be mechanically and electrically secure to the metal chassis. Power input cable shall provide for an equipment ground.

Conditions Harmful to Personnel

- Where dangerous voltages, pressures, etc. exist or are likely to be encountered by servicing personnel, safety provisions shall be provided such as protective covers, interlocks, etc.

3.10.14 Preparation for Shipment

- The Supplier shall maintain adequate control during shipment preparation to ensure that the quality of the fabricated articles is maintained. The supplier shall ensure that all articles are complete as specified, and that damage, deterioration, loss or unauthorized substitution is prevented.

3.11 Supplier Cooperation

- The LIRR encourages early resolution of any problems, or questions relating to the Supplier quality requirements. The LIRR Quality Assurance Department will provide assistance and consultation upon request for our material benefit. Questions or requests for assistance should be directed to the cognizant Project Manager at the LIRR.

APPENDIX C

DOCUMENTED CASE STUDIES

Case # 1 – New York City Transit (NYCT)/ 63rd Street Connection Project

Case # 2 – Port Authority of Allegheny County West Busway/Wabash HOV Facility Project

Case # 3 – Houston METRO/ Louisiana Street Reconstruction Project

Case # 4 – Central Ohio Transit Authority (COTA)/Preliminary Engineering for Downtown Multi-Modal Transportation Terminal (MMTT)

Case # 5 – Washington Metropolitan Area Transit Authority (WMATA) – Metrorail

Case # 6 – Tren Urbano / Puerto Rico Highway and Transportation Authority (PRHTA)

Case #7 – Montgomery County Department of Public Works and Transportation, Maryland/Shady Grove Parking Structure 2

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QA/QC CASE STUDY #1

New York City Transit (NYCT)/ 63rd Street Connection Project

Delivery Method	Design-Bid-Build
Project Description	<ul style="list-style-type: none"> • One-third mile of new tunnel construction to connect the 63rd Street tunnel in Manhattan to the Queens Boulevard Line in Long Island City, Queens and relieve congestion in the existing 53rd Street tunnel. • The project also consisted of widening the Queens Boulevard subway line between Queens Plaza and 36th Street in order to accommodate new ramps from the 63rd Street tunnel to come up between the local and express rail tracks in both directions. • Other project components included new ventilation plants, pump rooms, circuit breaker houses, substations, tunnel lighting, computer-based control systems, communications equipment, and property acquisition. • The project was completed while regular subway operations continued. Final track and signal work was completed in September 2001. • The project was divided into five phases from project planning to testing and start-up. Innovative construction techniques were applied during the early tunnel excavation and underpinning phases.
Total Project Cost	\$645 million
Timeline/Milestones	
Construction Start	June 1994
Service Began	January 2001

Lessons Learned

The 63rd Street Connection Project to the Queens Boulevard Lines is a very large and complex subway project that has involved six construction contracts and various construction activities including cut and cover, drill and blast, and pit and beam underpinning tunneling methods. Construction has spanned over 7 years while the subway has been in full operation.

The project required that all general contractors possess a quality program, which NYCT monitored and evaluated. The agency also initiated and successfully implemented a quality program for the project. This program was originally intended to ensure contractor conformance for quality and safety, but evolved into a more comprehensive tool to support continuous improvements of methods and products. It was also accepted by all project participants (i.e., contractors, NYCT program personnel, designers, FTA, MTA, and their respective oversight consultants), ensuring strong and dynamic partnerships that minimized rework, improved communications, and provided guidance. The lessons identified by the NYCT in the documented project lessons learned of October 2000 involved three key elements of the quality program – (1) preparatory phase construction inspection, (2) contractor performance rating system, and (3) just-in-time training – and are detailed below.

Lesson 1. Emphasis on the Preparatory Phase of Construction

An emphasis on the preparation phase of each new construction activity enabled project participants to coordinate their efforts and review the upcoming work together to ensure that the job was done right the first time and expeditiously. A preparatory phase before construction is specified by NYCT contracts; however, the first time it was fully implemented was in the 63rd Street project. Previously,

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New York City Transit (NYCT)/ 63rd Street Connection Project

preparatory activities for construction performed by contractors were limited in scope and independent of the NYCT. Consequently, the NYCT began requiring several joint procedures before all major construction so that all activities were understood and coordinated, to clearly communicate expectations about the final product, and to limit nonconformance. These goals were accomplished by a series of meetings and other activities identified by the NYCT, which included:

a. Review of Contract Requirements with the Contractor

This is a joint effort with the contractor to review the status of submittals (i.e., materials, shop drawings, procedures, and methods); clarify installation methods; define records to be maintained; develop checklists; determine hold and witness points; outline responsibilities; identify critical safety issues; and assess training needs for NYCT and contractor staff.

b. Review of Physical Field Conditions

This is another joint effort by the NYCT, contractors, installers, the contractor's quality engineer, and the designer's field engineers to ensure that the scheduled work is ready to be performed according to a risk assessment; the availability of materials, workers, and equipment on the site; the condition of the work site; and sample work already completed (where applicable).

c. Kick-off Meeting/Summary of Preparation Phase

The kick-off meeting brings together all members of the team to discuss preparatory phase findings, points out concern, and reach agreement on the process of upcoming work. Attendees from NYCT usually included the field engineer, resident engineer, representative from the user group, project QA personnel, project safety personnel, and specialized consultant. The contractor is usually represented by the installer (superintendent and foreman), quality assurance engineer, safety engineer, and project manager. Agenda items at the meeting include discussion of the work approach, action plan, requirements, anticipated difficulties, and a contingency plan.

d. Leadership

The highest ranking NYCT project executive, usually the program manager, personally discusses with the field engineers and contractors the importance of preparations to construction, periodically attending preparatory phase meetings to reinforce the message.

The results from the enhanced preparatory phase of the quality program identified during the 63rd Street Connection project included:

- Better relationships between contract parties;
- Contractors (who were initially reluctant to participate) became more active participants;
- Preparatory phase inspections and consequent revisions to the work plan assisted the contractors in meeting budget and schedule targets;
- The original design was improved from consultant and contractor input;
- NYCT was able to provide better support to contractors and field staff;
- A baseline agreement was established that provided guidance when discrepancies arose; and most importantly,
- The vast majority of the work was performed correctly, minimizing punchlist items, rework, and the turnover time of the project.

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New York City Transit (NYCT)/ 63rd Street Connection Project

Lesson 2. Measuring Contractor Compliance

A second key lesson learned during the 63rd Street Connection project involved the contractor performance rating system that measured contractor compliance and became a driving force for improvement.

In the very beginning of the project, the NYCT evaluated all six, project contractors on the implementation of their quality programs on a quarterly basis. The outcome of the original process was a qualitative attribute rating (i.e., satisfactory, needs improvement, and unsatisfactory) that did not satisfy the NYCT, contractors, or oversight agencies. As a result and in partnership with the contractors, the NYCT developed a more objective numeric ratings criteria and evaluation process of contractor performance. The process was consistently implemented every quarter and for each contractor until project close-out. The goals were to "create a performance evaluation system to ensure consistent ratings for satisfactory performance, recognize success and outstanding results with uniformity for all six contractors." The steps involved in the new rating system are listed below.

- a. Ten basic "elements" of the contractor's quality program evaluated:
 1. Quality organization
 2. Submittal management and document control
 3. Receiving, handling and storage of materials and equipment
 4. Subcontractor and supplier control
 5. Inspection and test program
 6. Control of construction processes
 7. Control of measuring and testing equipment
 8. Control of nonconforming conditions
 9. Internal audits
 10. Documentation by quality records.
- b. Quarterly evaluations were performed on five of the ten elements as identified by NYCT and each contractor, including two key elements that were evaluated every quarter – "control of nonconforming conditions" and "inspection and test program." All ten elements were evaluated at least once per year.
- c. Under the new system, each quality program element was evaluated for the approach or planning, deployment or implementation, and results or effectiveness. Therefore, a successful element is evident from a combination of planning, implementation, and demonstrated results.
- d. In scoring an element, several "checkpoints" were verified and evaluated. These checkpoints can be documentation or construction activities, depending on the element or nature of the work observed. The checkpoints are rated up to 30 points for being complete (planned), up to 40 points for being current and correct (implemented as planned), and up to 30 points for achieving the desired results. The ratings are tabulated directly on the checkpoint forms along with comments and an average score is calculated for each element.
- e. An overall contractor rating for the quarter is simply the average of the five individual element scores for the quarter. The contractor's performance is considered "satisfactory" if the final rating is greater than 75 points, "needs improvement" if between 50 and 75 points, and "unsatisfactory" if less than 50 points.
- f. The contractor is allowed to review and comment on the preliminary ratings during a 48-hour grace period. The construction manager approves the final ratings.

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New York City Transit (NYCT)/ 63rd Street Connection Project

As a result of this document review and compliance process, the NYCT saw steady progress from the contractors in achieving quality program requirements. Outstanding contractors were also recognized from the ratings process. In sum, the majority of the work for the project was done right and with minimal rework. The results justify the application of this process to other projects and contracts.

Lesson 3. Just-In-Time Training

Training was once viewed as taking time away from "real work" and a "costly overhead expense." However, the experience of NYCT in the 63rd Street Connection project has proven that proper and timely training can provide large returns by eliminating direct charges for rework and mistakes, and providing a safer and more productive work environment.

The challenges faced by NYCT that prompted the creation of a specific project training program, known as New Routes, included:

- The NYCT program staff that managed the project ranged from veterans and experts to college interns or others with no experience in the construction methods proposed.
- Standard construction hazards were exacerbated on this project by continuous subway operations, stability issues of surrounding buildings, and highway settlement.
- While conscious of project and contractor budget constraints, quality and an effective interface of the program team to many disciplines and contractors were critical concerns.

The objectives of the New Routes training program were to focus on near future work activities to provide "just-in-time" training, improve the field engineering skills, increase quality and safety awareness, and help with self-improvement and team building. Therefore, the scope of the training program included technical engineering disciplines, specific work element installation processes, field engineering, construction management, project management, QA/QC procedures, general and project specific safety, and team building. The instructors came from a variety of backgrounds, both inside and outside the project, as dictated by the training needs. They included outside experts, project managers, project team members with specialized knowledge, contractors, consultants, and FTA and MTA oversight consultants. The training was organized more like workshops rather than lectures. In fact, a number of sessions were conducted in the field to demonstrate tasks such as waterproofing, rail weld grinding, jet grouting, and concrete placement. Other training sessions were held in the project offices.

The training participants included NYCT field and office personnel on the project, user/maintenance groups, QA, safety, contractors, consultants, and project management oversight consultants. The twice-a-week training sessions were scheduled in advance, and usually fell on the same time and day of the week or at night to encourage participation from the night shift of this 24-hour operation. A training database was developed using Microsoft Access to record the training completed by each participant. This tool allowed the project to maintain an inventory of skills and disciplines and further identify the needs.

Part of the success of the training program was due to its constant emphasis by the project leadership. Although the quality representative within the program group administered the training program, the project manager did follow up on training status and attendance, and was one of the most enthusiastic participants of the sessions. Training needs and results were discussed at biweekly staff meetings and monthly quality update meetings. A training summary, including future schedules and reports, was issued monthly. Each course had a written outline and other handout materials that

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New York City Transit (NYCT)/ 63rd Street Connection Project

became a part of the technical library. The sessions were also evaluated by the participants who provided feedback to the instructors.

The results of the New Routes training program are characterized by the NYCT as a general increase in the level of professional and technical skills. About 120 sessions were held from 1995 to 1999 that included topics such as scheduling, specifications, concrete, signal design, steel installation, general orders, waterproofing, blasting, ISO 9000 quality standards, and utilities with over 1800 participants attending. The training ensured that project safety indicators exceeded industry standards, that the proper material was installed, and that proper procedures were followed. For instance, a session on the rail weld grinding process and inspection criteria was given after mistakes and defects prompted the stop of all work on this task. After the training, no additional defects were detected. Specialized outside knowledge also enhanced productivity and reduced mistakes. For example, the NYCT inspectors received training on two complicated construction procedures, jet grouting and slurry walls.

Finally, the NYCT also believes that training improved morale and strengthened relationships between the people who performed the work and those who provide oversight. In the end, the majority of the project work was completed correctly with little to no rework and the NYCT has recommended the training program on future projects.

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QA/QC CASE STUDY #2

Port Authority of Allegheny County West Busway/Wabash HOV Facility Project

Delivery Method	Design-Bid-Build
Project Description	Included: <ul style="list-style-type: none"> • Constructing 5 miles of exclusive bus right-of-way and associated access ramps • Constructing 6 stations • Constructing 6 park and ride facilities • Constructing 4,936 linear feet of noise walls • Reconstructing the Berry Street Tunnel • Reconstructing the Wabash Tunnel
Cost/Funding	
Project Cost	\$326.8 million
Timeline/Milestones	
Construction Date	October 27, 1994
Busway Opens	September 8, 2000
Completion Date	Minor construction remained on ramps and other contracts were let on park and ride facilities, which were still in construction as of December 2001.

Lessons Learned

The West Busway/Wabash HOV Facility Project is a very large project that has involved numerous contractors, 89 as of 6/30/00. While construction has spanned over 7 years and, although the busway is in operation, minor construction is still in progress. Implementing the FTA's Quality Assurance and Quality Control Guidelines on all of their projects has always been a priority with the Port Authority. However, "How to go beyond and use the guidelines to deliver a quality product?" on a construction project of this magnitude was the burning question in the minds of the Director of Civil Engineering and Quality and the Construction Manager. They did not believe that it was just enough to simply identify the requirement for a quality system in each of the numerous contract specifications. They also knew that most of the contractors would not be large entities that possessed quality staff personnel. Rather, they knew that the majority of the contractors would be small companies who, while capable of doing quality work, did not possess quality systems, against which they could be evaluated.

The Port Authority knew that the process of having the contractors tailor the quality system guidelines to fit the contractors' individual needs would be long and cumbersome with so many contractors involved in the project. Furthermore, they knew that the probability that the respective quality plans would all be consistent would be next to impossible. Finally, they knew that a quality plan for a large contractor would usually consist of more elements than a quality plan for a smaller contractor, based upon their individual scope of work.

The solution to this challenge came in the form of two sets of Port Authority guidelines that would lead the individual contractors through the process of developing a quality system and plan that would be tailored to the individual contractor's needs. The Port Authority developed these guidelines and entitled them "Guidelines for the Creation of a Quality Plan" and "Guidelines for the Creation of a Quality Plan (Minimum Requirements)."

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Port Authority of Allegheny County West Busway/Wabash HOV Facility Project

These guidelines list general requirements for each of the FTA Guideline fifteen elements, followed by a series of questions that are answered by the contractor in order to prepare a tailored quality system and plan. In addition, the Port Authority guidelines include various tools for use by the contractors, such as:

- A Responsibility Matrix
- An Engineering Change Notice Form
- A Document Control Matrix
- A Quality System Procedure Outline
- A Standard Operating Procedure Outline
- A Supplier Site Audit Checklist
- An Equipment Maintenance Log
- A Calibration Record Form
- A Nonconformance/Corrective Action Report Form
- A Summary of Nonconformance Reports Form
- A Process Audit Checklist
- An Employee Qualification/Training Record Form

By providing these guidelines to the individual contractors and then meeting with them, along with other key members of the project team, the Port Authority was assured that:

- Each of the contractors, whether large or small, was able to develop a quality system and plan in a fast, cost effective manner.
- The resulting quality systems and plans satisfied the requirements of the FTA guidelines, possessed the necessary quality elements, and were consistent from plan to plan.
- Every aspect of the West Busway/HOV Facility Project was implemented using a quality system.

QA/QC CASE STUDY #3

Houston METRO/ Louisiana Street Reconstruction Project

Delivery Method	Design-Bid-Build
Project Description	<ul style="list-style-type: none"> • Reconstruction of 34 blocks of a major thoroughfare running through the heart of downtown and midtown Houston as part of a \$250 million Downtown/Midtown Transit Streets Project. • Project components included street and sidewalk construction, upgrade of major public and private utilities, drainage enhancements, provision of diamond lanes for bus and carpool use, transit shelters and information kiosks, widened sidewalks, traffic signalization, landscaping and public art elements. • The project was constructed under three separate, sequential contracts. Major funding contributors included METRO, FTA, City of Houston and Downtown District. • Houston METRO provided the project management and hired design consultants. A construction management consultant provided CM services under METRO supervision. Onsite testing was performed by independent testing lab under contract to METRO.
Total Project Cost	\$ 24.7 million
Timeline/Milestones	
Start Dates	Segment 3 - July 1998 Segment 1 – February 1999 Segment 2 – August 2000.
Duration	Three years, four months
Lessons Learned	
<p>The Louisiana Street reconstruction project is part of a larger work program in downtown Houston under the supervision of the Metropolitan Transit Authority of Harris County (METRO). For the three contracts issued, METRO standard specification (section 01450) “Procedures and Quality Control” governed contractor QA/QC requirements for Segments 1 and 3, and METRO standard specification (section 01451) “Project Quality Control” governed contractor QA/QC requirements for Segment 2. The owner's quality assurance plan was prepared in accordance with METRO’s “Construction Quality Management Program” and the contractor QA/QC plans were prepared for each of the three contracts in accordance with the provisions of specification sections 01450 and 01451.</p> <p>The following are project lessons learned as provided by METRO staff.</p> <p>Lesson 1. Plan on training and extended follow-up when implementing a major change to the QA/QC program.</p> <p>In 1998 METRO adopted its “Construction Quality Management Program” and associated specifications. Significant responsibilities for project quality control activities (i.e. planning, inspection, testing, reporting and records preparation) were shifted from construction management (CM) personnel to the contractor’s quality control manager (CQCM). In the past, CM personnel had performed virtually all of the above listed functions. To familiarize the CM staff (both in-house and consultant personnel) with details of the new program, training sessions were conducted as implementation began. Early contractor submittals included Contractor QA/QC Plan and designation of CQCM. Informal contractor training included extensive plan review, mandatory</p>	

QA/QC CASE STUDY #3

Houston METRO/ Louisiana Street Reconstruction Project

QA/QC orientation meetings and active participation by METRO's QA Manager in early contractor QC activities, including weekly project meetings and the three-phase inspection process mandated by the program. Quality audits were conducted early in the construction contract to review daily inspection reports, test results and other required quality documents. Weekly project meeting agenda was designed to include quality issues including periodic review of contractor maintained "as-built" drawings. These training and monitoring activities were useful in the implementation of the program.

Lesson 2. The monthly line item payment for "full time" contractor quality control manager (CQCM) was determined to not be cost effective and QA/QC specifications were revised to eliminate this provision.

The inclusion of contract provisions to compensate contractors for the expenses of a dedicated CQCM was designed to address contractors' concerns, expressed during the partnering process during development of METRO's "Construction Quality Management Program". Contractors had argued that the proposed QA/QC provisions would result in added personnel costs and compensation should be made. Because METRO had traditionally structured roadway type construction contracts on a unit price bid basis, a pay item was included in the bid documents for contracts including the newly developed specification section 01450 "Procedures and Quality Control". Experience gained through the QA/QC process on Louisiana Street Segments 1 and 3, as well as other contracts underway at that time, led METRO to the conclusion that it was virtually impossible to assure that the CQCM was devoting full-time effort exclusively to QC activities. The availability of an experienced, well-qualified quality manager on the contractor's project staff invariably led to the assignment of other duties than those which were specifically quality related. CQCM personnel were observed functioning as assistant project manager or project engineer from time to time. Since METRO was unable to assure that CQCM worked exclusively on quality related matter, the specifications and approach were revised to better reflect reality. Monthly payment for the CQCM was eliminated, as was the requirement that that individual be employed on quality related duties on a full time basis. Specification section 01451 "Project Quality Control" was modified and further developed to reflect these and other changes and was adopted as the QA/QC standard specification governing most major construction contracts subsequently undertaken by METRO. Louisiana Street Segment 2, the third and final contract of Louisiana Street Reconstruction utilized specification 01451. The change has not led to any observable reduction in contractor quality program, has permitted easier migration of quality personnel between jobs to contractors holding multiple METRO contracts, and has reduced cost.

Lesson 3. Significant variations between bid quantities and actual paid quantities resulted in changes to procedures for establishing final quantity takeoffs included in bid documents and also to procedures for tracking installed quantities by CM personnel.

The Louisiana Street Reconstruction contracts were structured on a unit price basis as is customary for most roadway/utility contracts in the Houston area. Early on, METRO experienced numerous variations between planned and installed quantities. The resulting change orders to address quantity variations attracted management attention and direction for corrective action. Initially the problem was assumed to be errors in the final takeoffs prepared by the design consultants responsible for the bid documents. While in some instances takeoff errors did occur, it was also found that differing site conditions sometimes necessitated field changes resulting in quantity overruns. For example, new utility lines frequently had to be rerouted to avoid conflict with existing unrecorded utilities uncovered in the course of construction. Additional pipe, manholes or other features often resulted

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from these field changes. At the completion of the job, quantity variations could be substantial.

The corrective action plan focused on design, estimating and construction management procedures in an effort to reduce takeoff errors and to properly track valid quantity variations. Final quantity takeoffs are to be performed and checked by the design consultant. In addition, an independent estimating consultant is to perform a quantity takeoff and produce a variance report identifying any differences in quantities reported. Finally, the design consultant is responsible for reconciliation of any differences based on the variance report. As further insurance against overruns, the project manager is to apply a contingency factor to those quantities that have historically experienced overruns due to changed conditions.

Tracking of actual quantities versus planned quantities has been emphasized in construction management practice. Our procedures provide for a constructibility review performed by the CM consultant that furnishes the resident engineer and inspector(s) for the contract. Quantities are subject to particular emphasis during this final review of bid-ready documents. Additionally, the means of payment for installed bid items has been automated. Prior to the adoption of a common software program (now used on all Downtown/Midtown Transit Street contracts), installed quantities were entered in manual logbooks and reconciled with the contractors' invoice with each pay application. Among other benefits, this software includes a column showing the percentage of each bid item installed based on the original bid quantity. The means for early identification of items that will potentially overrun the estimate is readily available. Data is updated with each pay application. The adoption of these new procedures and preventive action plan resulted from root cause evaluation and is expected to prevent or better predict quantity variations in future contracts.

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QA/QC CASE STUDY #4

Central Ohio Transit Authority (COTA)/ Preliminary Engineering for Downtown Multi-Modal Transportation Terminal (MMTT)

Project Description	Includes design for: <ul style="list-style-type: none"> • New 12-bay, express bus terminal with entry/exits off High and Front Streets in downtown Columbus, Ohio • Ticketing/waiting/retail mezzanine levels • 28,000 square foot facility for future COTA Administration • Proposed site is over active freight rail lines, also proposed for future commuter/Amtrak service
Estimated Construction Cost	\$34 million
Timeline/Milestones	
Prelim. Engineering	October 2000 – December 2001
Final Design	June 2002 – June 2003 (tentative)
Construction	September 2003 – December 2005 (tentative)

Lessons Learned

The Central Ohio Transit Authority (COTA), in cooperation with the Mid-Ohio Regional Planning Commission (MORPC), has been pursuing the development of a multimodal transportation center in downtown Columbus for a number of years. According to the MORPC 2025 Transportation Plan, this center will have the ability to accommodate a variety of modes including taxis, buses, intercity rail service, future transit services, and bicycle and pedestrian traffic. The facility and surrounding area is also planned for a number of joint development uses including concessions, hotel, commercial, office, residential, and parking.

In 1994, MORPC completed a study to site the proposed multimodal transportation terminal (MMTT). The resulting location at High Street and Nationwide Boulevard would be accessible from the convention center and major downtown office buildings, and would integrate the new and proposed developments on the northern edge of downtown. Since then, COTA has worked with the railroads to conduct early surveys of the site and formulate legal agreements to pursue preliminary engineering work. Additionally, COTA has been fostering relationships with potential development partners to assist with financing the project. A market study performed in 2001 provided COTA with information on the types and amount of development that the MMTT site and facility would support.

One of the biggest challenges encountered with the project arose from subsequent discussions with CSX and NS Railroads. The proposed project site is directly over a junction of the CSX Buckeye Line and NS Cincinnati Line from the west that essentially shares a double-track right-of-way eastward. The site at track level is already heavily congested with existing columns from various street and roadway bridges above. The design for the new building structural support system has to accommodate future utilities, platforms, escalators and elevators to support future passenger rail service and provide the necessary vertical and horizontal clearance operating envelopes required by the railroads. The combination of these design requirements proved to be extremely challenging.

Further complicating the design process were the necessary engineering review periods by the railroads. COTA staff had little or no control over the process and had difficulty maintaining other pertinent timetables for the project. Although cooperative, it was difficult to gauge progress of reviews by the railroads since they were understandably more concerned with direct business-related initiatives. Nonetheless, COTA was eventually able to secure conditional approvals of the design by

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Central Ohio Transit Authority (COTA)/ Preliminary Engineering for Downtown Multi-Modal Transportation Terminal (MMTT)

the railroads, with the understanding that COTA staff would continue to work with the railroad's local and regional engineering and operating staff.

The key lesson from the project's preliminary engineering phase is that it is important not to underestimate or randomly dismiss the requirements of Class I railroads when working within their operating environment. This is true not only in terms of review times, but also in estimating applicable construction costs. Under these circumstances, the factors in cost estimation should include engineering review time, flagging costs for surveying (which is also necessary during construction), drainage, crash walls, etc.

QA/QC CASE STUDY #5

Washington Metropolitan Area Transit Authority (WMATA) – Metrorail

Delivery Method	Design-Bid-Build
Project Description	<p>The 103-mile Adopted Regional Metrorail System in Metropolitan Washington was completed in January 2001 after a 32-year construction effort by WMATA. The engineering and construction of this heavy rail transit system is considered one of the largest single public works projects of its type in the United States.</p> <p>During the first phase of the system's construction (89.5 miles), construction duration of a “typical “ station and a line section from the start of excavation to systems testing and start-up was 50 and 60 months, respectively. For the second phase of the construction program (13.5 miles), construction duration of a “typical” station and a line section from the start of the excavation to systems testing and start-up was 45 and 50 months, respectively. The second phase fast-track construction program included the following projects completed from June 1997 to January 2001:</p> <ul style="list-style-type: none"> • Blue Line from Van Dorn Street to Franconia-Springfield: \$74.7 million • Red Line from Wheaton to Glenmont: \$52 million • Green Line from U St-Cardozo to Fort Totten: \$7.1 million • Green Line extension from Anacostia to Branch Ave: \$145.4 million <p>Presently, two design-build contracts are being considered for a Blue Line Extension to Largo scheduled for completion within 42 months, for both track (3.1 miles) and 2 stations with parking, respectively.</p>
Total Project Cost	\$9.4 billion (uninflated cost of first and second phases of Metrorail)
Timeline/Milestones	
First Phase Groundbreaking	December 1969
First Segment Opens	March 1976
Final Segment of 2nd Phase Completed	January 2001
Lessons Learned	
<p>WMATA's Construction Contract Quality Assurance Program: WMATA required a Contractor Quality Control System (CQCS) in major civil construction contracts (in excess of \$10 million), from the mid 1980's through 2001. The construction contracts included minimum requirements for the CQCS and instructed contractors to describe the CQCS in a Quality Plan that was to be submitted and approved by WMATA prior to the start of work. Upon approval, WMATA's Resident Engineer and QA/QC staff monitored the implementation and effectiveness of the CQCS through field observations, inspections and audits.</p> <p>The success of the CQCS program varied depending upon the attitude of the contractor's job site personnel towards the CQCS program and the willingness of the contractor personnel to work as a team. Many contractors believed that the CQCS added little value to contractor operations. QA/QC staff was viewed as a contract requirement as opposed to an essential part of the project staff. In those instances where the CQCS program was successful, the CQCS staff performed as an integral part of the</p>	

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Washington Metropolitan Area Transit Authority (WMATA) – Metrorail

Contractor's job site team and was fully involved in the planning and execution of the work.

WMATA attempted to motivate Contractors to have a more positive attitude towards the CQCS program by introducing a Quality Awareness Program (QAP). The QAP included payments to the contractor for implementing an effective CQCS. The value of the QAP equaled 1% of the bid items and was included in the total bid price. QAP payments were made monthly if the CQCS was effective. Payments withheld because of an ineffective CQCS were forfeited and the value of the contract was reduced accordingly.

The contract included specific conditions that had to be met in order for a QAP payment to be made. The conditions were mandatory and not up to the discretion of the Resident Engineer. QAP payments were not paid in those months according to the following conditions:

- Payment was denied for a portion of the work that was determined to be deficient and non-compliant.
- The Engineer had determined that the contractor had installed unapproved or unsatisfactory material, components, or equipment.
- The Engineer had notified the contractor of deviations from the contract requirements for work in progress that resulted in the stoppage of the production of the work activity.
- The Engineer had written one or more stop work orders because work in progress was not in compliance with the contract requirements.
- The Engineer has provided more than three written notices, for work performed within the payment period, to initiate corrective action on construction work, procedures, or operations that do not meet the contract requirements.
- The Contracting Officer had determined that one or more of the Engineer's written corrective action or deviation notices demonstrate the severity, repetitive nature, or criticality of circumstances that the CQCS staff and/or procedures were not effectively controlling the quality of construction.
- The CQCS had been without the service of the approved full-time CQCS Manager and/or staff except where absences were for bona fide emergencies and the Contractor took appropriate steps, in the Engineer's judgment, to continue effective control of the quality.

WMATA anticipated that the QAP would motivate contractors possessing a marginal or ineffective CQCS to raise performance to an acceptable level. The QAP was introduced as a trial on a single contract in 1990. The contractor had previously performed work for WMATA and was familiar with the CQCS requirements. The contractor initially proposed a CQCS Manager who was unacceptable to WMATA. However, the second proposed candidate was found to be acceptable and was approved. The CQCS Manager proved to be an effective member of the project team and was recognized by the contractor as an asset to the project organization. An effective CQCS was implemented and the full QAP payment was made. The QAP did appear to motivate the contractor to have an effective CQCS although the trial itself was not conclusive.

The QAP was included in some subsequent contracts. Multiple QAP payments were withheld on two separate contracts with little or no improvement in CQCS effectiveness. One of the two contractors who had QAP payments withheld had also been awarded a contract without the QAP. Ironically, the contractor's CQCS on the contract without the QAP was highly effective and was viewed as a model for the rest of the WMATA contracting community. The CQCS was successfully implemented on this contract because the CQCS Manager effectively worked with the contractor's project staff in planning the work and thereby managed to prevent costly errors. Based on these results, WMATA had discontinued the QAP.

QA/QC CASE STUDY #6

Tren Urbano / Puerto Rico Highway and Transportation Authority (PRHTA)

Delivery Method	Hybrid (Design-Build and Design-Build-Operate-Maintain)
Project Description	<p>Phase I of the project includes:</p> <ul style="list-style-type: none"> • 17.2-kilometer heavy rail line in the San Juan Metropolitan Area serving Bayamón, Guaynabo, the Medical Center, University of Puerto Rico/Río Piedras, Hato Rey and Santurce. • 16 stations and a maintenance yard • About 50% of alignment makes use of existing right-of-way • More than half of the alignment is elevated, the remainder is at-grade or underground
Total Project Cost	\$1.68 billion
Timeline/Milestones	
Construction Start	1996
Completion Date	2003 (expected)

Quality Program Features and Lessons Learned

The Tren Urbano project is a very large transit project and the first of its kind in Puerto Rico or the Caribbean. As one of five "turnkey" demonstration projects selected by the Federal Transit Administration (FTA), one of its goals was to demonstrate advantages in project time reduction, cost savings, and new technology introduction over traditional delivery methods. However, the project has been delayed and current costs are more than 30% over initial estimates. Nonetheless, the project has demonstrated innovative techniques in project delivery combining six design-build contracts for fixed facilities and sections of the alignment, with one design-build-operate-maintain (DBOM) contract awarded to the Siemens Transit Team (STTT) for the systems, vehicles, control center, maintenance yard, and a seventh alignment section to be used as a test track. The table below presents some details of each contract and an eighth contract awarded by the project for QC oversight assistance.

Contracts (by System Section/ Function)	Stations/Facilities	Section Length (km)	Contractor	Original Contract Value (\$million)	QC Firm	QC Bid Value (\$million)
1 Bayamón	Bayamón, Deportivo	2.9	Grupo Metro San Juan	71.50	Vivoni, Villegas & Assoc.	0.94
2 Río Bayamón	Jardines	1.7	Redondo-Entrecanales	37.90	Miguel P. Vélez	0.66
3 Centro Medico	Las Lomas, San Francisco, Centro Medico	2.5	Redondo-Entrecanales	74.10	Miguel P. Vélez	1.10
4 Villa Nevárez	Cupey	1.9	Redondo-Entrecanales	71.80	Miguel P. Vélez	1.80
5 Río Piedras	Río Piedras, Universidad	1.8	Grupo Kiewit (KKZ/CMA)	245.30	Grupo Kiewit	2.22
6 Hato Rey	Pinero, Domenech Roosevelt, Hato Rey, Sagrado Corazón	3.6	NECSO-Redondo	125.80	Carillo Di Jerónimo	1.33
7 STTT	Torrimar, Martínez Nadal, Maintenance Facility, Operations Control Center	2.6	Siemens Transit Team	612.50	Delta	2.10
8 QC Oversight Assistance to TUO (for all sections other than STTT)		--	Siemens Transit Team	--	Parsons-Brinckerhoff QC Specialists	15.00

The contracts for all design-build segments of the project, except Río Piedras, required the section contractors to hire an independent QC consultant. The role of these independent and certified QC inspectors was to provide the day-to-day quality control monitoring, inspecting, and testing of work at the construction sites. The Río Piedras segment was excluded from this requirement because of the special tunneling expertise required to oversee critical elements of the work. Therefore, Grupo Kiewit's QC staff worked independently of those with direct responsibility for the work.

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Tren Urbano / Puerto Rico Highway and Transportation Authority (PRHTA)

Quality is a stated top priority for the Tren Urbano Organization (TUO). Its QA/QC program is centered in the Implementation Department and the staff includes a QA/QC Manager, who oversees the entire QA/QC effort, as well as the QA Manager and the QC Manager. The TUO QA Manager's role is to ensure that the contractors fulfill the programmatic and procedural quality assurance requirements of their contracts. Specifically, the QA Manager's responsibilities include:

- Reviewing contractor quality assurance plans
- Auditing design and construction activities
- Conducting on-site surveillance
- Monitoring the status of issues raised in nonconformance reports
- Reviewing the documentation certifying all tests and inspections.

On the other hand, the TUO QC Manager has more technical responsibilities, including:

- Reviewing contractor quality control plans
- Approving the qualifications of contractor QC staff
- Reviewing construction work plans
- Ensuring the contractor is working to TUO-approved design plans
- Coordinating inspection plans and coverage
- Monitoring construction progress and nonconformance issues
- Working with the QC oversight consultant to ensure that each alignment section is compatible and coordinated to overall system designs.

As shown in the table above, a QC oversight consultant, Parsons-Brinckerhoff, was hired by TUO for the majority of the alignment. The duties of these Transit Construction QC Specialists include:

- Interfacing daily with contractor's QC supervisors to determine construction activities, inspections, and tests to be performed
- Inspecting work to ensure it is performed according to construction plans and contract requirements
- Completing daily inspection reports, work logs, and nonconformance reports
- Reviewing inspection and testing reports submitted by the contractor's QC supervisors
- Advising the Contract Manager of potential claims and assist in resolving technical issues
- Monitoring maintenance-of-traffic and archeological activities
- Performing weekly reviews of construction work plans.

Based on a telephone interview of TUO quality staff, the key challenges and lessons learned from the project are mostly related to the complications of managing seven separate contracts for the construction of the project and an eight contract for QC oversight.

Lesson 1. Along with the various contractors came several different non-conformance reporting systems that complicated the tracking and performance of work on the overall project. The key lesson from this is to develop a uniform nonconformance system with identical forms, logs, and tracking procedures between all contractors involved. Ideally, such a system should be electronic (to expedite processing and tracking) and approval should also be sought from the owner's Quality Manager prior to implementing the dispositions.

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Tren Urbano / Puerto Rico Highway and Transportation Authority (PRHTA)

Lesson 2. Each contractor involved in the Tren Urbano project hired a different QC consultant. Although this may have helped ensure the independence of the QC consultant and the contractor, it probably contributed to the complexity of the overall quality program because each QC consultant approached the work differently. The lesson here is that reducing the number of QC firms involved probably would have reduced the overall complexity of the quality program and perhaps saved time or costs.

Lesson 3. The seven separate contracts also included different quality specifications for each. This was an administrative complication that was not anticipated when the specifications were drafted and the contracts were awarded. The lesson learned is that consistent contract language would have resulted in a more integrated and consistent program that would have reduced the contract administration burden.

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QA/QC CASE STUDY #7

Montgomery County Department of Public Works and Transportation, Maryland/ Shady Grove Parking Structure 2

Delivery Method	Design-Bid-Build
Project Description	<ul style="list-style-type: none"> • Parking garage constructed on existing Washington Metropolitan Area Transit Authority (WMATA) park-and-ride lot serving the Shady Grove Metrorail Station. • The new garage will provide space for 2,140 vehicles, increasing total spaces available at Shady Grove by 1,530.
Total Project Cost	\$ 27.4 million
Timeline/Milestones	
Start Date	March 2001
Est. Completion	Early fall 2002

Lessons Learned

The lessons learned from Shady Grove Metro Station Parking Structure project stem from the Contractor's Quality Control (CQC) program. There have been several instances where the CQC program has been influential and where improvements to this program have been identified. The CQC program required the following components:

- Network Analysis Schedule (Critical Path Method, CPM, schedule)
- Schedule of Values
- Testing
- On-site CQC Manager
- CQC Daily and Monthly Reports
- Project Record Information

Lesson 1. The first major incident to occur during construction was the identification of the location of a water main running through the project site. According to the construction documents, a 6-foot diameter storm pipe was to be installed over both a 3-foot and a 4-foot water main. As part of the CQC requirement, the contractor had to provide a detailed plan of how each major task would be implemented. During the planning meeting, it was evident that a test pit was needed to resolve the uncertainty associated with the task. The test pits determined that the location was incorrect and the storm pipe would not clear the top of the water mains. Due to the advanced notice of this situation from the contractor the design team was able to respond in a timely manner without impacting the final completion date. This was significant since the installation of the 6-foot diameter storm pipe was on the critical path for construction.

For this situation, the CQC program helped in the following ways:

- It provided advanced notice of the conflict via the test pits.
- It identified this operation as being on the critical path.
- The contractor was required to analyze their CPM schedule to mitigate any long-term delays to the project.
- The situation could have been resolved more easily if the CQC planning and test pits were performed earlier.

Lesson 2. Another incident that posed a potential problem for the project involved a contractual safety issue. The contractor anticipated starting pre-cast erection several months into the project. Even before the project began, a safety plan was requested of the contractor showing their cranes and locations. The purpose for this information was to identify whether or not the cranes were set

QA/QC CASE STUDY #7

Montgomery County Department of Public Works and Transportation, Maryland/ Shady Grove Parking Structure 2

back far enough away from the railroad to avoid an overlap of a perceived area of crane collapse. When received, WMATA reviewed this submittal for compliance with their adjacent construction requirements. They noted that their requirements were not being met and would not allow the erection operation to commence. WMATA requested that much of the critical work closest to the tracks be done during the off-peak hours, moreover suggesting that the pre-cast erection be performed at night.

By way of construction meetings, negotiations and resubmissions of the crane safety information, a settlement was reached. It was determined that the erection could proceed using a shorter crane next to the tracks. It was also required that a flagman hold traffic on the adjacent WMATA owned road during erection picks in that area. As erection proceeded to a certain building height (5th level) and away from the tracks, the crane boom could be extended and the other safety measures eased.

For this situation, the CQC program helped in the following ways:

- Through submissions and resubmissions, information was transmitted until WMATA and the contractor were able to agree on a plan.
- What could have been a change order of over \$3 million for nighttime erection was reduced to an approximate \$80,000 cost impact to the project.
- CQC reports were able to track the actual time impacts associated with erection delays due to WMATA associated safety issues.
- This situation could have been avoided if the issues were addressed much earlier, such as during pre-construction.