Control of Construction Quality on Public Construction Managed by Consultants

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ABSTRACT

New York City Transit Authority, part of New York's Metropolitan Transportation Authority, has a Five-Year Capital Revitalization Program. Daniel, Mann, Johnson & Mendenhall, with its associates, London Transport International, Corddry, Carpenter, Dietz & Zack, and LeRoy Callender is the general consultant for the barns and shops and bus depot rehabilitation and improvement portion of the program. Control of construction quality starts with the design of this effort. How this is carried out is discussed. The various philosophies followed in engaging consultants are covered, and the considerations bearing on selecting one of these for a large transit project are discussed. Considerations discussed are (a) use of a group of individual section design consultants or construction supervision consultants managed directly by the public agency staff, (b) a single general consultant with section designers either under direct contract to the public agency or under subcontract to the general consultant, and (c) more than one consultant performing general functions--the most common arrangement is one consultant for design and one for construction management.

The New York City Transit Authority (NYCTA or TA) is the major arm of New York's Metropolitan Transportation Authority (MTA). The MTA is currently engaged in an $8.5 billion, Five-Year Capital Revitalization Program that was started in 1982. The TA's $6.4 billion portion of the total MTA program is significant. A large proportion of the TA's capital program covers the purchase of 1,375 rapid transit cars for $1.5 billion and 1,300 new buses for $260 million. The remaining part of the program is the improvement, to varying degrees, of all of the rail and bus transit facilities. Included in the rail segment are rehabilitation and improvement of passenger stations; line structures; line equipment; track; signals and communications; power equipment and substations; emergency power equipment; security systems; and barns, shops, and yards. For the bus system, the program includes the rehabilitation of bus depots and base maintenance shops and the construction of new facilities.

Daniel, Mann, Johnson & Mendenhall (DMJM) is the general consultant to the TA for an important portion ($900 million) of these rehabilitation and improvement efforts. DMJM is in association through subcontracts with London Transport International; Corddry, Carpenter Dietz & Zack; and LeRoy Callender. One area of heavy involvement for DMJM and its associates is the program for modernizing the car barns and shops, amounting to $472 million to be spent over 5 years. Another is the bus depot and base maintenance shop improvement and new facility development that calls for $427 million to be spent over the program's 5-year duration.

This discussion will be confined to the car barns and shops portion because the bus depot program is similar. As general consultant for the barns and shops portion of the TA program, DMJM is responsible for surveying the needs, both physical and operational, for improvement and rehabilitation of the individual barns and shops, and, based on these needs, developing the scopes for the individual designers charged with preparing contract documents. After selection of these individual consultants and negotiation of their contracts by the TA, DMJM has the responsibility for administering their design efforts and, in some cases, when construction starts, for administering the consultants retained for the technical inspection efforts. In addition, three of the thirteen barns are being handled under a turnkey contract, and DMJM has the responsibility for preparing the contract documents for bidding by the turnkey contractors and for administering the final design and inspecting the construction after award.

In this paper the general subject of the control of construction quality is addressed. This control must, of necessity, start with the design. For public works projects, the construction contractors are chosen on the basis of low bids, and in each case the construction is performed in accordance with plans and specifications on which this low bid is based. One measure of the quality of the final product is, therefore, the adequacy of the design and the completeness of the plans and specifications. Furthermore, as with all projects, the budget is a compelling factor in the determination of the extent of the work to be done. In the case of the rehabilitation, improvement, and extension of the existing TA facilities, this is even more important because of the extensive scope of the work to be performed. Therefore, the scope must be tailored to the funds available, and, after this is done, the design must be tailored to this scope. This is not an easy task, given the age and condition of existing facilities.

Let us look at how this is being done at the NYCTA. Using the available funds effectively required a comprehensive analysis of the needs of each of the barns and shops. Also required was the development of an overall maintenance policy for existing and new rolling stock to which the rehabilitated facilities are to be geared. These efforts involved research of records, visits to sites, physical surveys, interviews with management and maintenance personnel, observation of facility operating conditions, and analysis of the needs for improvements. Allied with this have been visits to other transit systems to see how they are operating and to determine what possible improvements might be applied to the NYCTA system.

It must be remembered that the barns and shops at NYCTA have been in existence for a long time and, unfortunately, have been allowed to deteriorate because of lack of funds. The lack of funds has led to deferred maintenance and, in many cases, lack of maintenance. Therefore, the primary effort of this

program has had to be geared to the upgrading of the physical condition of the facilities to provide a more suitable work environment. Coupled with this have been investigations of existing maintenance procedures and practices and analyses of the capability of the facilities to carry out the planned maintenance and repair functions. The more important improvements necessary have been identified and, with TA approval, the recommendations of DMJM have been incorporated in final design contracts.

Among the improvements that have resulted are a new system of blowing out the cars before inspection; a better procedure for cleaning and maintaining air conditioning equipment before inspection; providing for more effective chemical and water washing of trains; a new organization and refurbishment of wheel truing facilities; new 600-volt DC stinger systems in the barns; and renovation of heating, lighting, and electric power and distribution systems. Probably the most significant change being made to existing practices is the installation of a full-service utility track at each barn for use in making 10,000- and 30,000-mile inspections.

The utility track embodies a number of features that are new for the NYCTA including posted rails in lieu of pits, which make the undercar more accessible and provide more working space for the inspection staff; the utility track is long enough to accommodate an entire train. It is planned that this utility track will be used 24 hr a day for individual inspections and allied maintenance functions. The cars will be brought in just before midnight, and the first 8 hr will be devoted to the cleaning of the under portion of the cars to remove dust, dirt, and steel particles that have accumulated since the last inspection. The air conditioning condensors and filters will be cleaned during this time by washing them out with a high-powered liquid jet stream containing a chemical detergent. During the second 8-hr shift, the same utility track will be used for the physical inspection and replacement of defective or worn components. The third 8-hr period will be used mainly for cleaning the interior of the cars, and the final portion of this third 8-hr period will be used for the chemical cleaning of the exterior of the trains. This will be performed in an enclosed chemical wash facility located at one end of the utility track where feasible. The train will be taken out of the barn and then run in again through the chemical wash facility, where a foam chemical cleaner will be applied. The train will sit on the utility track for the required reaction time, some 6 or 8 min., and then be taken out through the wash facility to remove the chemical foam and rinse and dry the car. It should be noted that these chemical wash facilities will also provide a year-round capability to perform special graffiti removal washing on weekends. Because the normal chemical wash will be applied to the cars on a 6- to 8-week cycle, it is necessary to provide additional water wash facilities for normal exterior cleaning at the various yards. This will permit trains to be water washed at more frequent intervals than is now possible.

The two large repair shops that handle heavy repairs and overhaul of car systems (i.e., propulsion units, brakes, heating and ventilation equipment, doors and electrical systems) will be modernized to incorporate newer, more advanced machinery and thus increase car equipment reliability. A major goal is to reduce the number of car failures and increase the mean distance between failures, which is the major indicator of train service performance. In developing the scope for these improvements, industrial engineering studies were made to evaluate shop work flow and maintenance and repair procedures with a view to increasing productivity and cost-effectiveness. The primary functions of these shops are major overhaul and repairs, car retrofits, equipment repairs, maintenance of machinery and equipment, and provision of support to the barns. In addition to modernizing individual elements and the support shops within the shop complex, the industrial engineering analyses have resulted in revised layouts and machine placements to improve work flow, repair procedures, material handling, and the movement of personnel. One of the significant shop improvements is to provide the truck shop with a flowline procedure, which involves progressive movements of the trucks along an inspection and repair line, to replace the fixed work station concept currently in use. At the Coney Island Shop it was necessary to provide a new repair bay and revise one of the existing repair bays to handle new 75-ft-long cars, some 15 ft longer than existing vehicles, that will increase in numbers as the procurement contracts for new cars are implemented.

The rehabilitation aspects of the program include restoring the physical structure and improving operations by rehabilitating and replacing heating systems, putting in new overhead lighting to produce a better working atmosphere that will be conducive to safer operations, upgrading ventilation to improve the workers' environment, refurbishing and replacing as necessary water supply systems and drainage, installing new fire protection systems and equipment, and, in all of the facilities, modernizing and improving the employee welfare areas, locker rooms, toilets, and lunch rooms. In addition, machine tools and material handling equipment will be updated and, where called for, replaced by more modern equipment with greater output capability. Pit lighting will be improved and public address systems will be refurbished or replaced as appropriate. Air conditioning will be provided in certain office areas; electrical services will be upgraded to serve the increased electrical needs; storage space will be enlarged, better organized, and better lighted; modernized doors will be provided where necessary; defective or deteriorated windows will be replaced; leaking roofs will be repaired; and floors will be repaired or replaced where necessary. In addition, the general appearance of the facilities, exterior and interior, will be upgraded by selection of appropriate architectural finishes and painting.

Guidelines for all of these improvements and changes have been incorporated in the scopes of work that were prepared for use in requesting proposals from qualified designers and in negotiating contracts with the successful consultants. Since these consultants were hired, it has been DMJM's responsibility to coordinate and administer their efforts in such a way that the scopes are complied with while the individual, specific requirements of the various barns and the two shops are accommodated. In the process of doing their designs, the consultants must, of necessity, base them on the requirements of the individual locations. They must consult with key personnel responsible for operating these facilities and, in many cases, resolve conflicting requests. It is DMJM's job to coordinate the consultants' efforts to ensure that there is compatibility between the designs for the various similar installations and, at the same time, to ensure that the designs meet the needs at the various facilities.

The construction phase of the rehabilitation and improvement of the barns and shops is currently in its initial stages. DMJM's part in construction management and technical inspection has been confined to participating in the rehabilitation of some of the passenger stations, one shop improvement contract, a barn extension, and the three barns in the

turnkey contract. Field inspection and construction management, as they relate to the quality of construction and conformance to the contract documents, are primarily practical, not theoretical.

The realization of a superior program of overseeing construction depends on achieving a number of results. The primary ones can be summarized as follows: adherence by contractors to the standards of materials and craftsmanship specified by the design consultants; avoidance of construction costs in excess of the approved contract costs; and adherence to construction schedules. To meet these goals, it is essential that the construction manager maintain on-going liaison between the design consultant, the contractor, and the client to assure prompt decisions and execution of the work called for in the contract. Some of the elements that go into achieving this are monitoring construction; checking shop drawings and evaluating materials for conformity with the specifications; eliminating unacceptable substitutions; interpreting the contract documents in cases of question; monitoring the coordination of the various trades involved in the construction; acting in a timely manner regarding adherence to progress schedules and cost constraints; preparing periodic reports on the progress of the project to keep the client and other agencies suitably informed; promptly issuing reports on safety violations; and, of course, analyzing field changes and any other extra work orders for validity of necessity and cost.

These activities are essential regardless of who is exercising the construction management--the owner or a consultant. The primary difference that exists when a consultant manages is that the construction contract is with the owner. In this case, there is a different relationship between the construction manager and the contractor than would exist if the construction manager were also a member of the owner's staff. This difference requires effective liaison between the construction manager and the client or owner. The ability of the consultant to carry out the construction management responsibilities is enhanced by a careful delineation by the client of the consultant's duties and responsibilities. It is important that this be definitively covered in the contract documents. When this is done, the consultant's position with respect to the contractor is strengthened.

It is important that on a day-to-day basis the consultant be the sole contact with the contractor. Dividing this responsibility can erode the consultant's authority and result in numerous difficulties. Making the consultant construction manager totally responsible, insofar as possible, and retaining only the minimum necessary control of the financial aspects and of those items that cannot legally be delegated is the surest way to ensure that the consultant obtains good construction quality from the contractor.

There are numerous philosophies about engaging consultants for transit programs. Underlying all of these philosophies is an early determination by each public agency concerned of whether its technical, contractual, and administrative capabilities fall short of those needed for the development and execution of programs it desires to carry out. From the experience of the past several decades, it appears that many public agencies charged with transit development programs fall far short in terms of existing, in-house staff capabilities to develop and administer the multibillion dollar programs that have been needed or are under way in various metropolitan areas. Nevertheless, the public agency concerned must at the outset determine how much work should be accounted for by its in-house staff and how much should be contracted for with consultants. It can be assumed, given the relatively tight time schedules, large dollar costs, and need for staff already trained and experienced in all major aspects of engineering, architecture, and management, that large blocks of work will be contracted to consultants in many of the major programs.

Accordingly, there is a variety of patterns of engaging consultants. To summarize, those that have been employed most often are

1. The public agency increases its technical and administrative in-house forces or uses its existing forces to manage directly a group of section designers or specific project design and construction supervision consultants.
2. The public agency contracts with a single consultant to furnish a general consultant organization, with section designers hired either under direct contract with the public agency or by subcontract to the general consultant. This general consultant furnishes both design and construction administration capabilities and manages the section designers, working closely with the public agency's staff, which usually is lacking in number.
3. The public agency contracts with more than one consultant to perform general consultant functions. One method is to contract with one consultant for design and a second for construction management. Another is to contract with one for facilities design, another for systems (including equipment procurement), possibly another for architecture, and still another for construction management.

Most engineers have, at one time or another during the past two decades, been exposed to all three of these methods of engaging consultants for transit programs. The strengths and weaknesses of each are well understood by those who have been continuously involved in this work during the 1960s, 1970s, and 1980s.

The usual perspective in the discussions leading to a determination by a public agency of which method, or variation, to employ in a specific program is that of tailoring a "plan of attack" to achieve the greatest cost-effectiveness, speed of execution, and overall efficiency given the particular circumstances of each public agency's budget, in-house staff levels, and time constraints (which are consistently tight).

It is possible, by calling on the 20+ years of experience gained from many different transit projects from the 1960s to the present, to draw some general conclusions about the most advantageous methods for engaging consultants.

The need for speed of accomplishment makes it essential that a tightly coordinated organization be put in place without the necessity of going through a long "learning curve" to get such an organization up to a high level of efficiency.

The need for cost controls that can be administered from a single organization, again tightly coordinated, is paramount if a wide variety of projects is to be completed within budget.

The need for quick and effective coordination of designs, for recognizing the owner's needs, and for monitoring the construction as it proceeds makes it highly desirable to have a dedicated project or program organization handle the total scope being prosecuted. The dedicated program organization should be in place from the outset of the program until the completion date.

It is undoubtedly true that older systems undergoing refurbishment and upgrading can have markedly different needs than do new systems. The older systems usually have fairly substantial in-house tech-

nical and administrative staffs that have been built up over the years and can furnish a broad range of capabilities. The newer systems, conversely, usually do not have such capability and would have to hire in-house staffs, necessitating a break-in and "learning curve" period to achieve effectiveness. In any event, time, cost, and design coordination still prevail as governing factors in tailoring the consultant forces to be engaged. This usually militates for achieving a "unity of effort" (i.e., a qualified consultant organization to take on the responsibility for program administration and planning, design, and construction management).

The author has observed and has been directly involved in major transit projects in which different philosophies have been employed. For example, in Baltimore, when the Metro was constructed, a variation of the multiple consultant philosophy was employed. At Bay Area Rapid Transit, on the other hand, the single consultant philosophy was used. Both projects were successful.

The author believes that the single consultant philosophy produces better results. It appears that the interests of the client are better served by having the same consultant responsible for managing both design and construction. The owner gets the product he desires with fewer problems and with less effort required on his part. It must be recognized that this is one point of view and that there will be just as many people who believe the opposite as who agree with this view.

The important thing is that it is possible to obtain a high level of quality in construction by using consultants, provided that the responsibility and the authority to carry out that responsibility are given to the consultant. Anyone who has been involved in large projects encompassing both new construction and the rehabilitation and improvement of existing facilities knows that the handling of new construction is immeasurably easier than handling the rehabilitation and improvement of existing facilities. This is natural because the rehabilitation and improvement of existing facilities must be done while operations at the facilities are maintained. However, the differences are largely a matter of degree and do not mean that consultants cannot or should not be used in either case.

In conclusion, it is emphasized that the control of construction quality on public construction is largely dependent on ensuring that the quality desired is incorporated in the design and the contract documents as a first step. This is necessary because the construction will undoubtedly be performed under contracts awarded on a low bid basis, with the construction geared to what has been specified in the contract. The construction manager must assure that the desired quality is achieved. He can do this when what is desired is well delineated in the contract documents. He can also ensure that the same quality is achieved if there are changes required as the contract progresses. When general consultants are necessary on a project, and on most large projects they probably are, either one of the philosophies described previously--separate consultants for various functions or a single consultant for all functions--may be followed. A number of people who advocate either of these philosophies will be found, but it is believed that there is some advantage in having a single general consultant responsible for all aspects of large projects.

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Contracting Practices and Payment Procedures

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ABSTRACT

A summary of National Cooperative Highway Research Program (NCHRP) Project 20-7, Task 23, is presented. The full report is available from TRB. The project evaluated nine selected topics concerning highway contracting practices and payment procedures. The topics include alternate bids, turnkey projects, incentive and disincentive provisions, retainage, documentation, methods of measurement, partial payments, payment for materials in storage or on hand, and acceptance and final payments. Included are recommendations for improving agency practices in these areas and a discussion of how agencies may apply these recommendations to their own operations.

A summary of the findings and conclusions of NCHRP Project 20-7, Task 23, is presented. The Agency Final Report for NCHRP Project 20-7, Task 23, "Contracting Practices and Payment Procedures" is available from TRB. The opinions and conclusions expressed or implied are those of the investigators and are not necessarily those of the sponsors of the research.

RESEARCH OBJECTIVES

Procedures for documenting quantities and payment for contract work require substantial amounts of agency personnel time often resulting in delayed payments. Improved contracting procedures and methods of determining reasonably accurate pay quantities could result in economic benefits to both public agencies and contractors and lower overall