for carrying out the replacement of warranted items; that is, the removal of the failed subsystem or element and installation of a new or repaired item supplied by the Seller. (11) The Seller shall guarantee free repair of any item failed under warranty; that is, identification and free exchange of any defective parts or subassemblies contained in the failed subsystems or elements, thus returning that item to compliance with the technical contract requirements. (10,11,12) The Seller shall be responsible for stocking and supplying warranty exchange parts. The Seller shall guarantee to promptly resupply, on a free exchange basis, replacement parts which the Buyer supplies from his maintenance spare parts stock for warranty repairs. Replacement of failed items with the Seller supplied or approved repair or exchange parts shall constitute continuation of the Seller's warranty for that item.******

######Option 2 (Buyer Completes all Warranty Work)—The Buyer shall be responsible for replacement and repair of all items failing under warranty. The Seller shall guarantee free exchange of all items needed by the Buyer for repair and/or replacement of failed warranty items, and actual labor costs for the repair of any failed warranty items. (10) Labor costs shall be computed as follows: (TBS). (11) The Seller shall be responsible for stocking and supplying warranty exchange parts. The Seller shall guarantee to promptly supply free exchange for warranty replacement parts which the Buyer supplies from his maintenance spare parts stock. Replacement of failed items with Seller supplied exchange or approved repair or exchange parts shall constitute continuation of the Seller's warranty for that item. (12)######

######Option 3 (Fleet Defect Warranty) (20)—A Fleet Defect Warranty shall be in effect for the entire warranty period of any subsystem or element of the rail car purchased under this contract. If the failure rate for (TBS) subsystems or elements exceeds (TBS) percent of that elements' or subsystems' fleet population during any 12-month period of its warranty, the entire fleet population of that subsystem or element shall be considered to be failed. (13,14) Whereupon the Buyer invokes the Fleet Defect Warranty, the Seller shall promptly provide the Buyer with a written Failure Analysis and Plan for Corrective Action including scheduling and scope of the fleet repair plan within (TBS) weeks. For those failed items which are still under warranty, the Seller shall provide FOB the Buyer's property or point of repair, parts and labor for (at its option) the repair or free exchange of failed items. (15,16,17) For those items included in a fleet failure for which the warranty period has expired, the Seller shall guarantee to provide FOB the Buyer's property, or point of repair, (at its option) repaired or free exchange parts to return the car to compliance with the technical requirements. (11,12,18) Whenever possible, Fleet Defect repairs and replacements will be completed in conjunction with scheduled maintenance or scheduled overhaul operations. (19)######

During the periods of the foregoing warranties, the Buyer guarantees to operate, maintain, repair and overhaul the rail equipment purchased under this contract in accordance with the requirements procedures prescribed in the Technical Contract Requirements and the Seller's Operating and Maintenance Manuals. The Buyer shall be responsible for maintenance records for each car covered under warranty as verification of compliance with the technical maintenance requirement provisions. (6,7) The Seller's warranties shall not apply to equipment that has failed or been damaged due to improper use or improper maintenance. (8)

In any case in which a part, component or item of equipment shall fail after the end of its normal service life (considering the usage to be expected in Buyer's normal service), and such failure shall occur prior to the expiration of the applicable guarantee period, such part, component or item of equipment shall be deemed to be outside the coverage of the guarantee. (4)

The foregoing guarantee is exclusive and in lieu of all other guarantees or warranties, whether written, oral, implied or statutory (except as to title). In no event shall the Seller be liable for incidental or consequential damages.

REFERENCES

1. N.D. Lea and Associates, Inc. Cost Savings Potential of Modifications to the Standard Light Rail Vehicle Specification. UMTA-MA-06-0025-79-11, February 1979.

2. U.S. General Accounting Office. Transit Equipment Warranties Should Be Enforced. GAO Report No. PSAD-80-12, December 1979.

3. Review of Commercial Airline Acquisition Methodology.

Rationalization of the Light Rail Vehicle Specification Process for Cost-Effectiveness

THOMAS J. MCGEAN, N.D. Lea & Associates

Light rail vehicle (LRV) requirements should reflect site-specific transportation service needs, performance requirements, and life-cycle costs. This paper examines the process of defining these requirements. It addreses both technical and nontechnical issues. Technical issues include the justification processes and attendant costs for critical vehicle options such as articulation, bi-directionality, doors on both sides, and propulsion system. Nontechnical issues include contractual requirements that might cause higher assigned risk costs.

The benefits of various LRV features and contract provisions are compared with the costs, both capital and operations and maintenance, and perspectives are established. Such considerations enable the buyer to maximize the return on his vehicle budget commensurate with real needs.

The process of defining light rail vehicle (LRV) requirements should consider site-specific transportation service needs and performance objectives in a cost-effective manner. The process is intended to be used in conjunction with the new Guideline Specification for Procurement of Light Rail Vehicles,[1] which was developed with UMTA funding through the cooperation of transit agency and supplier groups. It is currently being used by the Port Authority of Alleghany County in Pittsburgh for its forthcoming light rail procurement.

The guideline specification provides a means by which a transit agency can specify only those requirements actually needed for its own site-specific mission. The guideline document also provides a uniform specification format and language to facilitate interpretation by the supplier industry and to reduce problems caused by misinterpretation.

If procurement of a transit vehicle can be compared with buying a car, the baseline specifications represent a stripped-down model. For example, specifications for the baseline LRV are as follows:

BASELINE SPECIFICATIONS

Unidirectional operation
Nonarticulated vehicle
No coupling (tow bar for dead car retrieval)
Door on right side only
Low-level passenger loading only
600V DC power
No cab signals
Moderate acceleration (0-50 mph in 58 seconds)
No load compensation
Single-stage track brake
No slip-slide protection
No air conditioning
Trolley pole power collection
Switched-resistor propulsion control
No regenerative braking
No resilient wheels
No load leveling

The buyer may then specify optional provisions to suit his needs. Specifications for all optional provisions are an integral part of the guideline document; therefore, a compatible set of specifications to suit the needs of a particular application can be readily generated. Typical optional provisions include the following:

CONFIGURATION OPTIONS

Bidirectional operation
Articulated vehicle
Mechanical or fully automatic coupler
Doors on both sides
High-level passenger loading

POWER/PROPULSION/BRAKING OPTIONS

750V DC primary power
Pantograph power pick-up
Higher acceleration (0-50 mph in 37 seconds)
Load compensation
Slip-slide control
Chopper thyristor control
Regenerative braking
Ability to tow dead car
Full service capability without dynamic braking
High-performance track brake (articulated shoes, three-stage braking force)

PASSENGER AMENITIES

Air conditioning
Load leveling
Resilient wheels
Special seating layouts

EXTRA FEATURES

Fully enclosed operator's position
Battery box heater
Lighted passenger "stop request" signal
Automatic pantograph control
Remote-controlled destination signs
Double-glazed side windows
Rubrails
Advertising card holders

SIGNALING/COMMUNICATIONS

Cab signaling
Traffic signal preemption equipment
Full public address communications system

A complete table of options is provided at the front of the specification referenced to the appropriate sections of the guideline document. The specification thus provides a checklist to help the transit agency ensure that it buys only what it needs.

A new guideline specification thus encourages the purchase of cars with only those technical features appropriate to the mission they must perform. System trade-off studies can be performed to ensure that a cost-effective car is specified. This paper presents examples of how trade-offs can be considered for unidirectional versus bidirectional car, articulated versus nonarticulated car, resistor versus solid-state propulsion control, and cost of guarantee/warranty/reliability terms and conditions.

In performing cost trade-offs, the following assumptions have been used:

- Labor costs for assembly and installation were taken at 12 percent of the cost of the elements involved;
- The wage rate for labor used in manufacturing was estimated at $14 to $18 per hour;
- Engineering costs were estimated at $33 per hour, or $3200 per assembly drawing; and
- A vehicle order of 100 units was assumed in assigning nonrecurring costs on a per vehicle basis.

In assessing operational impacts, the following operating scenario was assumed:

- Fleet size of 70 cars,
- Interest rate 10 percent (constant dollars),
- Route length of 40 track miles,
- 20 curves with radius of less than 125 feet,
- Six switchbacks or turnbacks, including two at the ends of the route and four en route, and
- Cost of right-of-way, $0 to $50 per square foot.

The study from which these costs were taken was performed in 1979. The costs have not been adjusted for inflation since that time.[2]

UNIDIRECTIONAL CAR

One of the first determinations that must be made is whether the car should be unidirectional or bidirectional.

Many of the pre-PCC streetcars were double-ended to permit operation on simple track layouts with switchbacks. As streetcar systems evolved, single-direction operation became popular. Greater car reliability reduced the requirement for turnbacks, and maximizing seating became an important goal. However, where subway construction was involved, the bidirectional car remained preferable, since it could turn back at a simple crossover track.

Today the advantages and disadvantages of bidirectional operation remain much the same. The bidirectional car can turn back with a simple crossover, which requires less land than the loop or wye required by a single-ended car. In addition, the bidirectional car permits passenger loading from either island or side platforms.

Disadvantages of bidirectional operation include the requirement for doors on both sides of the vehicle; this arrangement reduces the seating capacity and increases the cost for doors. In addition, vehicle reliability is decreased, since there are twice as many door mechanisms that experience shows are particularly failure prone. Another disadvantage is that two operator's consoles are required; this reduces passenger capacity and increases the cost and technical complexity of the car.[3]

Because of these disadvantages, it is important to examine the operational need for bidirectional vehicles carefully. The new Canadian LRVs being built for Toronto are single direction. Many PCC cars, including those used in Boston, are single-ended, as are LRVs now operating in Amsterdam (the LHB eight-axle tram), Antwerp (BN four-axle tram), Basel (Schindler Be 4/4 and Be 4/6), Bern, Braunschweig, Bremen, Goteburg (ASEA type M-28), Helsinki, Nuremberg, and the Hague.[4]

The tendency toward tunnel construction for light rail in German cities and the high cost of underground turnarounds have caused a recent preference for bidirectional vehicles.[5] However, where construction is above ground, costs may often favor the unidirectional vehicle.

Savings in Car Costs

The unidirectional vehicle requires an operator's cab at only one end, and saves the cost of the other operator's cab along with all driver equipment, controls, and amenities. Additional seating is provided in the space formerly occupied by the cab. The rear destination sign is also eliminated. (Since some transit agencies may still require doors on both sides to handle center platform stations, savings from elimination of doors will be considered separately.) Table 1 gives the savings in vehicle first cost, estimated for a typical 100-car order. A six-axle articulated vehicle similar to the Boeing light rail car has been used as the basis for these calculations. Savings amount to nearly $20 000 per car.

It is common for unidirectional cars to have doors only on the right side of the car. Specifying doors on one side of a typical articulated LRV eliminates six door panels, actuators, and associated equipment, along with the door tracks and guides, stepwells, and electrical relays. Indirectly associated equipment that can be deleted includes special entry lighting, windscreens, destination signs on one side, and outside mirrors. Materials added include additional seating, windows, baseboard heaters, and additional car body materials and paneling.

Table 2 gives the savings in vehicle first cost. These savings amount to more than $22 000 per car. (In preparing estimates, doors were assumed to be the more expensive plug type as used on the Boeing light rail vehicle.) Operation of unidirectional cars with doors on only one side would thus save a total of $42 000 per car.

Table 1. Cost savings estimate: unidirectional car.

		Per Car (100 cars)
Nonrecurring Cost Savings		
Engineering design time	$ 30 000	
Manufacturing and tooling	30 000	
Total	$ 60 000	$ 600
Recurring Cost Savings (Increase)		
Material saved from deleting one cab:		
Instrument panels and cab lighting		$ 565
Cab heating, air conditioning, defroster wipers and washers		1 210
Replace cab glass, visors and mirrors with standard vehicle glass		1 090
Communications panel		600
Master controller		3 750
1 set head and tail lights		100
Destination and run signs		575
Motorman's seat and console furniture		1 460
Cab enclosure and support structure		4 950
Horn and gong		225
Glare curtains		175
Sand box and sander control		740
Associated wiring relays circuit breakers and miscellaneous		2 400
Total		$ 17 840
Materials added:		
Additional seating		(500)
Lighting fixtures and wiring		(640)
Interior paneling and trim		(750)
Total		(1 890)
Labor saved:		
Labor for component installation		1 800
Wiring installation		1 630
Total		3 430
Net Cost Savings (Increase)		$ 19 980

Table 2. Cost savings estimate: cars with doors on one side only.

		Per Car (100 cars)
Nonrecurring Cost Savings		
Engineering design time	(4400)	
Manufacturing and tooling	6000	
Total	$1600	$ 16
Recurring Cost Savings (Increase)		
Material saved from deleting half of doors:		
Switches, valves, and tubing		$ 300
Door panels (6)		3 600
Actuators (6)		720
Locking actuators and cams (6)		4 320
Tracks, waist rails, and trolleys		5 400
Door relay panels		800
Stepwells and windscreen assemblies		900
Lighting fixtures		390
Articulated mirror		400
Side destination signs (2)		1 000
Hardware, trim panels, and wiring		4 500
Total		$ 22 330
Materials added:		
Baseboard heaters		(50)
Car body side skin and structure		(600)
Windows and glazing		(450)
Added seating		(450)
Interior panels and flooring		(3,200)
Stanchion bars and fittings		(150)
Total		(4 900)
Labor saved:		
Door installation and testing		3 600
Wire bundle fabrication and installation		2 000
Total		5 600
Labor added:		
Cost of installing windows, interiors, and seats		(850)
Net Cost Savings (Increase)		$ 22 196

Impact of Operational Factors on Savings

Unidirectional cars are limited in their operational flexibility. They cannot terminate routes at switchbacks, but must continue to the more lightly patronized end of the line to turn around. This limitation can be overcome by installing turnaround loops with switches at intermediate locations along the route, provided that right-of-way is available. In performing this cost analysis, it was assumed that double turnaround loops are installed every 4 miles along the route and that the loops are interconnected by a double slip switch so that vehicles cannot only use the loops to turn around, but can also switch to the parallel track to bypass failed equipment or permit track repairs. These double loops are assumed to replace double crossover switches installed for the same purpose on a system with bidirectional vehicles.

The cost analysis performed considers the savings per car for unidirectional cars with doors on one side, compared with the cost of increased trackwork and right-of-

Table 3. Impact of operational factors on savings from unidirectional car with doors on one side.

Effect of increased vehicle capacity on fleet size	
Crush capacity is increased by 12 passengers due to removal of one cab. This increases crush capacity by 5.5 percent. For a 70-vehicle fleet, 3 fewer cars are needed.	
Savings at $700 000 per car are	$ 2 100 000
Savings on per car cost for unidirectional car	
Savings are (17 800 - 1890 + 3430) 67 + 60 000 or	$ 1 358 460
Savings on per car cost for doors on only one side	
Savings are (22 330 - 4900 + 5600-850) 67 + 1600 or	$ 1 487 660
Addition of double loops with switches	
Assume 4 double loops are added. Each has one double slip switch and 4 simple split switches. Cost for switches and interlockings is estimated at $558 000. Cost for extra track assuming 422 feet per double loop at $65.53/ft is $27 654.	
Total added cost	$(2 342 616)
Addition of simple loops at ends of line	
Two simple loops added, one at each end of line. Total of 80.8 feet of extra track per loop at $65.53 per linear foot.	
Total for 2 loops	$ (10 590)
Elimination of double crossover switches	
Eliminate 4 double crossovers, each costing $372 800	
Total savings	$ 1 491 200
Right-of-way-costs	
Added land for double loops	20 493 ft^2 each
Added land for end loops	9211.5 ft^2 each
Total extra land for 2 end loops and 4 double loops	100 395 ft^2
Summary of savings	
Reduced fleet size	$ 2 100 000
Reduced cost - unidirectional car	1 358 460
Reduced cost - doors on one side	1 487 660
Cost of 4 double loops	(2 342 616)
Cost of 2 simple loops	(10 590)
Elimination of 4 double crossovers	1 491 200
Total savings excluding right-of-way	$ 4 084 114

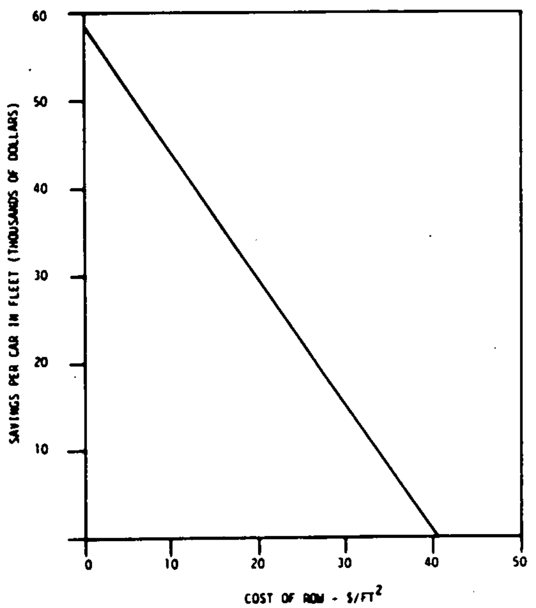
Savings Versus Right-of-Way Cost	Total	Per Car (70 cars)
Net savings - no ROW cost	$ 4 084 114	$ 58 344
Net savings - ROW $10/ft^2	3 080 164	44 002
Net savings - ROW $20/ft^2	2 076 214	29 660
Net savings - ROW $30/ft^2	1 072 264	15 318
Net savings - ROW $40/ft^2	68 314	976
Net savings - ROW $50/ft^2	(935 636)	(13 366)

way need to provide these turnbacks. In addition, the analysis considers the reduction in fleet size made possible by the larger capacity of the unidirectional car, which is assumed to hold 12 additional passengers.

The analysis is conservative in estimating savings for the unidirectional car because it ignores the following areas, both of which would be favorable to operation of unidirectional cars:

- It does not consider the operating cost savings that the larger vehicle capacity reflects in increased driver productivity; and
- It does not consider the reduced maintenance costs that should result from elimination of one set of vehicle controls and displays, with associated wiring and relays.

Figure 1. Net savings from unidirectional operation of cars with doors on one side, considering cost of added row.



The analysis assumes that the relative maintenance costs for the double loops and switchbacks are comparable. However, the tight curve radii for turnbacks increases wheel and track wear, thus favoring the bidirectional option.

The cost of right-of-way is a dominant factor in determining whether to purchase a bidirectional or unidirectional car. The estimate of potential savings from unidirectional operation given in this analysis is conservative. Table 3 gives the savings from a 70-vehicle fleet operating over a 40-track-mile system. Total savings exclusive of right-of-way costs are more than $4 million, or nearly $60 000 per car. Figure 1 shows the net savings per car as a function of the cost of right-of-way. Even with the right-of-way at $30 per square foot, savings of more than $1 million or $15 000 per car appear possible.

From these savings, it would appear that localities should give serious consideration to unidirectional cars for aboveground operation.

DELETION OF ARTICULATION SECTION

Savings in Car Costs

This modification would permit cities where civil features such as curve radii are not limiting to eliminate the articulated section. Savings estimates are based on a six-axle articulated car similar to the Boeing LRV. Vehicle capacity is assumed to be the same, but the body is reconfigured to a four-axle design requiring a larger turn radius of about 125 feet. Savings would accrue from eliminating the center truck, its brake system, and the articulation assembly and associated shrouding.

Table 4 shows the savings, which amount to $41 000 per car on a 100-car order.

Table 4. Cost savings estimate: articulation section deleted.

		Per Car (100 cars)
Nonrecurring Cost Savings		
Engineering design time	$ 103 840	
Wiring design layout	16 800	
Qualification testing	134 000	
Manufacturing and tooling	100 000	
Total	$ 354 640	$ 3 546
Recurring Cost Savings (Increase)		
Material saved by deleting articulation section:		
Brakes		7 250
Center truck		6 346
Wheels and axles		6 000
Articulation assembly		7 304
Lighting		529
Side shrouds, wire, and miscellaneous		3 000
Total		30 429
Labor saved:		
Assembly and installation		3 411
Wiring labor		4 000
Total		7 411
Net Cost Savings (Increase)		$ 41 386

Impact of Operational Factors

The minimum turn radius of a four-axle nonarticulated vehicle is 125 feet, as opposed to 42 feet for the present articulated design.

Although such cars may not be a viable option in many cases where right-of-way constraints make 125-foot turn radii impractical, an analysis was performed to get some idea of the trade-offs between land cost and vehicle savings. Vehicle capacity is assumed to be unaffected by the change. Savings from reduced maintenance associated with brakes, wheels, and articulation elements are estimated to 1.7¢ per vehicle-mile and the average vehicle mileage is estimated at 35 000 miles per year.

It is assumed that added right-of-way is required for 20 turns, formerly of 42-foot radius and now of 125-foot radius. Figure 2 shows the additional land required. The analysis assumes that all additional land required by the more gradual curve radius must be purchased, and that no credit is given for the land required by the 42-foot turn radius curve but no longer required by the wider turn.

A present-worth analysis was used to convert annual savings from reduced vehicle maintenance costs to an equivalent first cost. A 60-year period was used for the analysis, with the fleet renewed after 30 years. The total present worth of savings from vehicle costs and maintenance, but excluding costs for added right-of-way, were more than $3.5 million, or more than $50 000 per car (Table 5). Figure 3 shows the effect of right-of-way cost

Figure 2. Turn radius and right-of-way requirement.

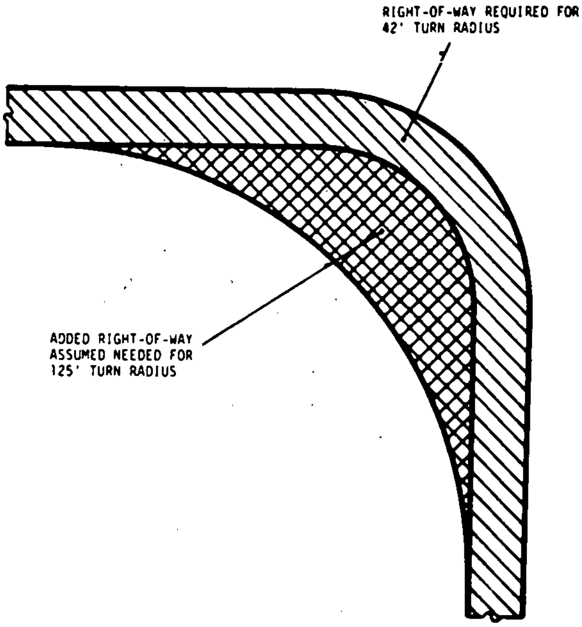


Table 5. Impact of operational factors on savings from elimination of articulation section.

Savings per car from eliminating articulation unit		
Savings are (30 429 + 7411) 70 + 354 640 or		$3 003 440
Savings from reduced vehicle maintenance		
Assume savings of 1.7 cents per vehicle mile for 35 000 miles per year per vehicle in the fleet		
For 70 cars savings are		$41 650/yr
Added cost of right-of-way		
Additional ROW for a 125 ft radius curve versus 42 ft radius curve is estimated at 2975 ft^2		
For 20 turns the row required is increased by		59 500 ft^2
Present worth of savings (Land at 60 years, vehicles at 30 years)		
Present worth of land		59 500 x (cost/ft^2)
Present worth of maintenance (60 years at 10 percent)		$415 134
Present worth of car savings		
First car order		$3 003 440
Second car order		172 127
Total present worth less land		$3 590 701
Present worth of savings versus ROW cost		
	Present Worth of Savings: Total	Present Worth of Savings: Per Car (70 cars)
No ROW cost	$ 3 590 701	51 296
ROW $10/$ft^2$	2 995 701	42 796
ROW $20/$ft^2$	2 400 701	34 296
ROW $30/$ft^2$	1 805 701	25 796
ROW $40/$ft^2$	1 210 701	17 296
ROW $50/$ft^2$	615 701	8 796

on the present worth of savings per vehicle in the fleet. With right-of-way at $30 per square foot, savings of more than $25 000 per car are possible. Even with right-of-way at $50 per square foot, savings are more than $8 500 per car.

In conclusion, it appears that serious consideration should be given, especially for new light rail installations, to designing the right-of-way to accept large, nonarticulated cars.

RESISTOR VERSUS SOLID STATE PROPULSION CONTROL

Chopper propulsion systems are currently more expensive than the traditional resistor controls, and the cost of the entire propulsion system can be from $10 000 to $30 000 more when chopper control is used. Energy consumption is not significantly better for the chopper if dynamic braking is used because the added weight of the chopper system compensates for its more efficient voltage control. For example, comparisons of weight differences for cam versus chopper control for the state-of-the-art car showed the chopper could increase car weight by almost 1000 pounds.

If regenerative braking is used, then the chopper controller can achieve a significant energy savings over resistor controls. Over typical urban routes, energy savings of 15 to 25 percent are possible.

Maintenance costs for chopper and resistor controllers can also be different because of differing failure modes and personnel skill levels. In addition, the different reliability of the two systems can mean that a different number of cars may be required to obtain the same number of cars available for service.

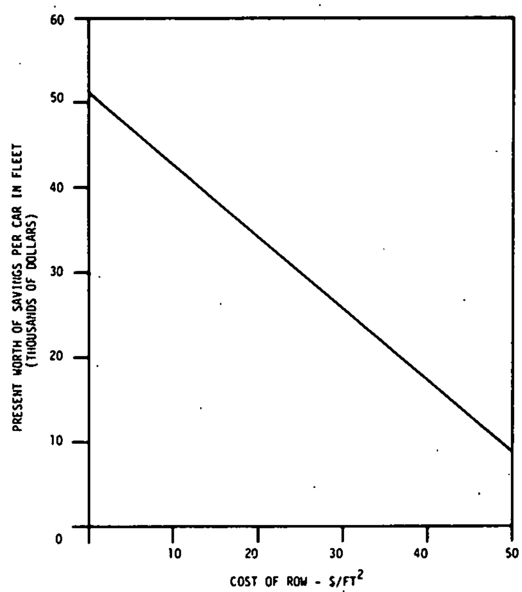
N.D. Lea and Associates (LEA) developed a life-cycle cost equation that can be used to determine whether to specify resistor or thyristor controllers. The life-cycle cost equation for life-cycle cost analysis of a rail car propulsion system is as follows:

$$PW_j = P_{O_j} + C_{S_j} + N_j\ P_j + A_{E_j}(d_E) + d(A_{PM_j} + A_{CM_j} + A_{RP_j}) \quad (1)$$

where:

PW_j = present worth of life-cycle costs from

Figure 3. Net savings from eliminating articulation joint, considering cost of added row.



propulsion system alternative j for the total number of vehicles in the purchase,

P_{O_j} = present worth of other costs and benefits associated with alternative j but not otherwise included in this equation,

N_j = total number of vehicles in purchase with propulsion alternative j,

P_j = purchase price of propulsion system j,

A_{E_j} = energy cost per vehicle per year for alternative j,

A_{PM_j} = cost of preventive maintenance per vehicle per year for alternative j,

A_{CM_j} = cost of corrective maintenance per vehicle per year for alternative j,

A_{RP_j} = cost of replacement parts per vehicle per year for alternative j,

C_{S_j} = cost of extra spare cars less the propulsion systems required for alternative j,

d_E = present worth discount factor adjusted for energy price escalation, and

d = present worth discount factor for nonenergy recurring costs.

LEA also recommends language for specifying propulsion systems and evaluating bids, including both chopper and resistor-controlled propulsion equipment.[6]

GUARANTEE/WARRANTY/RELIABILITY

Members of the manufacturing and supply industry have complained that guarantee/warranty and reliability (GWR) clauses are becoming too restrictive and are having adverse financial effects on the supply industry.

Analysis of past rail car contracts and discussions with both transit operators and suppliers support the claim that GWR provisions have been made more restrictive than in the past. More importantly, both the buyers and suppliers have generally not participated in drafting GWR terms and conditions, and adversary roles have developed. The costs of GWR requirements are difficult to pinpoint, since they encompass not only the cost for warranty provisions and associated risks, the costs of engineering and implementation of reliability requirements, but also costs associated with reconfiguration, redesign, or replacements of components that may be affected by certain GWR requirements.

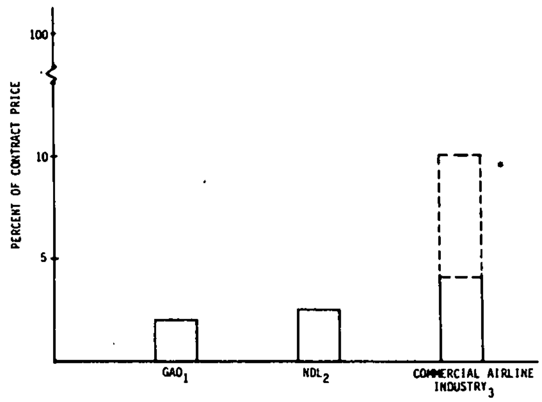
In a cost study performed by LEA for UMTA on the standard LRV specification[2] estimates for warranty and field service amount to 2.5 percent, and estimates for potential savings from simplifying reliability requirements (by deleting the 2-year demonstration and reliability analysis and substituting warranty provisions) amount to 1.8 percent. Thus overall costs of GWR requirements are estimated at 4.3 percent of the purchase.

In a report by the GAO,[6] a conservatively estimated figure of 2 percent is mentioned based on a survey of 35 contractors by the Defense Contracts Audit Service in February 1979. It must be assumed that not all of these contractors were rail car builders and that the estimate does not necessarily include reliability requirement costs.

A quick telephone interview of five car builders/system suppliers in May 1980 provided estimates similar to those by LEA and GAO. Higher figures are quoted in the airline industry,[7] where warranty costs range from 4 to 10 percent of purchase cost per year of warranty. These estimates are shown on Figure 4.

There has also been concern that increased warranty periods have caused escalation in car prices. In July 1975, Pullman-Standard gave UMTA the following response to this hypothesis: (a) Longer warranty periods on the car structure are less significant (by a ratio of approximately 1 to 15) than longer warranty periods on all parts of the car; and (b) Impact (in 1975 dollars) of the warranty period on all parts of the car is as follows:

Figure 4. Cost estimates of warranty contract terms.



*NOTE: AIRLINE INDUSTRY ESTIMATE IS A PERCENT OF CONTRACT COST PER YEAR.
SOURCE: REFERENCES 7, 8, 9

- 1 year—base price, no impact
- 3 years—$15 000 extra per car
- 5 years—$35 000 extra per car

By using the Consumer Price Index to convert a January 1981 (factor of 1.62 over 1975) dollars, the impacts would be:

- 1 year—base price, no impact
- 3 years—$24 000 extra per car
- 5 years—$57 000 extra per car

There apparently are opportunities to reduce GWR costs through careful preparation of terms and conditions. The transit authority should not buy more than it needs, whatever is bought must be paid for—and the result is a more expensive car.

APPLICATION TO AN ACTUAL CASE

In 1979, LEA was asked by UMTA to review the proposed Niagara Frontier Transportation Authority (NFTA) light rail specification to ensure that the level of complexity was compatible with the actual transportation requirement.

NFTA had required articulated vehicles because of their greater carrying capacity. However, articulated vehicles offer greater capacity only when compared with smaller cars. The LEA review indicated that a nonarticulated car with a similar carrying capacity would be practical. Front overhang on curves could be solved by tapering the front end of the car as is done on the Boeing LRV. The remaining problem was the chording on the inside of curves. Sketches showed that a 70-foot nonarticulated car would require only an additional 1.57 feet on the inside of a 100-foot radius curve. As there were relatively few tight radius turns on the route, NFTA decided to permit large nonarticulated cars to be bid to see if there would in fact be a cost savings. The low bidder was Tokyu Car Corporation, which bid $21.8 million for 33 cars. The lowest bid for articulated cars was from Siemens, which bid $25.2 million for 27 cars. (The nonarticulated cars were slightly smaller.) NFTA's savings amounted to $3.4 million. It saved money by not buying what it did not need. Not only were the cars cheaper, but NFTA now has 60 fewer wheels to grind and 60 fewer brakes to overhaul for the life of the cars. Maintenance of 27 articulated joints has also been eliminated, and car traction has been enhanced on grades.

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Factors Affecting Rail Car Costs

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Five major factors affect light and rapid rail car prices: (a) inflation, (b) market conditions, (c) technical aspects, (d) procurement and contractual practices, and (e) financial condition of the supply industry. Except for general inflation, most of these factors, particularly in the technical and contractual areas, are controllable to some degree by agencies purchasing rail equipment.

Many people in the transit industry and government are concerned about the dramatic increase in rail car prices. The light or rapid rail car that cost $150 000 to $200 000 in 1970, for example, may now cost $1 000 000. Two questions should be asked: (a) Have light and rapid rail car prices increased faster than the dramatic inflation of 1970-1981? and (b) Are rail car prices controllable? These questions are examined below.

INFLATION

Over the past decade, the transit industry, along with other sectors of the economy, has suffered from the effects of inflation. Figure 1 shows the escalation of rail transit car prices over the years. Inflation, as measured by the Consumer Price Index, has raised prices 250 percent since 1967. However, the General Rail Equipment Index shows rail car prices increasing more than 330 percent over this same period. Some of the increase in rail car prices may be attributable to general inflation, but almost half is clearly due to other factors.

In an inflationary period, where "time is money," a delay in any step of the procurement process has a negative effect (for the buyer) on bid prices. Costs of labor, materials, and overhead are rising constantly, and inflation will continue to take its toll on rail car costs.

MARKET CONDITIONS

Rail cars are largely custom designed for individual rail operators. Units are built in varying production runs, which have ranged in recent years from 14 units for the San Diego light rail to 754 units for the New York City Transit Authority rapid rail.

The market for light and rapid rail cars has been on the order of 300 to 400 cars per year. In terms of the domestic industry, where some items are produced in quantities of hundreds of thousands or millions, the rail car market is very small in quantity, but large in dollar cost per unit. The market has been characterized by a feast-or-famine cycle, with orders coming in bunches during certain periods. This irregularity of demand is reflected in prices, since production facilities and a core staff of skilled people are usually maintained in an active status even in periods of low production.

In terms of traditional economic supply and demand curves, large orders should result in significant competition among bidders. However, competition for small light rail car orders has been great, while competition for rapid rail car orders has been considerably less (see Table 1). The large capital requirements, perceived technical and contractual risks, and long delivery times associated with large procurements may have contributed to the decline in competition for large orders. On the other hand, foreign-based winners of light rail procurements, such as DuWag, continually build small production runs of relatively standardized equipment. (Procurements affected by the domestic assembly requirement of the UMTA Buy-America regulation for UMTA-funded procurements are not included in this group.) These firms are geared up for orders of 20 to 50 units and are therefore able to bid competitively for small orders, if the specifications do not require a new design. Recent light rail car procurements in San Diego, Buffalo, and Portland were based on in-production models.

The sequencing of orders has an effect on car prices. Recently, there has been a remarkable clustering of orders. In Chicago, Cleveland, Philadelphia, Atlanta, San Diego, Miami, Baltimore, Buffalo, Portland, and New York, transit agencies have all called for bids or placed orders in the past several years. This bunching of orders for different cars gives prime bidders and subcontractors minimal time to review specifications, seek cost estimates from vendors, and make the detailed technical analyses necessary to respond to bid documents. The time compression leads to added insurance costs for unknown conditions or risks.

Most orders are for a limited number of cars. The lack of assurance that there will be follow-on orders for similar cars contributes to high car prices. (In the past, a few orders have carried large options, such as CTA's order in 1978 for 300 rapid transit cars, with an option for an additional 300 cars.)

Bid timing and funding assurance also affect car prices. In an inflationary period, delays in the grant and multistage procurement process escalate costs. Funding should be timed so that local, state, and federal shares are all available at the appropriate time, and prime bidders must be given assurance that procurement will occur in a timely manner.