provided by a stepboard, which retracts under the car when not in use. The footboard and the door are interlocked so that the door will not open until it is swung out, nor will the door close and lock unless the footboard is fully retracted.

2. The California Public Utilities Commission, following provisions of General Order 143, decided that because service would operate with numerous highway grade crossings, the cars should be equipped with collision posts. The Frankfurt U-2 does not have collision posts, but a rams-horn type was developed for Calgary, and this modification was used on the San Diego model.

3. The standard U-2 provides the operator with an entirely enclosed cabin. As the San Diego project developed, it became apparent that the operator, who was expected to provide passenger assistance when possible, should not be sealed off. This requirement called for a modification to provide a window in the rear wall and a dutch door cabin entrance.

4. The San Diego project called for chair lift access for elderly and handicapped passengers. Because there was no standard lift equipment, a development subproject was required. The car builder engaged a subsupplier, and the purchase order was amended in three ways. The first amendment provided for engineering and installation of one lift at the car builder's factory. The lift manufacturer and the car builder would then refine the design before proceeding further. The second amendment, a consequence of the first, called for modifying one end of each of 13 cars in preparation for later installation of the lifts in San Diego. The third amendment provided for lift installation on the cars in San Diego. Unfortunately, the operating experience with the lifts has been unsatisfactory.

5. The radio equipment was furnished separately from the car. The radio units are portable, but are located in a cradle/charger when on board, and are connected to a low-profile antenna on the car roof when the portable unit is encradled. The car builder prepared the necessary wiring harness, terminations, backboard, and roof plate so that the equipment could be installed after car delivery.

6. The fare collection system had not been resolved at the time of the car purchase order. It was thought then that there might be a requirement for onboard ticket cancellation. To prepare for that possibility, an amendment was prepared requiring the car builder to install wiring (six-line circuit) in stanchions near two doorways on each car and in the trainline. The wiring would provide battery energy and controls from the operator's console. These cars are so equipped, but the feature is not required and will remain unused.

7. Under the provisions of the California Public Utilities Commission General Order 143, light rail vehicles that operate on streets must have front, rear, and side markers and turn signals in accordance with the California Motor Vehicle Code. (It is interesting to note that the code does not itself require these markers.) The purchase order was amended to include the specific requirements of the motor vehicle code.

These seven amendments added about 6 percent to the base fleet price for the cars. In addition to the provisions of these amendments, the purchase order provided for spare parts, a maintenance contract for 1 year, which began in January 1981, and major shop equipment required to perform major maintenance on these cars.

CONCLUSIONS

Although the project criteria called for standard equipment and discouraged custom requirements, the San Diego light rail vehicle is not strictly an off-the-shelf standard nor was it unmodified. It is a standard design as evolved by the manufacturer from past projects and modified according to the particular requirements of this project. However, these modifications can be seen as contributions to the basic design of the car, and in this sense, the San Diego light rail vehicle is a standard car.

Optimizing the Light Rail Vehicle Pre-Procurement Effort

TITUS ANDRISAN, Parsons Brickerhoff-Gibbs & Hill

Over the past 18 years, great technological advancements have been made in the development of rail transit systems. In conjunction with these developments, vehicle systems, related equipment, and operating techniques have become more complex and costly. These factors result primarily from the requirements of accommodating overall system configuration, increased sophistication, Buy-America constraints, vehicle improvements and standardization impacts, initial capital cost versus life-cycle cost considerations, critical vehicle options, and many other factors that tend to complicate the procurement process.

The objective of optimizing the light rail vehicle pre-procurement effort—to satisfy all functional, operational, safety, and site-specific requirements within predictable and reasonably acceptable cost and time constraints—can only be accomplished through a systematic and practical approach. The approach must have sufficient flexibility to permit tailoring the pre-procurement process to the site-specific requirements and must consider the various financial and technical compromises and constraints that may be imposed on the procurement.

Over the past 18 years, great technological advancements have been made in the development of rail transit systems. In conjunction with these developments, vehicle systems, related equipment, and operating techniques have become more complex and costly. These factors result primarily from the requirements of accommodating overall system configuration, increased sophistication, Buy-America constraints, vehicle improvements and standardization impacts, initial capital cost versus life-cycle cost considerations, critical vehicle options, and many other factors that tend to complicate the procurement process. Periodic changes in employment, residential locations, and travel patterns also have a direct bearing on the selection of the most suitable and cost-effective transit system for a particular area.

Whether a new system is developed or an existing system rehabilitated, contractor assistance is frequently required. If government funds are used, the contractor must be selected through a bid process that allows two or more qualified candidates to bid on each system element to be acquired. The only control the transit authority has is to award the contract to the lowest responsible, responsive bidder that is in compliance with the bid documents for the particular system element. For transit authorities who are not dependent on funding from the government agencies bidding requirements are less rigid. If permitted by state or local law, they may negotiate a purchase order and an agreement with the preferred contractor, and thus avoid having to prepare a specification. The savings in time and money can be considerable.

Regardless of which procurement is used, the transit system should give serious consideration to the system element to be procured. The contract documents should have two objectives: (a) to provide a legal contract that can be established and executed, and (b) to define the general and detailed requirements for acquiring the vehicles that will result in efficient, reliable, safe, and maintainable operation.

These objectives can only be met within cost and time constraints through a systematic approach to pre-procurement. The effort must have sufficient flexibility to permit tailoring the pre-procurement process to the site-specific requirements and to accommodate the various financial and technical compromises and constraints that may be imposed.

SYSTEM CONFIGURATION

Light rail vehicle (LRV) requirements are contingent on the overall transit system configuration. When a new transit system is being developed, determining the LRV configuration may not be too difficult. The new track alignment and fixed structures, although dependent on site-specific constraints, may have flexibility to accommodate a preferred LRV. However, if an existing transit system is to be rehabilitated, the track alignment and fixed structures usually cannot be altered. Such constraints will have an effect on the LRV configuration.

INCREASED SOPHISTICATION

Increased sophistication of any system element may be desirable. However, added cost, increased equipment and interface complexity, and possible reduced initial reliability are usually associated with increased sophistication.

Because the sole purpose of the LRV is to transport the public, the vehicle and all of the major subsystems involved must ensure safe and reliable operation at the lowest possible cost. Serious consideration should be given to using service-proven vehicles and equipment, even if site-specific requirements necessitate certain modifications. The cost, in all probability, will be lower than with a vehicle that is more sophisticated, but untried.

BUY-AMERICA CONSTRAINTS

There are no American-owned LRV manufacturers at the present time. Although the existing Buy-America constraints ensure that most of the major subsystems will be available in the United States, some feel that the Buy-America constraints impose undesirable restrictions on foreign manufacturers. Buy-America constraints may hamper the vehicle supplier and at times even the transit system; they may add to procurement costs and time. Major impacts on LRV procurement are described below.

Design Changes

When procuring service-proven (off-the-shelf) vehicles, the manufacturer may be required to modify an existing vehicle system to satisfy site-specific requirements. As a result, different subsystem suppliers may be used, who may require changes on assembly and component drawings, possibly on as many as 4000 drawings, depending on the system involved. At a nominal cost of $400 per drawing, the cost could be $1.6 million. An added cost of this magnitude could increase the bid price.

Assembly Line

The general policy of foreign manufacturers is to intersperse several vehicle procurements in the same assembly facility. They not be able to do this if the Buy-America constraints are too severe. If procurements are required to be segregated, the manufacturer may not be able to maintain continuity of effort. The end result may be increased costs and schedule delays.

Shipment of Equipment

To comply with the Buy-America provisions, foreign manufacturers must transport some major subsystems and components from America to their overseas facility for final assembly. The equipment must then be shipped back to the transit system. Such extra shipments incur added costs.

Testing Program

Incorporating American-manufactured equipment into a previously service-proven vehicle may result in system interface conflicts that require additional tests to verify that the total vehicle is acceptable. The requirement for such added tests will obviously increase overall procurement costs.

VEHICLE IMPROVEMENTS AND STANDARDIZATION

Recently procured LRVs have been varied. Vehicle operational performance of some transit systems have had minor problems requiring minimal modifications; others have been extremely dissatisfied with delivery and subsequent pre-revenue performance and have required extensive retrofits before satisfactory operations were achieved. Vehicles may be unacceptable because they are highly sophisticated, because the vehicle or subsystem design is new, or because there are conflicts in the interface of major subsystems. Some of the problems might have been avoided through the procurement of service-proven vehicles or equipment.

An advantage of standardization includes lower costs and inventory storage requirements; however, these must be taken into consideration during the pre-procurement effort. There are two basic approaches to standardization when applied to vehicle procurement; total vehicle system standardization and subsystem and component standardization. Standardization of the total vehicle system may be achieved through cooperation and joint procurement of two or more transit systems (see Appendix A). Rarely will the identical vehicle satisfy the site-specific requirements of more than one system. However, in some cases, a joint pre-procurement effort could define a basic vehicle that, with a few alterations, would be satisfactory for more than one system. Subsystem and component standardization, to the extent possible without sacrificing total vehicle performance and safety requirements, is a more achievable goal.

ESTABLISHMENT OF THE AUTHORITY'S CONFERENCE COMMITTEE

About 3 years ago, the Port Authority of Allegheny County (PAT), under the leadership of Robert Sedlock, Manager of Systems Technology, began its LRV pre-procurement effort. Meetings were held with the various candidate vehicle manufacturers to inform them of the PAT site-specific requirements (as well as those of other systems) and to determine if the manufacturers had service-proven vehicle manufacturing capability. The manufacturers were also asked if the PAT-desired and essential requirements were considered achievable and reasonable. Other transit systems were invited to these meetings. On completion of the presentations by the manufacturers, the transit systems discussed each of their specific constraints and site-specific requirements.

The main objectives of these meetings were to determine the current status of service-proven vehicles and associated equipment and the feasibility of achieving standardization of LRVs among the various transit systems. Most systems agreed that the meetings were beneficial. Since this effort somewhat resembled that of the

President's Conference Committee (PCC), which resulted in the development and manufacture of the PCC car, all participants involved expressed the desire to continue and to identify themselves as the Authority's Conference Committee. UMTA has recognized that the positive results achieved so far should eventually provide advantages to the industry. Several systems indicated strong interest in the possibility of joint procurement. However, they agreed that, due to site-specific requirements, complete standardization of a total vehicle system was not feasible.

INITIAL CAPITAL COST VERSUS LIFE-CYCLE CONSIDERATIONS

Life-cycle costs are anticipated costs of initial procurement, the present value of implementation and training, and the value of the initial inventory of replacement parts and associated storage requirements. These various costs can be categorized as the costs of purchasing, operating, or maintaining a fleet of LRVs. To calculate life-cycle costs during the pre-procurement effort, sufficient data must be obtained to permit preparation of the bid documents and meaningful evaluation of the bids.

Life-cycle cost analysis is an effective tool for selection of specific major subsystems and components. It should, however, be considered an alternative to, rather than a replacement for, low initial price evaluation. As such, it can be employed as an adjunct to the pre-procurement effort.

Initially, a transit system should consider the merits of various types of LRVs that may satisfy the total system requirements. Then, the anticipated costs, directly influenced by each vehicle design, can be evaluated.

Purchase Price

The purchase price of LRVs depends on the quantity, type, and size of vehicle to be specified, the degree of sophistication involved in the vehicle design, the extent of standardization specified, and the impacts imposed on the bidders by the Buy-America constraints. Site-specific requirements must first be considered, as these will determine the vehicle configuration and performance requirements and the quantity required. The degree of sophistication and quantity of vehicles will depend on the funds available for procurement and the operational needs to satisfy the anticipated patronage.

Other important factors that will affect the purchase price include contract terms and conditions, inflation rate, potential for add-on orders from the transit system, the possibility of joint procurement with other systems, and general business conditions of interested bidders. The clarity and thoroughness of the bid documents and specifications are also important factors in minimizing contractor claims during the procurement.

Operating Cost

Operating costs involve recurring and nonrecurring costs. Recurring costs include operator cost, energy consumption, and maintenance; nonrecurring costs initially include training and scheduling and implementation of revenue service. These factors depend on the type of LRV procured.

For instance, based on an evaluation performed for the Pittsburgh LRV program, it was determined that a nonarticulated vehicle fleet would require 133 operators, whereas an articulated fleet would require only 88. It was also determined that the use of regenerative dynamic braking could reduce total system energy consumption. Considering all associated recurring costs involved, the use of articulated bi-directional LRVs would save $1 400 000 each year.

Energy consumption has been determined to be directly proportional to the vehicle weight, assuming that the performance and profile are kept constant.

Maintenance Costs

Maintenance costs include replacement parts inventory and maintenance operations. Initially, replacement parts inventory requirements may be greater due to the introduction of new vehicles. However, these requirements may be reduced through standardization of components and use, where possible, of the components equivalent to those used in the existing fleet (e.g., automotive-type tempered safety glass, standard bus seats, head and taillights, floor covering, windshield wipers, rear view mirrors).

Maintenance operations include both scheduled and unscheduled maintenance. Maintenance activities on a new fleet of LRVs may initially be higher, depending on the extent of new design and sophistication involved. Routine and repetitive maintenance should reduce significantly once the maintenance personnel become familiar with the new vehicles and the "bugs" are removed. Unscheduled maintenance is normally directly related to the reliability of equipment. By specifying the requirement for service-proven equipment in the LRV procurement, reliability values can be acquired to permit the transit system to determine which equipment is acceptable. This obviously cannot be achieved on new designs of equipment.

CRITICAL VEHICLE OPTIONS

Critical subsystems must be selected with care. Criticality of subsystems should be determined by the impact a specific major subsystem has on operational availability, total system interface, overall vehicle system reliability, associated maintenance, and passenger safety. Arbitrary selection of major subsystems or components may jeopardize overall system effectiveness and user safety.

A method used by some transit systems for selection of critical vehicle options during the pre-procurement stage, is step 1 of the two-step procurement process. Step 1 is basically bidders qualification. During this period, interested bidders submit proposed designs to the buyer for review and approval. Before it reviews the submitted proposals, the transit system should identify those elements considered critical and to what extent options would be permissable. Another approach employs a modified two-step procurement. Under step 1 interested bidders would submit pre-bid data, to verify their experience as vehicle manufacturers and the experience of their proposed major subsystems suppliers, with sufficient data to prove that their product is service-proven.

CONCLUSIONS

The procurement of a new LRV fleet is a major effort and, depending on the number of vehicles involved, may constitute the largest expenditure for a system element in the total system cost. Bid documents must be prepared properly to ensure (a) that a legal contract that can be executed without litigation is established, and (b) that all specific requirements of the vehicle have been defined to provide proper interface with the total system and efficient, reliable, safe, and maintainable operation.

By using a systematic pre-procurement effort the procurement of a new LRV fleet may be accomplished in a timely and cost-effective manner.