system prior to excavation of the primary tunnel cross section. Although the design did not attempt to direct how the contractor should proceed with performance of the work, it clearly established an acceptable and safe sequencing of the work. The initial support system in this tunnel reach provided for a multidrift operation with crown and foundation drifts, in that order or simultaneously, to be completed prior to the excavation of sidewall and arch drifts, for a total of nine drifts in all. Considerable reluctance was expressed during the design phase of the first tunnel to a specification by the owner of such a support system.

The essential responsibility of the state and its engineers is to provide this type of basis on which the contractor can submit a bid proposal. Inherent with this, of course, is acceptance of the risk for the adequacy of the design and specifications. As a professional, this is a responsibility that the engineer must take. In addition, three other support systems, all of a horseshoe configuration, were provided. These were termed light, medium, and heavy tunnel support systems. Although the anticipated approximate stations for each of the four support systems were included in the plans as was a geologic summary of tunnel support types, these locations were not deemed to be fixed or unchanging, and throughout the construction process discussions with the contractor were considered as each support system was finally established. In my view, the proper role of the engineer as a designer and the contractor as a constructor was developed for this project. The design resulted in the contractor's confidence in the designer's understanding and knowledge about what was necessary to hold up the mountain and willingness to accept the risk of that design. Provision for alternate designs was not made but, in my judgment, the flexibility of set spacing and support system selection resulted in benefits equal to or better than what may have resulted from alternate design opportunities without the major problem of analysis of proposals by the contractor for comparability with the state's design. The design scheme for the construction of the support systems is available to the reader by contacting FHWA or the Colorado Department of Highways.

SUMMARY AND CONCLUSIONS

The innovations introduced into this project have the potential for continuing to improve or eliminate the adversarial relationship that is often thought must exist simply because the engineer and contractor have different perspectives on the purpose for their involvement in the project. This need not be the case. In fact, (a) their purpose for involvement in the project is more alike than dissimilar, (b) continued innovations are warranted to further improve the relationship, and (c) labor and materials escalation, bidder prequalification, affirmative design details, selective and proper use of escrow documents, and clear definition of dispute settlement procedures are a few of many possibilities for improving or eliminating an adversarial relationship that this paper has discussed. An overriding goal for underground construction should be the minimizing of adversarial relationships and, in its place, the development of a team concept between the engineer and contractor. For, after all, the mission of both is to produce works that are beneficial to the public and serve a useful societal need.

Management Strategies for Quality Assurance for Pittsburgh's South Busway

WALTER G. HEINTZLEMAN

The management strategies for quality assurance are examined for Pittsburgh's South Busway Program. Specific consideration is given to (a) management structure, (b) end-result specifications, (c) sharing areas of risk, (d) mutual respect, (e) open communications with bilateral resolution of issues, (f) process for feedback, and (g) monetary and nonmonetary rewards. The avoidance of adversarial relations between owner, engineer, and contractor was key to a successful quality program in an adversarial political environment.

This paper is the first of three to examine and evaluate management strategies for quality assurance used on Pittsburgh's South Busway Program from viewpoints of staff who represent the owner (Port Authority of Allegheny County), engineering manager, and a contractor. This evaluation is an outgrowth of the recognition of the interdependence of quality assurance and productivity and their dependence on management strategies.

These evaluations were initially stimulated as an outgrowth of ideas presented by Judson (1) in his paper at the American Society of Civil Engineers (ASCE) symposium on productivity in the construction industry. These ideas have been expanded in response to work being done by the Transportation Research Board.

BUSWAY DESCRIPTION

The port authority is engaged in a capital improvement program in excess of $0.5 billion. The first element constructed was the South Busway, a 6.4-km (4-mile), two-lane, two-direction, limited-access roadway. It begins at the Smithfield Bridge near downtown Pittsburgh and travels in a southerly direction through a 1.04-km (3400-ft) bus-trolley tunnel, through a trolley yard, across a new 520-m (1700-ft) bridge that crosses two major arteries, and then along a steep hillside that is parallel to the Norfolk and Western (N&W) railroad tracks for 2.5 km (1.5 miles). The busway then drops under a newly constructed N&W railroad bridge to merge again on a common right-of-way with trolleys for the last 1.6 km (1 mile) to its current terminus at the PA-88--PA-51 Glenbury intersection. The busway has 11 stops and three on-off ramps. All bus service is via existing bus routes, which now use the South

Busway to avoid the congested Liberty Tunnels and Bridge and approach arteries.

The South Busway reduces normal travel time to downtown by as much as 15 min and, during times of heavy street congestion, by as much as 45 min. More importantly, the busway helps increase service reliability and reduces wait time for passengers from buses otherwise delayed in street traffic. The South Busway services approximately 21 000 patrons daily.

QUALITY-ASSURANCE OBJECTIVES

The objective of the busway construction program was to construct a busway that facilitates bus operations, has minimal maintenance, and also accomodates other concerned parties, at a cost that can be justified by the port authority and the funding bodies.

Quality-assurance objectives, from the owner's perspective, focused on the objectives of the busway construction program and, in turn, on the ultimate use of the busway from an operational and maintenance viewpoint.

The decisions of the authority's staff encouraged the engineer and contractor to follow these objectives as a guide.

ENVIRONMENT FOR QUALITY ASSURANCE

The owner, engineer, and contractor had to function within the political, social, and economic environment. In the early years of the project, the mayor of Pittsburgh vigorously opposed the project and publicly attacked construction contractors as the cause of the city's public works woes. It was popular and politically advantageous to use contractors as scapegoats and treat them in an adversarial manner.

Nonetheless, the staff for the owner, engineer, and legal counsel recognized that contractors must function cooperatively as important participants in the total effort and not be treated solely as advocates to the program.

MANAGEMENT STRATEGIES

Guided by the paper by Judson (1), seven strategies are presented that were effective in reaching quality-assurance objectives.

Management Structure

The authority tried to maximize private enterprise in design and construction. A small professional staff was employed to manage the program and the engineering management services of a general engineering consultant (GEC) were retained for engineering design and engineering management of construction. In turn, the GEC retained several subconsultants.

The actual construction was performed under contract to the authority, and contractors were selected through competitive bidding. Exceptions were track, signal, and communication work, which was handled mostly by force account.

Use of End-Result Specifications for Construction Contracts

Contract documents were based on the contractor's providing the end product, as configured in the specifications, to meet functional requirements within the time specified. Contractors were not told how to do the work, only what had to be done. The contractor guaranteed the work by bond for one year and, in some situations, up to five years. Inspectors were expected to anticipate problems and had to be problem solvers, not policemen. The authority expected the contractor to use quality-control standards to ensure that construction would meet those specifications that were designed around operational and maintenance requirements.

Management Risks

The owner and engineer made an effort to identify and deal with areas of potential risk in a timely manner. It is the policy of the port authority to identify known problems at the time of bidding and to share potential risk when feasible.

Mutual Respect

Perhaps the most important personal contribution in obtaining quality assurance was mutual respect. Mutual respect was important to develop trust and confidence in the performance of each entity in its area of authority. In this regard, it also was helpful to avoid second guessing, passing the buck, public criticism, and using other parties as scapegoats. Mutual respect also required understanding the role of others and the issues from their perspectives.

Open Communications and Bilateral Resolution of Issues

Mutual respect and willingness to identify and deal with risk generally led to open communications. An effort was made to avoid adversary relationships and to try to resolve issues with a cooperative approach within the framework of the contract documents. Open communications and bilateral resolution of issues provided the opportuntity for dozens of involved autonomous agencies and groups to participate in the process of identifying and resolving issues in a timely and relevant manner.

Process for Incorporating Learning into Future Actions

Four methods have been used to incorporate learning into future action:

1. Meetings, which provide opportunity for information and feedback;
2. Professional critiques;
3. Comparison of work done by contract with force account; and
4. Evaluation of finished work in light of alternate designs and management strategies.

Use of Monetary and Nonmonetary Rewards

Accurate, fair, and prompt payment for all work done in accordance with plans and specifications is, in itself, a form of reward.

Four methods of nonmonetary recognition also were used:

1. Personal expression of appreciation for work done well,
2. Letters of appreciation,
3. Professional recognition, and
4. Community recognition of work through the media.

CONCLUSION

These seven management strategies have been important in implementing the busway program. By com-

parison, these strategies could not be used effectively during the first few years of the busway program and productivity suffered. In the early 1970s, the program was delayed by political controversy, a year-long court suit, change in scope, and further studies. Openness and bilateral resolution of issues were not permitted by some municipal officials. This resulted in lack of information, lack of mutual respect and trust, subsequent delays in resolution of issues, redoing of work, and missed design opportunities.

Clearly, the management strategies found to be most effective in obtaining quality assurance while maintaining productivity were those that

1. Involved the parties in reaching mutually agreed-on objectives, and more important, agreeing on timely action;
2. Delineated areas of risk;
3. Avoided adversary relationships and encouraged mutual respect, with trust and confidence in the integrity of the involved parties;
4. Were based on open communications that allowed for bilateral resolution of issues;
5. Provided a process for feedback for future actions; and
6. Provided for monetary and nonmonetary rewards.

This list, although it is not exhaustive, has set the stage for effective action. The effectiveness of these strategies in obtaining quality assurance while maintaining construction productivity for the busway program can be further judged from the papers by Drosendahl and Mascaro in this Record, which provide viewpoints from the perspectives of an engineering manager for construction and a contractor.

REFERENCE

1. A.S. Judson. New Productivity Improvement Strategies for the Engineering-Construction Industry. In The Civil Engineer's Role in Productivity in the Construction Industry, ASCE, Vol. 1, 1977, pp. 49-67.

Construction of Pittsburgh's South Busway: An Engineer's Viewpoint

JON W. DROSENDAHL

Contractual relationships play an important role in the success of a construction project and must be defined by contract. However, the participants in a project bring their own objectives, ideas, strengths, and resources to the effort. Because of the interrelationships of the participants, these individual characteristics must be understood and a cooperative attitude must be developed. The engineer, because of his or her unique understanding of the project, can play a leadership role in the development of the necessary cooperative attitudes. When the engineer is successful in this role, the project is a success and the objectives of the participants are achieved.

This paper is based on the role of Michael Baker, Jr., Inc., in the development of the busway system for the Port Authority of Allegheny County. As explained in a companion paper by Heintzleman in this Record, a busway is essentially a two-lane highway built for the exclusive use of buses. These busways bypass extremely congested areas of Pittsburgh, which permits rapid movement of the buses into or out of the downtown area during rush hours.

The firm of Michael Baker, Jr., Inc., was engaged as the consulting engineer by the port authority to perform the planning, design, and construction management tasks in conjunction with the development of the South Busway and East Busway. This overall engineering effort was managed by Baker's director of engineering, who supervised the various discipline managers.

As manager of construction inspection services, I reported directly to the director of engineering and was responsible for the management of the construction effort required for busway construction. The actual construction was performed by independent construction companies under contract to the port authority. The viewpoint of one of these contractors is also being presented as a companion paper by Mascaro in this Record.

The busway program is considered quite successful. The South Busway was opened three years ago, within the anticipated time and within the budget. Construction overruns were limited to less than 7 percent of the contractual cost of the project and, in half the cases, it was the result of changes in scope required by the funding agencies after the design phase had been completed. The East Busway, now under construction and scheduled to be in operation by early 1983, is on schedule and within budget.

CONTRACTUAL RELATIONSHIPS

As indicated in Figure 1, both Cameron Construction Company and Michael Baker, Jr., Inc., were under direct contract to the port authority. Cameron was contractually responsible for providing a product that met specifications. To ensure that these specifications were met, Cameron also provided a specified testing program through an independent laboratory.

Michael Baker, Jr., Inc. was contractually responsible for development of the specifications for the product and the specifications for the testing program. Michael Baker, Jr., Inc. was also required to monitor the testing program and conduct inspections to ensure that the product met specifications.

This, of course, is generally regarded as the traditional approach to construction and has been practiced both successfully and unsuccessfully for hundreds of years. However, there is more to quality assurance than is indicated in this sketch. Figure 2 indicates the relationship of the project team as developed for the busway construction. The owner, engineer, and contractor are all shown overlapping at the center of the project because