Designing to Fit

The Boston Experience

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The light rail vehicle (LRV) procurement process, easy to describe but difficult to effect, is intended to provide transit systems with LRVs that are both reliable and maintainable within given constraints. In Boston the process succeeded. The chosen vehicle has performed so well during the past 2 years that the original order has been doubled. Yet the process was complicated by the city's problematic operating environment—the new LRVs must operate on a subway system built at the turn of the century and in extreme weather and traffic conditions. The Massachusetts Bay Transportation Authority obtained the LRVs that suited their needs by assembling a capable internal staff with a balance of theoreticians and practitioners, carefully selecting an outside consultant, working closely with the consultant, and developing the specification by circulating drafts throughout the organization's various departments.

BOSTON, ALTHOUGH NOT UNIQUE, faces a variety of institutional constraints, both operational and social, that present a somewhat unusual environment in which to design and operate a light rail vehicle (LRV). The development of a state-of-the-art vehicle that will readily interface with a turn-of-the-century subway system is difficult in and of itself. Further exacerbating the situation are the legendary Boston automobile driver, traffic congestion, varied rights-of-way, extreme climatic conditions, track geometry, and a local populace with an advanced understanding of the political process—all of which tends to stretch the limits of technology. However, it appears that after almost 2 years of operation a large measure of success has been achieved with the introduction of the new Kinki Sharyo-built surface rail car.

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THE NEW LRV

The Massachusetts Bay Transportation Authority (MBTA) car is a 72-ft, six-axle, articulated, bidirectional vehicle with air conditioning and straight air braking. A 55-kv-A motor alternator is employed to provide power for the various ac-driven auxiliary motors as well as for primary lighting, floor heat, and convenience outlets. Pantograph current collection provides power for the microprocessor-controlled dual dc chopper propulsion system driving bimotored, parallel-drive powered trucks. The vehicle is outfitted with outwardly folding bifold single engine doors for low-platform loading. The maximum width of 8 ft 10 in. and maximum height of 11 ft 10 in. are established by the constraints of the vintage subway system. The vehicle must be articulated to negotiate a minimum radius curve of 43 ft. Empty vehicle weight is 84,500 lb.

Chopper control was selected based upon Boston's previous experience with the Garrett system of the older Boeing Vertol LRV. Although some may argue that resistive controls are more desirable, Boston's experience has been to the contrary. After the technological gap had been overcome, the system proved very effective. A further benefit was derived from the selection of chopper control—the dual system approach. Basically, the Boston dual chopper system provides two separate and distinct propulsion systems whose only common elements are input power, load weighing, and train-line information. The advantage is significant—limp-home capability on incidents of on-line failure. Boston's decision has proven extremely beneficial on the rare occasion when such a failure occurs.

Although selecting the propulsion system is perhaps the single largest decision, a successful vehicle is dependent on overall design. In general Boston's philosophy was to insist on transit-proven technology. During the acceptance process, we also learned to be very wary of suggested "product improvements" or modifications to existing proven designs developed by other than actual operating experience.

Boston opted for bifold doors based solely on our own experience. Past excursions with other technology proved less than successful. Initially, we selected a dual-engine type for operational flexibility, but during design review yielded to the simplicity of a single engine. Both decisions have proven prudent in that on-line door system failure currently hovers around 90,000 mean miles between failures.

The decision to revert to straight air braking was similarly founded on past experience. The effort to maintain a hybrid system proved to be extremely labor-intensive, and the system was somewhat unreliable. Although some mechanical problems have surfaced within the new vehicles' braking systems, they generally fall into the category previously mentioned, product improvements. Modifications are currently under way to correct this situation and we remain convinced that straight air is more effective.

Air conditioning, in the eyes of the maintainer, should be avoided. The motivation to incorporate this system is driven more by the political perspective, "You can't take away what you have already given them." However, past experience also yielded significant benefit in this area. We have learned our lesson well: form follows function. System design is not the only criterion for successful operation. Placement, particularly on a trolley car, is crucial. Although it may spoil the sleek look of the vehicle, the system must be roof-mounted. Through one full summer of operation we have yet to suffer the first major subcomponent failure.

The decision to incorporate ac technology was twofold; the volume and weight of a continuous-duty three-phase ac motor are significantly less than its dc counterpart, and contact surfaces (brush/commutator) are eliminated, thus making the motor inherently more reliable and maintainable. Consequently preventive maintenance schedules are now established by internal bearing life rather than the more critical brush/commutator interface. A singular exception to the selection of ac motors was made. The new vehicle's air compressor utilizes the standard dc alternative. Similar to the selection of a dual chopper, this decision affords limp-home capability in the event of loss of auxiliary power.

It should be pointed out, given the recent advances within state-of-the-art gate turn-on (GTO) device technology, that if the decision were made today, we would most probably have opted for a static converter rather than the motor/alternator, again for reasons of reductions in size, weight, and number of contact surfaces. Further we would seriously investigate the use of ac traction drive. However, before such a large step could be taken, extensive study would be required.

As a final note, a specific advantage is offered the transit operator selecting microprocessor control—the availability of full diagnostics. Although there is some well-founded disagreement with the use of microprocessor control, there are some distinct advantages. Diagnostics most certainly enhance maintainability. They provide not only improved troubleshooting capability, but also systems self-test, preoperative checks, and fault logging. Among these diagnostics, fault logging appears to be the most significant. Logging also gives the maintainer the ability to reconstruct the actual circumstance leading to the fault, which is extremely beneficial in segregating cause and effect.

THE PHYSICAL ENVIRONMENT

Light rail service is provided in Boston on four distinct lines, all of which join in what is locally called the central subway. Unlike the situation in many areas where light rail service is just now being reintroduced, the MBTA has been providing light rail service continuously since 1897. The introduction of a new vehicle to an old system presents some interesting problems that must be dealt with at the outset. Issues such as power, tunnel dimensions, track geometry, and point loading must be considered. In rare instances modification is possible; in general, they simply must be dealt with as constraints.

In Boston, power upgrading was necessary (and is still under way), and all inclines leading from the subway portals had to be reinforced. All other aspects led to design compromise. At present, the MBTA provides two- and three-car consists on three of its four lines but is limited to single-car operation (with the new vehicles) on the remaining line until the power improvements can be made.

The vagaries of weather clearly have their impact in the Boston area as well. From the snow-filled days of winter to the humid days of summer, service is expected to be reliable and somewhat comfortable. Issues of maintenance simplicity tend to receive low priority when juxtaposed with the needs of freezing or sweltering passengers.

Finally, vehicle storage and maintenance facilities can present further constraints. If, as is the case in Boston, preexisting facilities are to be used for maintenance of the new vehicles, modifications may be required. Issues such as hoists, pits, and track loading must be examined and facilities modified or replaced.

PROCESS AND PHILOSOPHY

As is the case with many major decisions at the MBTA or in any public service organization, it is critical that all pertinent information be gathered and assembled by staff prior to final decision-making by top executives. Thus the steps to a successful procurement can be described quite simply:

- Assemble a capable internal staff,
- Engage a competent consultant,
- Develop a solid specification, and
- Select a reputable manufacturer.

Although simple in theory, this is extremely difficult in practice.

The initial step, the assembly of internal staff, is significant in that a proper balance of theoreticians and practitioners must be achieved. Intellect alone will not ensure success. A firm sense of reality must be maintained.

The way the MBTA handled this first step was through a staff in what was then the department of engineering and operations planning. At that time, the

MBTA was in the process of buying a new fleet of buses, the new light rail vehicles, and a fleet of heavy rail vehicles. Initially, this department took the lead role in all of the acquisitions and, fortunately, contained the proper blend of talent.

The staff established the basic concept of what was desired and assembled a draft specification for internal circulation. The interface with all operating departments was essential at this point. The MBTA's structure dictates an extremely close relationship between the equipment maintenance department (the maintainer), the transportation department (the eventual operator), and the engineering and maintenance department (the right-of-way, power, and facilities agent). All parties achieved a consensus as to what was required and provided the appropriate input for later incorporation into the formal specification. This step's importance cannot be overstated; consensus is not generally achieved easily, and patience is required.

Staff must also conduct a parallel effort—consultant selection. Again, this is a crucial step. The consultant must be selected on the basis of experience, talent, reputation, and cost-effectiveness. Larger, established properties may have significant advantage in this area given past experience with most prominent firms.

As is the case with most public agencies in a project of this scope, the MBTA used a competitive selection process. Proposals were submitted for evaluation by an independent review board, a short list was developed, and successful candidates were interviewed.

Upon ultimate selection, a team may be assembled on the basis of past experience with certain individuals within that consulting firm. Previous relationships may prove beneficial. Some have recommended that, once a consulting firm has been selected, the major responsibility be left to it. However, it is strongly urged that in-house personnel maintain their influence; nobody knows their railroad better. It is the opinion of the author that the property should drive the specification and that the consultant should form it to fit.

The relationship between internal staff and the consultant is, once again, critical. It is very important that the basic concept be conveyed clearly and distinctly, with all key elements specifically defined. The environment for consensus must be established. It is extremely difficult for staff to keep abreast of state-of-the-art technology; they are generally kept occupied running the railroad. The proper consultant not only provides this expertise but also brings along a wealth of experience, talent, and information not otherwise locally available.

The specification process, described in short form, is simply the establishment of the physical dimensions, the selection of a propulsion system type, and, thereafter—working through the vehicle—a series of trade-offs and a decision based on functionality, circumstance, cost, and desired result. This process, initiated at the conceptual stage, advances through design review and continues to actual procurement, all the while accompanied by a series of adjustments, which, it is hoped, produces a successful vehicle.

When a draft specification is complete, it is important that it be circulated in-house. This gives all concerned parties an opportunity to review all the changes submitted by various other departments as well as to note and provide exception to variations of their own. Thereafter it should be let for industry review. This will provide a forum to review the latest technology as well as to become acquainted with changes to or upgrades of existing equipment. Should industry review yield significant modification to the specification, it would be wise to recirculate it in-house.

THE CURRENT PICTURE

In retrospect, the Boston experience has been rewarding. The process defined above has yielded an overwhelmingly successful vehicle. With almost 2 years of operating experience on the initial vehicles, we remain confident that they will serve us well. Indicative of this confidence, the original order for 50 vehicles was expanded to 100, of which 25 have since been delivered and placed into revenue service. The remaining 25 are scheduled to be completed by September 1988.

ADDITIONAL COMMENTS

Some elements of the process not detailed herein but seen as noteworthy cannot be left without at least a brief comment. First, full-scale mock-ups should be requested in the specification and subjected to detailed review prior to final design. This is a good opportunity to see if the concept transfers to reality. The best human engineering can be carried out at this stage. Resident inspectors should be put in place at both the manufacturing facility and final assembly point. This can sometimes be difficult with off-shore procurement, but is crucial to success.

Design review is a continuous process throughout the procurement. The milestone chart may indicate otherwise, but the design review process extends beyond delivery. The temptation to overdesign the LRV must be resisted. Although safety cannot and should not be compromised, it is undesirable to remove all responsibility from the operating system, because this generally must be done at the expense of reliability.

And finally, a word on problem solving. A significant number of solutions are most apt to be developed by the project staff. Hands-on experience is invaluable, particularly when backed by direct knowledge of the operating environment.

CONCLUSION

The intent of the procurement process is to provide a vehicle that is both reliable and maintainable within given constraints. What is described herein is not meant to imply that this method or equipment would be totally suitable if applied by others, nor that it is the only approach. Given the variations within the industry, there is only one truly common thread—the success of any project is solely dependent on the people involved.