LIGHT RAIL PERMANENT-WAY REQUIREMENTS AND SOURCES

Robert J. Landgraf, Shaker Heights, Ohio,
Department of Transportation

This paper sets forth the technical requirements for the permanent way needed in construction of light rail transit facilities and then develops sources for assembling rights-of-way. Described first are the physical capabilities of light rail transit for grade, curves, and clearances. Requirements for the guideway are established with the development of standards for track work suited to light rail transit. Latest techniques in track component design are evaluated. Pitfalls to be avoided in light rail facility design are pointed out. General requirements for stations are set forth with particular emphasis on space needs. Types of platforms, shelters, and security enclosures are described. Station needs for light rail transit are contrasted with the needs of full-scale rapid transit. Sources that can be considered for light rail rights-of-way are treated in a way intended to stimulate the imagination of the engineer and planner in locating potential routes. Dealt with are surplus railroad tracks, boulevard and freeway center strips, canal beds, stream channelization, electric transmission lines, parkways, street running, reservation of streets, and the selective application of elevated lines, bridges, and subways to light rail transit. Advantages and limitations of each type of right-of-way are explained.

This paper will discuss the technical requirements for the permanent way needed in constructing light rail transit (LRT) facilities. It also will develop sources for assembling rights-of-way.

CONFIGURATION LIMITS

Grades

An outstanding feature of LRT lines compared with most other forms of fixed-route transit, whether they have a fixed guideway or do not, is its physical flexibility. Light rail transit can do things that a heavy-duty rail line or a busway cannot approach.

Grades of 6 percent or more both ascending and descending are common with light rail vehicles. Short grades of up to 14 percent are the extreme limit. Some light rail grades such as those in Pittsburgh were simply too steep for bus replacements; other routes had to be developed.

Because of low vehicle weight and high power-to-weight ratio, LRT can handle grades at a faster speed than the usually heavy trains can. The desire to operate long trains in conventional rapid transit work precludes doing some of the things that have been done with LRT. The controlling factor is braking capacity, a feature that easily can be made higher than standard on light rail vehicles.

Curves

Vertical curvature can be rather extreme on LRT compared with that on conventional rapid transit. Having no requirement for riders to pass between vehicles, light rail vehicle design can provide great freedom in vertical curve limits, both sag and crest. Single vehicles made to the rather short Presidents' Conference Committee (PCC) truck centers can do amazing things in this respect. When light rail vehicles (LRVs) are operated in multiple units, the couplers with their drawgear and radial carriage requirements can tend to restrict the vertical curves that can be taken. However, this limit is not reached on any active North American operations.

Articulation can place fairly restrictive limits on vertical curves, though the new standard light rail vehicle seems rahter liberal in that respect with a limit of 310 ft (94.5 m) radius crest and 460 ft (140.3 m) radius sag (1, pp. 2-4, paragraph 2.1.7). Passenger apprehension of the change in curvature might be greater with articulation. Just about anything reasonable can be done. The decision involves how much seating capacity to sacrifice to make the connecting drum larger.

Horizontal curve capability is what sets LRT apart from conventional rapid transit. Light rail transit was originally conceived to have a track that could accommodate the right-angle intersections on city streets.

Light rail cars usually have been designed with rounded ends. This has been done not so much for aerodynamic design as for clearance on turning, particularly when they are run in multiple units. Couplers are radial; they swing in a semicircle rather than ride in a striker box as they do on a railroad car. When knuckle couplers are used, the capability of going around curves becomes very high.

Today's light rail vehicles are designed to negotiate curves of 42-ft (12.8-m) inside rail radius (1). Anything tighter than that would place limits on features other than the coupling or articulation. Car width, location of trucks, and wheelbase might have to be restricted unduly.

Usually, the most extreme horizontal curves in a light rail system are in the nonrevenue tracks required for reversing single-end vehicles at the end of a route. The single-end design is highly desired in markets that demand maximum seating, and the relative inflexibility and need for turning trackage of the single-end car can be a favorable trade-off for its lower first cost and greater number of seats than double-end cars. Loops and Ys can be placed in a relatively small space because of the 42-ft (12.8-m) radius.

Clearances

Clearances can be very close in any fixed-guideway system when compared with those needed to allow for steering variations. Indeed, only the sway of the vehicle and a small allowance for air movement and any door folding need be considered for clearance in tunnels. Recesses for maintenance personnel to stand clear are needed at regular intervals. However, the low first cost of very tight tunnels for a light rail system may result in a later generation being unhappy with what was done originally. The Boston Central Subway testifies to this problem; later add-ons were built less restrictive than the original construction. The possibility of eventual conversion to full-scale rapid transit ought to be considered at the beginning.

An important factor not to overlook when one establishes controlling clearances is whether railroad interchange will ever be needed. Many things can be done on vertical and horizontal curves with railroad cars handled 1 at a time, but no side or top clearance means that no car can pass. Of course, not all parts of a light rail system may be candidates for interchange traffic, and designers can take this into account. As in all engineering work, a cardinal rule is to plan ahead. Many of the light rail systems built on standard-gauge track in the early years of this century provided full railroad clearances for the freight cars of their day.

The maximum clearance desired also can be important. There is no gain in taking on responsibility for more land than a light rail operation can use to any advantage. This situation has arisen at Shaker Heights, Ohio, where a light rail line may be absorbed into the Regional Transit Authority (RTA). Boulevard center strips of 60 ft (18.3 m) and 90 ft (27.4 m) were originally provided, and title to these has been held by the transit system. However, when the system goes from the city to the RTA, a perpetual easement for 42 ft (12.8 m) may be granted; the city would retain the land and maintain the landscaping (2). Existing paved platforms, which are adequate, fall within these dimensions.

It is possible to provide a double-track light railway line having cars 9 ft (2.74 m) wide and ample, 40-ft-wide (12.2-m-wide) side platforms directly across from each other. This leaves plenty of room for landscape screening except at the platforms. Any width beyond 45 ft (13.7 m) saddles the light rail operator with more land than can be used. Someone is going to compel the operator to keep that land free of weeds or mow it. By offsetting platforms and using reverse curves in the track, widths as narrow as 32 ft (9.8 m) could be used. For single track without stations, or for each additional track, a horizontal allowance of 14 ft (4.3 m) is adequate.

Vertical clearances must leave enough room for overhead wire and not cause insulating problems or difficulty with current collectors. Twenty ft (6.1 m) from top of rail to ceiling should be enough for any light rail application and still allow later conversion to any other rail use. A minimum of 14 ft (4.3 m) should be observed if there are severe restrictions because a potential bottleneck has been built in.

GUIDEWAY REQUIREMENTS

Rail Weights and Types

Light rail lines in the early days used just what the name says: light rail. It would be difficult to find any 60-lb/yd (29.8-kg/m) rail remaining, but at one time it was very common. Many interurban lines were built with 75-lb/yd (37.2-kg/m) rail. The minimum-weight T-rail now in common use on light rail lines is 80 lb/yd (39.7 kg/m).

A desirable standard for light rail operations is 100-lb/yd (49.6-kg/m) rail. A fairly heavy rail, because it is more rigid, can help to overcome a poor roadbed. The 80-lb/yd (39.7-kg/m) rail in wide use is just too light, and 90-lb/yd (44.6-kg/m) rail is becoming difficult to obtain. One-hundred-pound-per-yard (49.6-kg/m) rail, particularly in the ARA-A cross section, will probably remain common for many years.

Some rebuilding of existing light rail lines has been done with much heavier rail. Anything larger than the popular 115-lb/yd (57.0 kg/m) AREA rail may be a waste of money, unless a larger section is wanted for greater electrical return and it proves more economical than supplementary negative cable. The trade-off must take into consideration that the rail will have to be replaced eventually and that the cable should last indefinitely.

The use of grooved rail originated with street railways. It still finds wide application even in open running on curves because it provides the safety feature of a separate restraining rail at a low cost. The underground portions of the Rotterdam Subway in the Netherlands are built with grooved rail; they probably want very much to avoid any derailment (3).

Grooved rail was originally meant for pavement on which the paving material was likely to fill up the flangeway inside T-rail and cause cars to climb and wander off the rails especially on curves. It is recommended for the portions of the line that are in pavement. However, interchange railroad cars and their larger wheel flanges will be difficult to handle unless the very large rail sizes designed especially for full-size railroad car wheels in pavement are used. New light rail projects should consider adopting Association of American Railroads standards on wheel contour to ensure easy availability of track components.

Rail Gauges

Rail gauges for light rail applications have ranged from meter gauge common in Europe to as wide as 5 ft 4½ in. (1.64 m) in the Baltimore street railway system (4). The narrower gauges [meter and 3 ft 6 in. (1.07 m)] originally were adopted for economy; ties could be shorter, and the ballast cross section was narrower. These gauges generally are inadequate for U.S. practice. To avoid poor riding of cars, narrow-gauge rail lines must have better maintenance than standard-gauge lines, particularly for cross level. The meter-gauge light rail lines of Europe usually are maintained superbly.

The nonstandard wide gauges [4 ft 10⅞ in. (1.50 m)] once fairly common in the United States and still surviving in Toronto were imposed by city councils who wished to prohibit physically the operation of interchange railroad cars in city streets. So-called wagon gauge, which is about 5 ft 2½ in. (1.59 m), survives in Pennsylvania, in both Philadelphia and Pittsburgh.

Although the wide gauges are better than narrow gauges for controlling sway, they have no particular riding merit and have cost disadvantages in light railways, for which 4 ft 8 in. (1.44 m) is just about right for the usual light rail car. Wide gauges of 5 ft 6 in. (1.68 m), which are used in Spain and on Bay Area Rapid Transit in San Francisco, are better than standard gauge for today's giant railroad operations that have very high cars and fast unit trains, but a general change probably will never be economically justified.

Any new light rail system should be built to the common gauge of the country in which it will be located. Extensions to existing nonstandard systems, such as might take place in Pittsburgh, Philadelphia, or Toronto, should follow existing gauge. There are 3 advantages to standard gauge or the country's common gauge. First is the availability of standard components. Second is the possibility for railroad interchange on parts of the line where other conditions permit. Third and perhaps most important is the capability to transport materials for extensions and maintenance projects in 1 rail vehicle from supplier to installation site. A substantial unnecessary cost for transferring materials from one car to another thus can be avoided. Any new light rail line ought to have, at absolute minimum, the ability to handle the interchange of 50-ft (15.2-m) flatcars except at turning loops and Ys and other problem locations where no full-clearance solution is practical. Each stretch of the line blocked from the others by such a clearance restriction ideally ought to have its own access to the general rail network.

Special Work

For ease of availability, special work (frogs, switches, crossings) ought to be standard railroad or heavy rapid transit types except when tracks are in pavement. When using the street types of special work intended for paved surfaces, one must take care that the rail contour and flangeways will accommodate the wheels of any equipment to be used on that part of the line. Deep flanges can readily smash street railway switches; again, any new project should use full-depth railroad types of paved-area special work.

Special elastic switch points and improved frogs have been developed in Europe and are used widely in light railways. In the United States, use of the spring frog, which required conscientious maintenance, has declined. One special work item that should be considered more often is expansion points. Expansion points minimize problems with continuous welded rail (CWR), especially on sharp curves. If CWR with all its advantages is not installed correctly and is not maintained to the best standards, it can be terrible for a light rail line whose cars are sensitive to misalignment. At the speeds proposed for most new light rail projects, this alignment matter can be very important. In other words, CWR must be done right or be avoided. Field welding is not as suitable as shop welding because the latter generally gives better accuracy of alignment.

Track Structure

The time-proved support for all types of railroad still is treated hardwood ties on crushed-rock ballast. For light rail, the ties can be smaller than standard railroad practice. Cross section of 6 by 8 in. (15 by 20 cm) is adequate. Length of 8 ft (2.4 m) is suitable, but 8 ft 6 in. (2.59 m) is more common. Tie centers can be 24 in. (60 cm); this requires 2,640 ties/mile (1650 ties/km) versus 3,000 ties/mile (1875 ties/km) or more for heavy-duty railroads. In a light rail application in which properly selected hardwood ties are used on a well-drained and adequate ballast and in which tie plates are used and good maintenance practices are observed, the ties should last an average of 40 years.

Concrete ties are becoming more established in the U.S. market even though their problems seem to continue year after year. Failure by cracking is still too high; special fasteners are required; and insulation is always a problem where rail-actuated signal systems are involved. It is awkward to replace a few concrete ties; the problems of gradually converting existing track to concrete are formidable.

Metal ties have been used in rail applications where speeds are low and cushioning demands are light, such as in yards and spur tracks. However, in an electric railway with return current in the track, they promote electrolysis. They probably would generate considerable noise except at very low speeds.

Slab track, on which the ties or a substitute method of support and gauge holding are completely enclosed in 1 or more concrete pours, has proved satisfactory in preserving excellent alignment and minimizing maintenance costs. Pittsburgh has several examples, some of which have been in use a long time. Indeed, joint use of private right-of-way by buses requires this method and pavement up to top of the rail. The line thus becomes a restricted-use street for public transit vehicles only. A law enforcement problem is created in keeping automobiles out. Disadvantages of slab track include a far higher installation cost than ballasted track and the difficulty of using track-actuated signal systems, which require special rail-to-rail electrical insulation. Noise transfer ought to be studied carefully before a decision is made to install slab track at a particular location. Major railroads are studying the entire question of track structure because it is believed that the present standard practices are inadequate for heavy loads at high speeds. Open types of slab track with rail and fasteners fully exposed show promise, and considerable advanced testing is going on in both Europe and Japan (5). However, the conventional standards even when applied at the minimums suggested in this paper have served light rail very well. Moreover, it must be emphasized that there is no substitute for proper track maintenance.

STATIONS FOR LIGHT RAIL TRANSIT

Limits of Range

Stations for light rail facilities can vary all the way from a mere patch of cleared ground to elaborate enclosed facilities in a subway or terminal building. The type of station to be provided is a function of several variables: passenger volume, train frequency, climate conditions, method of fare collection, immediate surroundings, and civic requirements.

One thing to keep foremost in mind when one plans stations for a light rail facility is that most sites should be able to be upgraded later if conditions warrant. When possible, it is important to obtain control over enough land at the station locations at the beginning to allow for later elaboration. Space for parking requirements ought to be a major consideration in locating some of the stations.

Platforms

Most LRVs have the first step at a considerably greater height from rail head than the intervals between steps including the car floor. This extra height is to give better clearance from snow or foreign objects near the track. It is therefore helpful to provide a platform somewhat above rail height as is done in commuter railroad practice. The PCC car first-step height was selected to work very well from a "safety island" with foldout doors, and it is quite difficult to board from pavement (rail-head) level (6).

The practice on some U.S. light rail lines of paving up to the running rail on open track to give a no-cost edge to the platform should be avoided. Not only is the platform too low, but an ideal environment for electrolysis is created. The seam between the paving (usually asphalt) and the rail quickly opens up, and moisture, salt, and dirt go in.

Where it is desired to run railroad interchange traffic, the standard gauge light rail lines should avoid platforms that are so high and close to the running rail that they interfere with railroad clearances. Of course, if other factors, such as tight tunnels, preclude interchange, platforms do not matter. With this limitation in mind, it is a good feature of light rail lines that floor-height platforms can be constructed at selected high-volume stations not on interchange territory simply by equipping some or all vehicle doors with automatic high-low steps. This is being done on the center doors of new LRVs for San Francisco. The downtown subway will have floor-height platforms to speed passenger flow.

Platforms on light rail systems usually are on the outside of double tracks, but center platforms often are used at locations accessible only by stairway or escalator to avoid the need for 2 platforms at each station. Double-end cars or left-side doors make platform location choice flexible; in some instances, left-hand running has been used with single-end cars having doors on 1 side only to allow use of center platforms. Note that light rail systems can be adapted to any need in this respect.

Station Enclosures and Security

When on-board fare collection is used, light rail operations need not have fenced stations. It is desirable to have fencing in the center strip between tracks at busy stations to prevent passengers from stepping across in the way of oncoming trains. Reverse-flow, off-train fare collection concentrated primarily at 1 or a few points also can eliminate need for fencing at all but these points. With a prepaid fare collection, the security needs for LRT can become as great as for standard rapid transit systems, which eliminates one of the low-cost advantages of LRT. European-style self-validating fare systems avoid this problem. Certainly fencing should be minimized to help light rail stations blend into the environment.

Shelters or buildings for LRT can be minimal where frequency of service is good. The main purpose of a light rail shelter is to protect the passenger from the weather. Monumental facilities are to be avoided unless the light rail boarding point is only an auxiliary use of the building.

Any shelter should provide good visibility on the inside as well as the outside. Passengers feel safer when they are not hidden. The new designs of shelters that use metals and clear plastics are especially suited to light rail. These designs give the impression of permanence without seeming overbearing.

Unless frequency is very high, little amenities such as interior lighting and radiant heat are desirable. Every shelter ought to have a good bench that is large enough for the patron to wait in comfort. Making transit benches narrow enough to keep vagrants from sleeping on them is typical of negative thought in the industry.

An attractive idea for downtown portions of light rail lines is to run the tracks on tangents or gradual curves adjacent to the sidewalk on a lane reserved exclusively for transit vehicles, taxis, and emergency automobiles. This method makes the sidewalk the continuous platform and helps to solve problems of mixing buses and light rail cars on the same street. No shelters are needed because there are usually plenty of stores and building lobbies to provide shelter in bad weather. The concept of combining this layout with transit malls could be very attractive. Allowance must be made for unusual geometry when turning from one street to another.

SOURCES FOR LIGHT RAIL RIGHTS-OF-WAY

Surplus Railroad Tracks

Today, a great deal of attention is being given to lightly used railroad tracks in and around urban areas as the most obvious opportunities for establishing LRT service (7). Freight-only branches that go radially from downtown, such as those in the Dayton, Ohio, proposal, are good candidates. Freight operations can be continued on a twice-daily basis, and a short train can run during a midday lull. Any fairly long trains and most switching would be confined to night hours after the transit operation is closed. Institutional problems on work rules, crew sizes, and jurisdiction among unions are encountered, but these obstacles are of a political rather than a physical character. They should be overcome by agreement in advance.

Second main or third main track no longer needed on a full-time basis offers a chance to establish LRT economically. Indeed, such multiple-track facilities often have grade separations and plenty of room for stairways and platforms already provided. Although the extra tracks may be gone, restoration is fairly easy. The 2 tracks for light rail need not be adjacent, though they might best be in the innermost tracks of such a facility to minimize the need to cross the light rail tracks for industrial switching. Here again, the light rail tracks could be relinquished at night for freight movement. Some proposals involve the use of 3 tracks for both freight and LRT; one commonly is used for both services in the middle of the day.

A few cities, particularly in the East, have obsolescent radial rail routes that primarily were for passenger service; freight service was merely incidental. These commuter facilities can make fine light rail routes and often carry more passengers at a lower unit cost after conversion as shown by the Riverside operation in Boston. Proposals to convert such lines to full-scale rapid transit are often needlessly expensive and not justified by volumes to be realized; LRT then becomes a lower cost alternative. In some cases, the underused or abandoned downtown passenger station can be included advantageously in the light rail plan.

Belt or bypass rail routes in the major cities are looked on now as candidates for LRT as feeders to radial routes. Freight sharing is essential; heavy-duty rapid transit possibly is not justified; so-called railbus did not work out. It is light rail or nothing for such a line.

Boulevard and Freeway Medians

The center strips or "parkways" of boulevards are favorite targets for planners of LRT. After all, that is what many of them were in the heyday of the trolley era. Why not restore them? We must be careful here not to pick such a boulevard while overlooking a better but less obvious right-of-way possibility in the same corridor. Many of these older boulevards have so many cross streets that a light rail line would run too slowly unless some crossings could be eliminated. In general, it is undesirable to encounter grade crossings in boulevards more frequently than station stops, and it helps safety to have both at the same locations unless the light rail car can preempt the traffic signals (7).

A narrow boulevard strip can be used for one track in a light rail line if another linear way nearby can be used for the return. In fact, the 2 tracks of a light rail line could be a city block apart if that is what works out best. Again, light rail is flexible.

Some streets and highways are lightly used because they have been made somewhat superfluous by construction of parallel roads such as freeways. A new median strip could be created for light rail in such older roads without having to take extra land; the new use would interfere little with vehicular traffic. Indeed, the paving could remain as an excellent foundation for ballasted track. Cities with fully developed freeway networks may have several such opportunities.

Older freeways with all ramps at the outside lanes may be suited to light rail construction in the center median, especially if at least one lane for vehicular traffic can be given over to mass transit (8). Such a conversion will become more feasible if the economics of private automobiles and electric mass transit continue in the direction they have been going. Such a light rail line would have the virtue of being as fully grade separated as the freeway it supplements. The practice of placing light rail lines in freeways is common in Europe. The smaller, less obtrusive rail vehicles have somewhat less of a visual impact on motorists than do full-scale rapid transit lines with high-platform stations, such as those in Chicago and Oakland.

Other Linear Ways

Abandoned rail rights-of-way are the ground on which planner and historian meet in today's renewed interest in light rail. There are many stretches of former street railway, interurban, or steam railroad rights-of-way still intact; every one of these in an urbanized area seems at first glance to be a target for LRT. Caution must prevail; perhaps the very reasons why the line did not become a street or highway after the tracks were taken up are valid reasons today for not selecting that route for restoration. The temptation to put LRT back merely because it is cheaper to build there must be resisted; LRT has to go where the customers are.

Old canal beds have made good light rail lines; the existing Newark line and a possible Rochester facility are examples. A high degree of grade separation is built in. A somewhat related possibility for LRT can be found in the channeling or culverting of existing streams. Slopes can be built up with gabions or crib walls to provide a horizontal surface adequate for light rail, especially if a track is located on each side of the stream. Culverting of waterways has been used for making streets; it should be as easy to use for LRT.

Many metropolitan regions are crisscrossed by electric transmission lines. Combining these with light rail facilities is an old idea that had outstanding application in a famous and unwisely abandoned line. This type of routing is being considered for a light rail line in the northeast Toronto area. When the rail-transmission project is planned as a unit, the electric towers can carry the rail overhead contact wire along with commercial power and rail power feeders.

Parks are often linear especially in cities. A light rail line can be blended into the environment of a park better than any other permanent way transportation (9). In Europe, there are several light rail lines with the track intentionally imbedded in sod, as was done on Saint Charles Street in New Orleans. This arrangement makes for quiet running, although track maintenance costs will be increased somewhat and the rail must be kept free of leaves and grass.

Street Running

Operating light rail lines with mixed traffic in the style of a streetcar is a last resort. It should be confined in future installations to those critical locations where no other practical alternative is available. Certainly the major portion of any light rail line should not require the trains to compete with mixed traffic. Some LRT in general-use paving is tolerable in areas where automotive traffic is light.

Light rail operation in streets or portions of streets that have been reserved for the exclusive use of transit vehicles is a completely different proposition. It should be highly desirable especially as a low-cost yet extremely convenient method of downtown distribution. It has found a wide and growing application in the older city centers of Europe. The rebuilt line in the Pittsburgh Mount Washington tunnel combines LRT and a busway. There are various ways to set off the reserved area, from temporary striping to permanent curb-type barriers that still allow passage for emergency vehicles (9).

As mentioned earlier in the discussion of slab track, signaling results in higher costs. Advanced technology involving use of electric eye, radar, or some other unproved sophisticated method could provide the equivalent of signals.

Elevated Systems, Subways, and Bridges

Because of cost, elevated systems, subways, and bridges must be limited to the highest density locations or key bottlenecks. Light rail transit is meant to be a lower cost alternative, and an excess of fully grade separated structures or tunnels can quickly eliminate most of that cost advantage. However, there is no other practical way to cross a freeway or a railroad of major importance.

The subway, as a method of downtown distribution for LRT, has wide application in Europe and in 3 cities on this continent. Aside from costs, it is a mixed blessing. The facility is removed from the customary habitat of the rider, and the subways are difficult to keep attractive. When the light rail line has several branches, there may be no politically realizable downtown solution other than a subway because too many surface streets would have to be sacrificed otherwise.

A general rule to be followed in designing any light rail elevated structures, bridges, or subways is that physical capabilities for heavy rail transit operations must be built in unless no possibility exists that later conversion will be desired. Bridge design should allow excess capacity in any event. As mentioned earlier, LRT tunnel clearances that proved inadequate for rapid transit have been the bane of several underground transit operations. It is better to err somewhat on the side of generosity and leave enough for future generations to work with.

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