NORTH AMERICAN LIGHT RAIL VEHICLES

Joseph S. Silien and Jeffrey G. Mora,
Urban Mass Transportation Administration

This paper presents the evolution of North American light rail vehicles from the 1920s to the present. Emphasis is placed on conditions of the electric street railway industry in the 1920s, attempts at car standardization, and movement toward a radically new, high-performance car as background to the development of the Presidents' Conference Committee car of the 1930s. Events leading to the new standard light rail vehicle are presented along with its significant dimensional specifications and performance characteristics. The proposed Canadian light rail vehicle is described.

The development of a new generation of light rail vehicles (LRVs) is both a timely reflection of and a stimulus for widespread interest in light rail transit for North American cities. Recent vehicle developments have a close relationship to the process by which the predecessor of today's LRV, the Presidents' Conference Committee (PCC) car, was developed. In fact, today's LRV is part of the continuing and long evolution of transit vehicles.

In the early 1920s, the electric urban and interurban railway industry reached its zenith in profitability and ridership. However, automobile ownership began to increase dramatically at that time. The automobile proved to be a strong competitor for public transit and negatively affected the transit service that existed because it worsened traffic congestion. Along with these competitive factors, the street railway industry was burdened with obsolescent equipment that became increasingly expensive to replace as the depression neared. It was pointed out at the 1926 American Electric Railway Association (AERA) annual convention that more than 28,000 electric railway cars over 20 years old were in operation causing not only higher operating costs but also an increasingly poor public image. Although car design and performance had not changed dramatically during the 1920s, car prices escalated rapidly. The street railway companies were in financial difficulties because franchise restrictions frequently mandated a low flat fare that companies were unable to change in spite of higher capital and operating costs.

Two AERA subcommittees, the Committee on Unification of Car Design (1924) and the Committee on Essential Features of Modern Cars (1926), were formed to deal with the car replacement problem. The latter group developed what we would consider a set of standard specifications for street and interurban railway cars to overcome the problem of a proliferating number of car designs that were among the most important factors in dramatically increased car prices, and, of course, to stimulate ridership by providing modern equipment.

However, in spite of the importance of these committees in standardizing streetcar design and components, there was increasing discussion within the industry of even more radical improvements in car design and performance. For example, Charles Gordon, editor of the influential Electric Railway Journal, presented a paper in 1928 that discussed future rolling stock requirements and emphasized the difficulty in getting key technical personnel (master mechanics, in those days) to accept progress and innovation.

Of greater significance was a little known report prepared by an AERA Committee on Research in 1929. This committee conducted a survey of many electric railway companies to determine what research efforts were under way throughout the industry, and, more important, to make recommendations on what action AERA should take to coordinate or encourage these efforts. Prominent among the findings was the need for "a study to develop the type of street car needed for the future including its general design, control equipment, method of drive, and the like" (1). W. A. Keller of Pittsburgh Railways continued the discussion on a better car at the 1929 American Electric Railway Engineering Association meeting (2).

The movement toward a research program that culminated with the PCC car coalesced in a paper delivered in 1930 by Thomas Conway (3 pp. 137-148), president of the Philadelphia and Western Railway Company [Conway's legacy survives as the high-speed Norristown Line, which is operated by the Red Arrow Division of the Southeastern Pennsylvania Transportation Authority (SEPTA)].

Conway reviewed the serious problems then besetting the street and interurban railway industry. He focused his discussion on the car as the key to the problem. He complimented efforts at standardization but noted the lack of coordination of research projects being conducted by various companies. Conway pointed out that, of 74,000 electric railway cars operating in the United States in 1930, almost 40,000 were more than 20 years old and were ready for retirement. He stated that the 1930 automobile was far superior to its predecessors and that its cost was rapidly decreasing compared with the increasing cost of electric railway cars. He also stated that "so long as improvements are made in the private automobile, the electric railway car must keep pace. We cannot anchor while our rivals continue to sail ahead" (3). Conway then compared performance characteristics of the latest automobiles and streetcars and concluded that the automobile far outperformed the newest streetcar. The ideal performance characteristics of the streetcar had never been determined. Conway also was keenly aware of how important image was, even to streetcars of the 1920s, when he said: "There is . . . a brief and fleeting period of public attention when new equipment is placed in service on a line, but the fact is that . . . no one has yet evolved a railway car which possesses that elusive quality sometimes called 'it' which has been such a tremendous factor in the phenomenal success of certain makes of automobiles" (3, p. 143).

The 2 factors Conway cited as helping the industry decline were (a) individualistic master mechanics and (b) the fact that the streetcar was assembled and the joint product of many manufacturers (3, pp. 144-145). The systems integration problem was recognized even then.

At Conway's suggestion, a committee of presidents of street railway companies was established to direct a major research effort leading to the production of a new streetcar. The research and development program was funded by the street railway industry, suppliers, and manufacturers.

The committee chose C. F. Hirshfeld, director of research for Detroit Edison, as chief engineer. Hirshfeld was chosen because the committee wanted an engineering executive from outside the electric railway industry who could manage a large research and development project and who could win the confidence of key persons both inside and outside the industry. Hirshfeld approached the problem by using the concepts of systems analysis long before that term came into existence. Some of Hirshfeld's research is available elsewhere (4). In 1935, the research and development program was completed and the first production order for the PCC car had been placed. About 5,000 PCC cars were built in the United States and Canada, and nearly 1,200 are still in daily operation.

The streetcar systems in operation in the 1970s are far different from those of the 1920s. The systems in use now are few in number; they are for the most part publicly owned, and, except for New Orleans, they are served by PCC cars. The last U.S.

PCC cars were built in 1952. The PCC cars remaining in service are physically and economically obsolete.

Several large PCC fleet operators, notably the San Francisco Municipal Railway (Muni), the Massachusetts Bay Transportation Authority (MBTA) in Boston, and the Southeastern Pennsylvania Transportation Authority (SEPTA) in Philadelphia, were faced with the problem of what to do with their streetcar systems. Should they upgrade them or should they eliminate them? San Francisco was the first to make a decision and opted to upgrade in conjunction with a new high-platform subway being built below Market Street for the Municipal Railway streetcars. In the fall of 1971, Muni requested bids on 78 new cars designed by L. T. Klauder and Associates. The cars were 2-section, 6-axle, articulated, double-ended units featuring a powered center truck [for 65 mph (104.6 km/h) top speed], air conditioning, and a new fare collection and transfer issuing device and were capable of multiple-unit operation. In November 1971, 2 bids of approximately 500,000 dollars per car were received. After consultation with the Urban Mass Transportation Administration (UMTA), the bids were rejected as excessively high. The rejection of the Muni bids coincided with a decision by the transit authorities in Boston and Philadelphia to preserve and upgrade their light rail systems. A primary element of the upgrading naturally was to be a new vehicle.

The recent Muni bidding experience, the urgent requirement that 20- to 30-year-old cars be replaced quickly, and the previous experience of the transit industry in developing the PCC car prompted UMTA to call together the light rail system operators and urge that they work together toward a standard performance specification for common use. The proposed industry design effort was to be geared toward meeting current and future needs with a minimum cost vehicle. The market for replacement vehicles on existing systems is limited to perhaps fewer than 800 cars. If this market is diluted by purchases of 80 to 100 cars with no insurance of following orders, car builders have no choice but to charge all engineering, development, and tooling costs to the initial order. This fact was borne out by the Muni experience on the 78-car bid in 1971.

The rationale for a new standard vehicle seemed obvious. Rebuilding the PCC cars was not considered a satisfactory alternative principally because of the lack of readily available parts, the overall age and condition of the fleets, and the requirement for doors on both sides of a double-ended vehicle.

Transit property staff and UMTA had been reviewing the situation in Europe where the trend had been for many years to expand and improve light rail systems and where new equipment was operational. The review of European rolling stock led the MBTA to propose importing and demonstrating a modern European car not only in Boston but also in the other U.S. cities operating streetcars.

The proposal progressed to the point where, after an on-site inspection and negotiation, the so-called Hannover car built by Duwag as a prototype for a new generation of equipment was to be modified and imported. The program as envisioned might have shortened the specification development process by enabling the cities to test the equipment firsthand and to specify only required modifications.

Because the United States found itself in an adverse balance of payments position, the European vehicle demonstration was never implemented. Instead, the project was restructured as a specification development effort with the MBTA designated as the lead agency and UMTA grant recipient (5). Ground rules were few and rather rigidly enforced. The already developed Muni car specification was to be the basis for the new design. Variations among the properties were to be minimal and dictated by system requirements rather than preference. Advanced technology propulsion similar to that developed on the state-of-the-art car (SOAC) was to be an allowable bid item.

In a fashion not unlike that of the Presidents' Conference Committee, a Project Technical Committee was formed. Consulting assistance was obtained from Parsons, Brinckerhoff-Tudor-Bechtel, which used the UMTA Guideline Specification format in developing the new car specification.

The process of designing the car involved compromise on many points. As a basis for proceeding, it was decided to determine the largest possible car size that would satisfy the 3 principal users' needs (MBTA, Muni, and SEPTA). (SEPTA's clearances remain somewhat questionable because of a less than successful attempt to operate the

MBTA clearance car on the SEPTA system.)

Nevertheless, agreed on dimensions reflect the envelope of Muni and MBTA and are probably suitable for SEPTA as well. The new car, as specified, measures 71.5 ft (21.6 m) over anticlimbers, 8 ft 8 in. (2.64 m) wide, 11 ft 6 in. (3.5 m) high with locked down pantograph, has 23-ft (7.0-m) truck centers, and three 4.5-ft (1.3-m) doors per car side (6). The car is a 2-section, articulated vehicle. It is double ended but can be constructed in a single-ended version. The specification is heavily performance oriented and reflects a synthesis of the requirements of the operating agencies while preserving latitude for the manufacturers to innovate.

MBTA requested air conditioning, and Muni did not. Muni requested convertible high-low steps for the Market Street subway where platforms are at car floor height. The October 1972 specification bidding resulted in a low bid from Boeing Vertol Company of $316,616 each for 80 Muni cars and $293,422 each for 150 MBTA cars. That compares with the low bid price of $473,000 per unit in response to the 1971 Muni solicitation.

In a technical sense, the new LRV will be a success. Although it is somewhat less of a "hot rod" than either the PCC car when it was new or the earlier Muni design, the new vehicle incorporates all of the performance considered useful and practical based on the duty cycle requirements of the properties involved.

Removal of the requirement for a powered center truck resulted in a reduction in top speed from 65 mph (104.6 km/h) to 50 mph (80.5 km/h). Although the car can incorporate different rates of acceleration, the Standard Light Rail Vehicle Specification requires a maximum acceleration rate of 3.1 mph/s (1.4 m/s^2), a nominal rate of 2.8 mph/s (1.2 m/s^2), and a minimum rate of 2.5 mph/s (1.1 m/s^2). (Deviation from the nominal shall not exceed 10 percent.) The original PCC specified maximum acceleration rate was 4.75 mph/s (2.1 m/s^2).

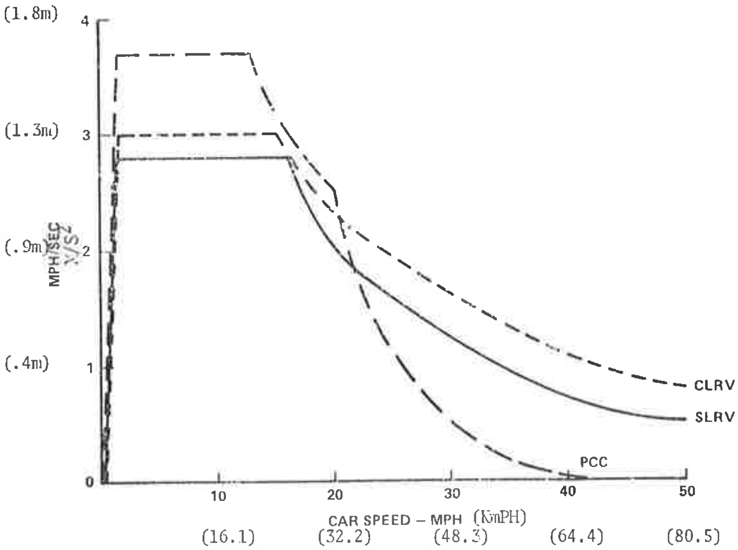
Let us compare the effect of the higher initial rate of the PCC car with the capability of the LRV to sustain acceleration for a longer period. The LRV is required to reach 50 mph (80.5 km/h) from a standing start in 37 s; the PCC could reach only 36 mph (58 km/h) in the same time period (Figure 1). The result is the ability of the LRV to travel between stations more quickly and comfortably than its predecessor could. The new light rail cars have several other innovations worthy of mention. These include an energy-absorbing coupler designed to sustain a 72,000-lb (320 000-N) compression while deflecting 14 in. (35.6 cm); a 2-position movable step (for Muni); a smooth-sealed articulation unit; a monomotor truck with both motor and gear box mounted to the truck frame, which reduces the unsprung weight and thus improves ride quality; a unitized car body that uses equipment bays as structural-load-bearing members to redistribute loads around the large 54-in.-wide (1.37-m-wide) door openings; and biparting plug doors (7).

The car body is constructed primarily of low-alloy, high-tensile (LAHT) steel except for the central roof skin, which is fabricated from stainless steel. The articulated section permits a rotation of 16 deg in a horizontal plane. In the vertical plane, the inclusive angles of 3 deg in a sag condition and 4.26 deg in a crest condition are the limiting values.

The LRV has a solid-state propulsion and a thyristor chopper-control system similar to that used on SOAC cars. The system uses a monomotor truck with a separately excited direct-current traction motor rated for 210 hp (157 kW) continuous. The armature voltage is controlled by a single 600 Vdc to direct-current force-commutated chopper with fixed frequency and variable pulse width. The field voltage is controlled by a separate, single 600 Vdc to direct-current chopper with variable frequency and fixed pulse width. The trucks are constructed of welded steel and have an inboard frame design. Twenty-six-in.-diameter (66-cm-diameter) resilient wheels are used. The truck frame has a rubber-chevron primary suspension system at each journal bearing, and a secondary air-suspension system that provides vertical and lateral cushioning.

The first new LRV became operational on a 0.5-mile (0.8-km) track at the Boeing plant late in 1974. Late in 1975, several pilot cars will be tested on the UMTA rail transit test track at Pueblo, Colorado. In 1976, the first new light rail vehicles built

Figure 1. Light rail vehicle acceleration curves for average passenger load.



CAR	PCC	SLRV	CLRV
PASS. LOAD (CRUSH)	75	219	93
LOADED WT (LB)	43,800	82,500	62,400
GEAR RATIO	7.17	5.57	5.57
WHEEL DIA	25 IN.	25 IN.	25 IN.
MOTORS (NO.)	4	2-DA214.3	–
MFG (MOTORS)	GE/WE	GARRETT	–

LEGEND

— — — PRESIDENTS' CONFERENCE COMMITTEE CAR (PCC)
——— STANDARD LIGHT RAIL VEHICLE (SLRV)
- - - - CANADIAN LIGHT RAIL VEHICLE (CLRV)

in the United States since 1952 should enter service in San Francisco and Boston.

A second significant LRV development program is under way in North America. The Canadian Urban Transit Development Corporation has developed a specification for a single-unit (nonarticulated) replacement vehicle for PCC cars operated by the Toronto Transit Commission.

The Canadian LRV will include a chopper-regenerative propulsion system, resilient wheels, a new suspension system, and low-level step entry for passenger convenience. The car will be 51 ft (15.5 m) long, 8 ft, 4 in. (2.54 m) wide, and 11 ft (3.35 m) high and will have a seating capacity of 45 to 51, depending on interior configuration.

The car is designed to be 10 dBA quieter than PCC streetcars. Exterior noise level specification is 75 dBA measured at 15 ft (4.57 m) at 40 mph (64.4 km/h). Interior noise is reduced by acoustical treatment of the car structure. A 3-level brake system is specified: electrodynamic, friction disc, and magnetic track brakes. The acceleration rate is specified at 3.0 mph/s (1.35 m/s^2), and the car is designed to go from 0 to 30 mph (0 to 48.3 km/h) in 12 s and from 0 to 50 mph (0 to 80.5 km/h) in 30 s. Maximum speed in a streetcar version is 50 mph (80.5 km/h) and 70 mph (112.7 km/h) in a light rapid transit configuration. The maximum service braking rate is 3.5 mph/s (1.6 m/s^2). The car also features energy-absorbing front and rear bumpers. Design life is specified at 25 years.

In summary, the new U.S. and Canadian LRVs represent a new generation of urban rail cars for medium-capacity light rail service. Although the heritage of these new vehicles can be traced from the first electrified streetcars of the 1880s and the PCC development of the 1930s, the LRVs represent a unique blend of contemporary performance requirements and industry criteria that will result in a vehicle of the 1970s that will satisfy its share of today's urban transportation needs.

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