PART 5

Operations and Maintenance

Cleveland's Light Rail System in the 1980s: The Ongoing Revolution

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In the early 1980s, the light rail lines in Cleveland were completely reconstructed and equipped with a new fleet of radically different cars not at all suited for street running, effectively converting the line to a low-platform semi-metro and thus realizing much of the long-term intention of the original builders. But these projects, costing upwards of $100 million, were not the end of the matter. Despite the damage to riding volume caused by the disturbances of reconstruction, the revolution resumed near the end of the 1980s. Five recent, basic changes have been made to the system: conversion to right-hand running in the formerly left-hand area, installation of a cab signal system on the western portion, construction of a combined end-to-end high-low platform station downtown as part of an indoor shopping center, evolution of the two boulevard center strips into linear parks, and retrofit of the new car fleet to overcome two major problems. The work reveals much about tolerable levels of deviation and disruption in planning and construction of new or revamped light rail lines. The lesson is derived that operations management must be more assertive early in the planning process when rail transit systems are being altered for purposes not directly related to their performance.

In the early 1980s, the former Shaker Heights Rapid Transit, now known as the Blue and Green Lines of the Greater Cleveland Regional Transit Authority (RTA), was completely reconstructed at a cost approaching $100 million, with all new track, new overhead electrical distribution, two additional substations, new retaining and guard walls, new platforms and shelters, refurbishing of the sole downtown terminal, a huge new shop (shared with the heavy rail system), and a fleet of specialized articulated light rail vehicles (LRVs) 80 ft long and weighing 90,000 lb, which were a radical departure from the various adapted streetcars that had always been used on the lines from their 1913 beginnings. The system was transformed into a true semi-metro, with only the old signal system, parking lots, and two substations built in 1968 remaining. These changes are well described in the literature (*1–3*). For the most part, the reconstruction and refurbishment has proved to be a first-class job and easily maintainable. From the passenger's viewpoint, the far more comfortable and quiet ride with air-conditioning was nothing short of a revolution.

The reconstruction drew to completion with an afterthought: the second complete rerailing of the shared trackage that had been rebuilt with 100-lb ARA-A continuous welded rail in 1955 to accommodate the new heavy rail line. Selected curves had been rerailed again, but this type of rail had become hard to obtain. Instead of using 100-lb ARA-B as had been done on the light rail construction, making procurement compatible with New York's subways, it was decided to go top-drawer with the popular, more rigid, 115-lb AREA, which rested well on the existing tie plates. The result is a very stable roadbed, better coping with the forces caused by frequent operation of two very different types of cars. Unfortunately, this project dragged on over a period of 5 years because the first contractor had problems.

These radical innovations with their large investment were far from the end of the matter. The revolution once set in motion took on a life of its own. Ideas that had seemed like pie-in-the-sky took form without thought as to whether the system had undergone enough already—enough investment, enough change, and perhaps too much disruption.

The inner end of the system just had to be switched over to right-hand running, even though it was converted to left-hand when street-running downtown ceased in 1930 and had worked well enough. A sophisticated cab signal system has been installed on the 3 mi of line shared with and approaching the heavy rail route, replacing a dilapidated three-aspect light system with automatic stop trip-arms installed in 1955 that had not been maintained properly since its youth. Moreover, this older technology depended on assuming a level of competence among drivers not experienced since the RTA began in 1975.

The two separate downtown stations for light rail (low-platform) and heavy rail (high-platform), which had high capacity for future growth and for dealing with special situations, have been taken out and combined into one through station with high and low platforms end-to-end. The new station has a strained capacity, little capability to cope with problems, and a costly turnaround operation. Its stairways and escalators have the appearance of a Dantesque pit in the midst of a very sophisticated major downtown shopping mall and entertainment area.

The above three projects affect only the western 3 mi of the light rail system and are no direct benefit to the rest. They are intertwined in that the change to cab signals and right-hand running had to be coordinated with the work of combining the downtown stations. The cab signal system was planned in the 1970s and would have been installed eventually without the new station.

Landscaping was greatly enhanced along the boulevard center strips in Cleveland and Shaker Heights, with RTA assuming the cost of maintenance in Cleveland. The two light rail branches were, in effect, converted to linear parks with little or no benefit to the riders.

Acquiring the radically different car fleet in the first phase of the revolution brought in a new set of troubles, with snow choking electrical ventilation systems and nearly complete premature failure of the original gear drive sets. These prob-

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lems are not all corrected yet, and further major headaches may be expected from cars now a decade old. But, from the rider's viewpoint, these cars are the crowning achievement of the system's renaissance.

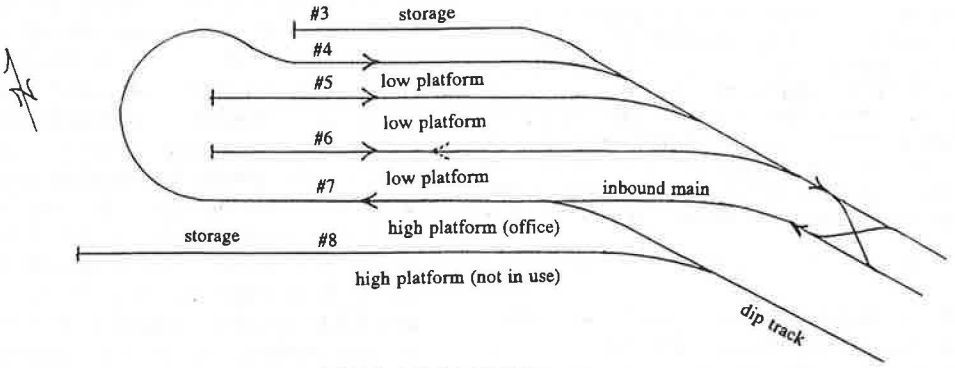
It is hoped that planners and operators of light rail systems will learn from the ongoing Cleveland experience.

CONVERSION OF SHARED TRACKAGE TO RIGHT-HAND RUNNING

Combining the light rail and heavy rail stations in Cleveland Union Terminal into one end-to-end facility, as described later, necessitated the change of light rail's western terminus to right-hand configuration, with passengers alighting and boarding on the left sides of the cars (except for the single stub track, which allows either side of a car to be used). That portion of the line from the junctions east of East 55th Street into Union Terminal had been left-hand long before the heavy rail line was built. The reason for that strange operation lies with the types of cars.

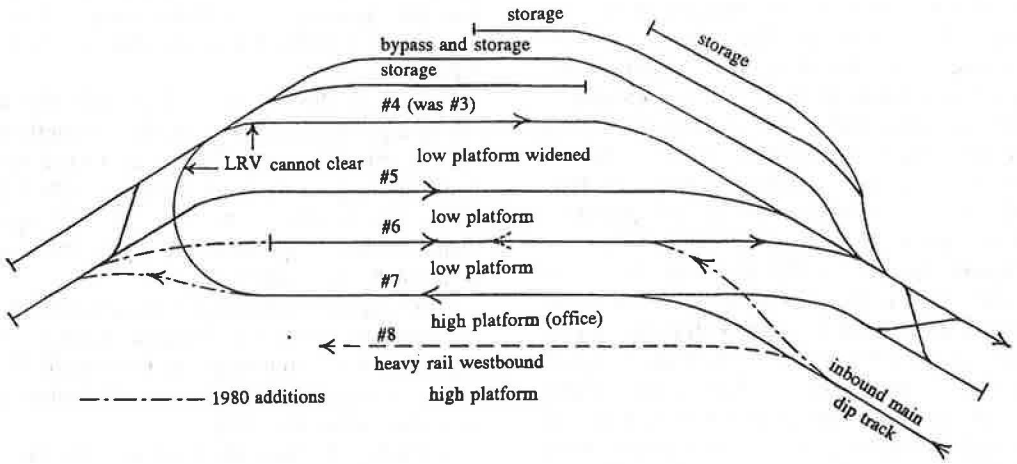
From the time the first parts of the Shaker Heights lines were opened in 1913, single-end streetcars had been the mainstay of the rolling stock. With the exception of seven interurban cars purchased in the 1930s, all cars on the light rail system had doors only on the right. The original fleet, in fact, had only a pair of center doors. All operation was right-hand (with all platforms on the outside) until operation into Cleveland Union Terminal began in 1930.

To minimize trackwork in the terminal and to maximize space for platforms, the "temporary" track arrangement of 1930 (Figure 1) consisted of an inbound track at the left, a clockwise semicircle loop to an outbound track, and two stub tracks in between to be used by backing in or out. In the 1950s one of these stub tracks was extended to cross the loop into a "tail track," permitting easier filling after cars had



1930 VERSION

Note: Schematic only.
Not to scale.



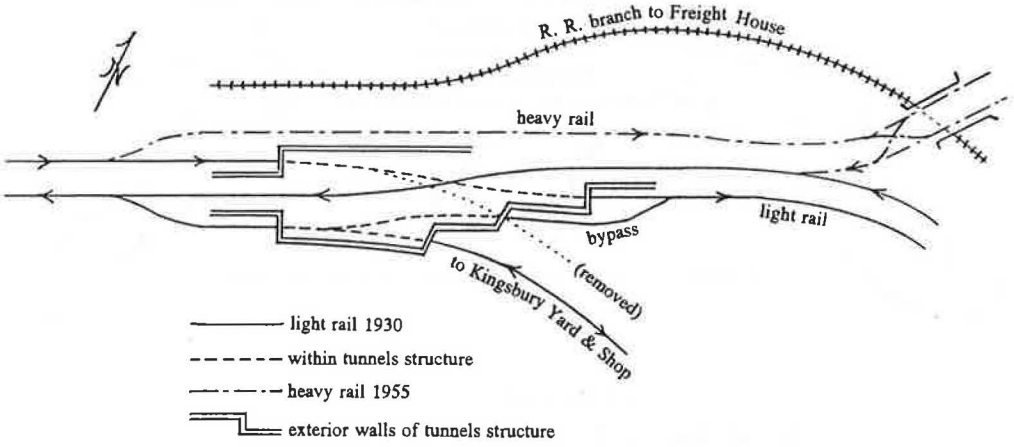
1955 AND 1980 VERSIONS

FIGURE 1 Light rail station in Cleveland Union Terminal.

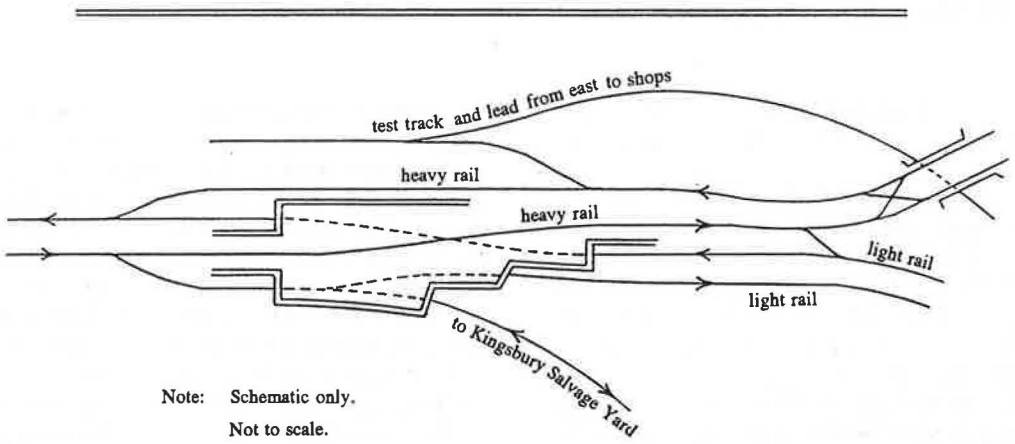
passed around the loop, backing and then pulling forward. This compact arrangement produced a very flexible loading operation (Figure 1, lower part).

The change to left-hand running was made with an over-under braiding move at the new junction tunnels structure east of East 55th Street (Figure 2). This was easy to do after the project constructing the (heavy rail) line to East Cleveland was abandoned in 1930. The westbound line was redirected over the top of the tunnels, and the planned westbound tunnel became the eastbound. The planned eastbound tunnel was used only for switching and an approach to the new Kingsbury Yard and Shop. A center island station was built at East 55th with a very strange shelter at high-platform level, steps leading out of it to the "temporary" cinder low platform. All signals between the junction tunnels and the new 1930 trackage at East 34th Street had to be relocated for left-hand running.

In 1955 when the heavy rail line to East Cleveland was finally completed, it was decided to retain the left-hand configuration east of the downtown terminal, simplifying the junction problem at East 55th. An existing dip track in the terminal was used for both lines to "duck under" the Cleveland Transit System (CTS) eastbound as it changed from right to left (Figure 3). The West Side (of Cleveland) CTS line was constructed right-hand as the easiest way to use this dip for the blending of the two lines at the terminal with no crossing at grade. The first fleet of CTS cars (the "blues") was built with the cab on the right because it was guessed (wrongly) that left-hand running with center platforms would predominate, especially in a downtown subway that was never built. As time went on and the right-hand downtown and West Side operation became more important, this decision was regretted. From the time of the 1967 airport extension, all heavy



1930 AND 1955 VERSIONS



1990 VERSION

Original plan is fulfilled.

FIGURE 2 Transit junction east of East 55th Street in Cleveland.

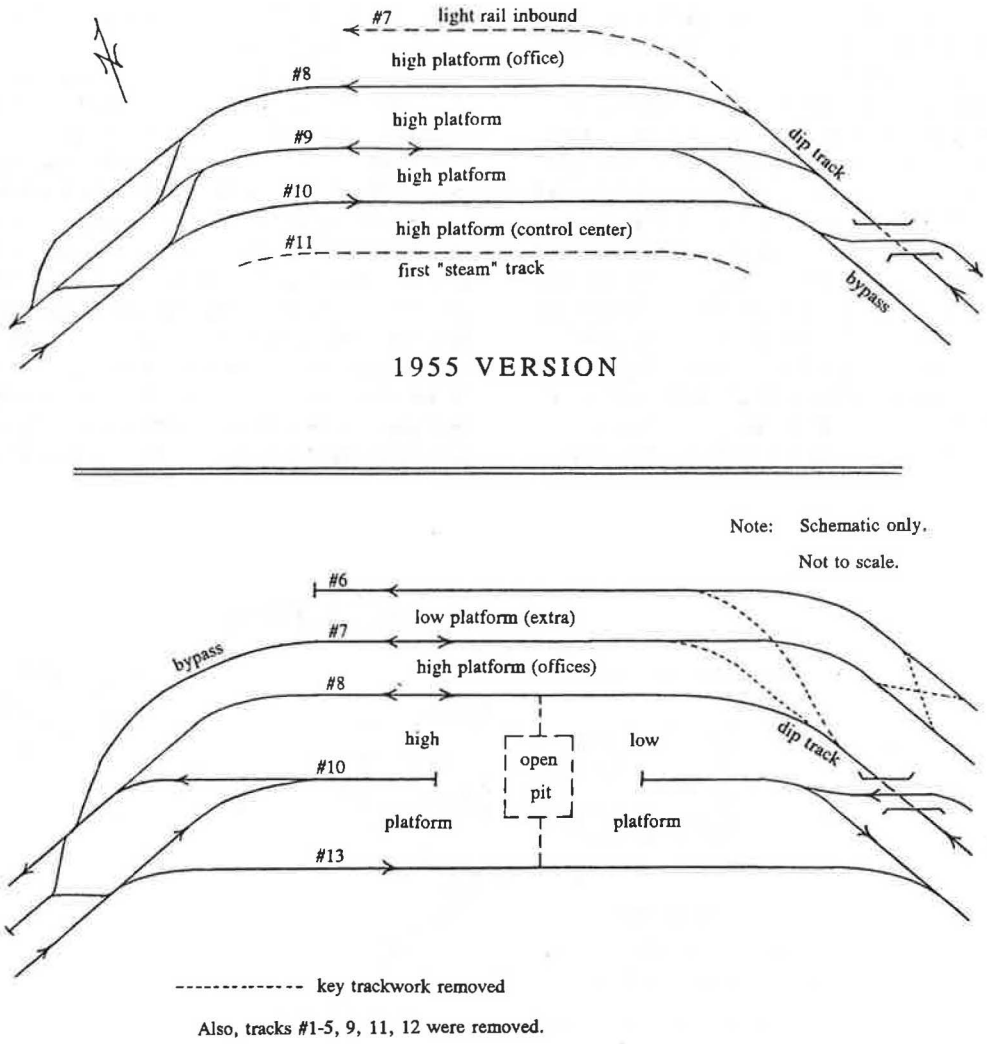


FIGURE 3 Heavy rail and later combined station in Cleveland Union Terminal.

rail car orders have been for vehicles with cabs on the left. Except for East 55th, no heavy rail stations used outside platforms.

With the retirement of Shaker's President's Conference Committee (PCC) car fleet and discontinuance of the separate light rail station, all reason for the left-hand operation has gone. Along with the new Tower City Station, a conversion to cab signal operation (discussed separately) provided the opportunity to go right-hand without having to relocate existing block signals and automatic stops. They were being removed anyway. The new cab signal system is operational on all the heavy rail lines, on the shared trackage for its entire length, and on the light rail system nearly to East 79th Street. By restoring the light rail tracks at the junction tunnels to their original configuration, right-hand running has been resumed, as shown in lower part of Figure 2. The meeting of the light and heavy rail systems at that point even looks more normal.

One feature of the "temporary" junction arrangement (which lasted for 60 years) has been retained. A part of the old westbound over-the-top track has been converted to a crossover from the westbound light rail to eastbound heavy rail, providing an escape operation for light rail in case the tunnels are flooded (which has happened many times). This feature plus the "test track" and shop lead from the east provided as part of the 1980s reconstruction produce an alternate flood-free route that is almost entirely double-track.

A powerful incentive to convert the East Side portion of the heavy rail line to right-hand operation arises from an arbitration finding: all heavy rail trains of more than one car were required to have two-person crews in the left-hand territory because the cabs were on the left away from the platforms. Management's wish to change to one-person operation was carried out east of East 55th Street recently as right-hand running went into effect. Conversion to right-hand running and installation of the cab signal system discussed below are

all part of one project. Total capital cost is $15 million, including completion of the Red Line change to Windermere.

CHANGEOVER TO CAB SIGNAL SYSTEM

The CTS (and later RTA) has had a long history of unfortunate experience with block signals having automatic stop, including unauthorized entry of occupied blocks, failure of trip-arms, and years of undermaintenance. Several bad accidents and many minor ones occurred, especially as the system aged. Operator failure and equipment deterioration combined to produce a hazardous riding environment. This system had negative return current in only one rail of each track, shutting down the line if the return rail broke too far from a cross-bond.

After RTA took over, the light rail system had problems with its own very old three-aspect block signals (no automatic stop), arising primarily from operator disrespect of occupied territory. A number of used signals from the Chicago Transit Authority were installed to divide some of the very long blocks on the main stem (Shaker Square to the shared trackage with heavy rail) and make the system more operationally meaningful by having the operator encounter the red aspect more reasonably close to the train in front. This helped, but the system is very old (mostly 1924 vintage) and costly to maintain. It does allow negative return in both rails, an essential feature in the old days of jointed rails. At this point, the only apparent "original" appurtenances that remain are these signals, surely an anachronism in 1992.

The shared trackage with heavy rail has been recently converted to cab signal operation with reverse running capability, making easy the changeover to right-hand running discussed earlier. Both rails are now used for negative return, decreasing power loss. A plethora of three-aspect lights and trip-stops (all made to subway quality and not meant for a long life outdoors) has been removed, eliminating a lot of clutter. Furthermore, the original placing of those signals (at side or in center strip) seemed almost arbitrary, brought about in some cases for ease of installation rather than for operator visibility. For the light rail operation, this conversion virtually eliminates the use of trip-stops, which are retained only at certain stub ends and in three places on each through track in the downtown station. The new system is much more foolproof and frankly does not require as dedicated and disciplined a driver as the former.

Cab signals extend on light rail to west of East 79th Street, well beyond the junction with heavy rail and past the point where the third or "test" track joins in. Thus the entire area where the two lines meet and operate together is now under control of the latest very safe type of control. The chance for collision of two different types of trains (outside of yard operations) is nearly eliminated. All main line crossovers in this territory are under the control of a central "tower."

It is planned to extend cab signal operation on the remainder of the 3-mi "main stem" (to Shaker Square from East 79th) shared by the Green and Blue Lines. This part is a candidate for conversion because of its frequent trains, long steep grades, no grade crossings, and history of a bad accident on its only blind curve. The operation should no longer depend on very old simple three-aspect block signals to govern what is really a rapid transit operation despite its light rail styling. At this time, funding is not available for that project.

The branches east of Shaker Square, with 24 grade crossings, are a different problem. Signal territory now stops 1.5 mi west of the terminus of the Green Line and 0.6 mi before the end of the Blue Line, leaving the outer parts a strictly line-of-sight operation. Every street intersection is governed by traffic lights arranged primarily for motor traffic. All but two stops at grade are nearside, and there is no signal preemption. A marvelous opportunity to go to farside stops at grade crossings with signal preemption was lost when these lines were completely reconstructed a decade ago. One major grade crossing was converted to farside stops to provide room in the median for left-turn lanes, and it works better than nearside stops even without preemption.

It is questioned whether the type of cab signal system now installed would function well in an area with numerous grade crossings, being more sensitive to current leakage than block signals are. Moisture is almost always present in the rail grooves, and some of the rails installed in rubberized crossings in 1980 have already worked loose. Without preemption, one school of thought says that the traffic lights for automobiles will control the trains well enough. But that view does not settle what to do about the 1.3 mi of the Green Line at the east end that have no intersection grade crossings and thus no traffic lights. Certainly a case can be made for leaping from line-of-sight operation to cab signals on that straight stretch, which has undulations restricting visibility.

A great advantage of the cab signal system compared with any type of lights system even with automatic stop is the ability to control speed. In this application, the cars had control points for 15 mph maximum, 25 mph maximum, 35 mph maximum, or full speed (about 60 mph). Thus a positive control can be enforced at stations, sharp curves, turnouts, and anywhere else where full speed would be dangerous. Unfortunately, in retrospect the 35 mph top restriction did not allow enough choice, excessively slowing running time. Another control zone at 45 mph maximum is desirable, and the shared track and heavy rail line have been refitted with such restrictions where needed. The cars have now been modified to add a 45 mph control point. The running schedule in the areas controlled by cab signals is noticeably slower than before, and the light rail has a substantially longer running time than when it first pulled into Cleveland Union Terminal in 1930. In fairness, some of that slower running results from the need to "baby" the gear drives on the new rolling stock when running downhill, as described later. That long hill is not yet under cab signal control, so it is up to the operator to use restraint.

COMBINING THE DOWNTOWN STATIONS END-TO-END

Certainly the most controversial and obvious-to-the-consumer improvement to the light rail system since reconstruction is the combining of heavy rail and light rail stations end-to-end in the Tower City redevelopment of Cleveland Union Terminal and the former arcade area of Terminal Tower. An indoor regional shopping center and entertainment areas fill the old traction and "steam" concourses, with two elaborate fountains and multitiered balconies for shops. That part of

the cost assignable to the transit station is $60 million. Although this is all very grand and glamorous, certain major sacrifices have been made that are not apparent to the rider until something goes wrong.

First, a background description of each station (they were side by side) is necessary. The heavy rail station had three through tracks (Nos. 8, 9, and 10) and two very long, fairly narrow platforms, as shown in the upper part of Figure 3. Two trains 300 ft long could be simultaneously berthed at each track, with the center track able to load and unload on both sides of the train. The station was intended to handle through service or reversal of trains to the East Side or the West Side or any combination. Reverse signaling was installed to allow this; in practice, the center track was normally used only for terminating and originating some rush hour trains to the West Side, the more heavily patronized line (a line, incidentally, not having any shared light rail operation).

The best part of the three-through-tracks feature was the ability to get around problems in the station, such as a dead train. The center track often was used as a siding for disabled equipment, while the operation could proceed normally.

The light rail station just before the combining took place was an improved version of the 1955 station shown in the lower part of Figure 1. After RTA took over, all the tracks except lightly used storage tracks were renewed in situ, with three key tracks added that had been called for in the original plan 50 years earlier. These are shown as 1980 additions.

The principal inbound track No. 7 was given a turnout just where the turning loop began, allowing the new double-end cars, which cannot clear the loop, to go out in the "field" and reverse ends. Track No. 6 was extended across the loop, as had been done for track No. 5 in 1955. These improvements gave the new cars access from the back end to tracks Nos. 6 and 5. Furthermore, a disabled PCC car could be pushed into the field without having to take it around the loop, always a derailment risk when pushing.

A track with a crossing frog was installed from the regular inbound track to track No. 6, creating a second easily reached unloading opportunity instead of only the one that had been regularly used for 50 years. With doors on both sides of the cars, trains could berth at the regular inbound platform and deposit passengers from both sides. This feature saw a lot of use under RTA.

The new cars could not enter track No. 4 from the field because of clearance problems; they could use the bypass and be backed in from the departure end, though this was rarely done. PCC cars were stored there for a while and also on the storage tracks Nos. 1, 2, and 3 as before. When the PCC cars were discontinued, these four tracks were removed to begin constructing an additional underground auto parking area as agreed to by RTA.

The light rail station functioned extremely well under RTA after these improvements. There were two inbound tracks, Nos. 6 and 7, and potentially three outbound tracks, Nos. 5, 6, and 7, with access at both ends and no interference from heavy rail trains. The tracks, overhead wires, and platforms had all been rebuilt as a key part of the light rail reconstruction.

This well-operating, highly flexible station proved its worth time and again when problems or overloads arose. It was especially valued in sending out large crowds after major downtown events, an important feature in a system having only one downtown terminal at one end.

All these tracks except Nos. 6 and 7 were removed in the zeal to combine both rail stations end-to-end and add more parking, with this area now providing 415 spaces. No. 7 was retained as an emergency bypass of the main station, with a long stub remainder of No. 6 and one low platform providing an extra load and unload point for special events. Key connecting trackage was arbitrarily scrapped. Trains can no longer cross between No. 7 and No. 6, nor go from the dip track to No. 7 and No. 6. See lower part of Figure 3 for these removals and a diagram of the combined station described next.

Track No. 8 serves as one of two inbound tracks for light rail and the westbound track for heavy rail. Track 9 has disappeared altogether in the interest of making the platforms vastly wider than before. Track No. 10 has metamorphosed into two stub tracks, one serving the heavy rail to and from the West Side only and the other serving light rail only. Plans for a second light rail stub to allow trains from either the Blue or Green Lines to berth simultaneously out of the path of through traffic were unfortunately dropped to cut costs.

A new eastbound track was built at approximately the location of long-gone "steam" track No. 13. The positions of tracks Nos. 11 and 12 were filled in for the eastbound platforms. Originally an eastbound bypass track was planned for about the location of former "steam" track No. 14, but this was eliminated to cut costs and provide still more automobile parking. The large south parking area now has 2,230 spaces. There is talk of someday restoring Nos. 14 and 15 for the National Railroad Passenger Corporation (Amtrak) or for intrastate high-speed trains.

The approach from the Public Square level to the rapid transit platform level is now via a pair of long escalators that bypass the old station concourse level, now a major shopping area. Other escalators connect the concourse and track levels. The four long ramps that connected the concourse to Public Square have been eliminated to the great relief of heart patients.

Combining the passenger platforms into one giant (with two stubs penetrating it) has made possible a very dramatic opening from the concourse and Public Square levels right into the bottom level of the terminal. The rapid transit facilities, especially light rail, are a lot more visible at the upper levels than they ever were before. Also, large sheltered waiting rooms have been added on the platform level, an amenity much appreciated by those who remember how the wind howled through the track level, especially on the light rail side.

It was planned originally that only one fare collection point would be provided for both rail services at track level, but this has not been done. Fare collection for the lines differs in that the light rail line is pay-leave westbound, pay-enter eastbound, resulting in most fares on light rail being collected at its west end downtown in the terminal. Heavy rail is always pay-enter. Management has yet to come up with a way to save personnel by collecting fares for both systems from one set of gates; each line's fare method works very well for its characteristics. Passenger volume transferring between the systems is still very light despite the highly convenient combined station. Good riding has never developed from the Heights area eastern suburbs to Cleveland's major airport at the west of the heavy rail line.

A major drawback of the new station arrangement is the elimination of tail tracks for light rail in the immediate vicinity. It was necessary to construct a long tail track with two long approach turnouts on the viaduct over the Cuyahoga River valley, well beyond normal walking distance from the station. Trains in the tail are much more exposed to severe weather conditions than formerly, and turnaround time has lengthened by 9 min. Movements into and out of the tail interfere with the through operation on the heavy rail system, in effect greatly extending the shared trackage. Moreover, a blockage has been placed in the way of someday restoring passenger railroad service across the viaduct. Maximum use is made of the one stub track to minimize the delay and other problems caused by using the tail. However, inbound trains sometimes have to wait for outbound trains to clear the stub.

All these changes have combined to radically reduce system capacity, especially for light rail. The statement is frequently made that the old agreed-upon capacity of 43 trains per hour in each direction on the shared tracks east from the terminal was never needed anyhow, so why not sacrifice capacity for amenities and convenience? Now the maximum capacity is 30 trains in and 30 out in the peak hour if all goes without a hitch. Breakdown of a train in the station on the through tracks leads to chaos with the present arrangement, whereas the old stations coped well with some extraordinary train failures and derailments. It is clear that experienced operating people were not given a strong voice in deciding on the new design. Good railroad practice was sacrificed to help create a remarkable and impressive regional indoor shopping center with a maximum of auto parking on the lower level. Much of the cost, of course, is tax dollars spent for a nongovernmental purpose, enhancing the value of the investment made by those who got control of the railroad terminal from Penn Central and the Consolidated Rail Corporation (Conrail). Clearly the shopping center people were the dominant party in this arrangement with RTA negotiating from a position of seeming weakness.

LANDSCAPING ALONG BOULEVARD MEDIANS

When the system was still owned by the city of Shaker Heights, some of the residents along that part of Shaker Boulevard having a 60-ft-wide median approached the city with a plan to screen the tracks visually and reduce sound. In those days the tracks on that stretch of the Green Line were very worn and noisy, and the cars of that time rumbled more loudly than the present fleet.

It was decided to plant a screen of Washington hawthorn trees halfway between the inner curb and the rails along certain stretches where the residents raised the money. Some of these trees have been there for over 20 years and now must be trimmed regularly so that they won't scratch the cars. The plastic windows are especially vulnerable. The residents in one block did not care for the hawthorns and had flowering crab trees with a vase-like shape planted instead. This stretch has been photographed heavily; in fact, a photo by Lee Rogers was featured years ago in a magazine article about light rail.

After the reconstruction was completed, the city (at no capital cost to RTA) greatly extended the plantings, covering the rest of Shaker Boulevard that had the 60-ft median. The same type of hawthorns were used. In fact, at locations where crab trees have died, they have been replaced by hawthorns. The landscaping now serves its purpose, but it creates the impression that the rail line should be barely seen and not heard.

Along the Van Aken Boulevard Blue Line, which had a 90-ft median laid out for potentially four tracks (narrowed to 86 ft by lane widening right after the reconstruction), landscaping treatment was quite different. At each surface station, at least one parking lot is in the median strip and complete screening was not possible. The city of Shaker Heights has converted more than 2 mi of the line into a linear park with clusters of flowering fruit trees, tall gingkos, and ornamental pines and spruces. The rail line is not especially hidden by this arboretum, and the effect enhances rather than detracts from the operation. Again, the maintenance is handled by the city. RTA pays a proration of the cost of maintenance based on the space in the medians occupied by the transit easement, generally 42 ft wide.

On the short westerly stretches of the two branches that lie within the city of Cleveland, RTA had similar landscaping installed, using a simple screen of hawthorns on Van Aken and placing hawthorns at the station on Shaker Boulevard, which has a 90-ft median at that point. West of that station, a double row of pin oaks borders a center-siding area with six turnouts. Maintenance is done under the same contracts for care of the RTA grass median and station landscaping in Shaker Square.

The result of all this tree planting illustrates the law of unintended consequences. Many of the hawthorns have grown quite large, while some in waterlogged areas have died. This type of tree is a menace to anyone running wildly because of the plethora of sharp thorns. To this point, no person has been struck by a train while running between trees. Certainly there is a heavy burden on various taxpayers to maintain all this, and a splendid rail line is screened from beautiful homes. Leaf removal from the tracks will be a yearly problem, especially in the oak tree area. The fact that most stations are nearside does reduce the cross-traffic hazard caused by not seeing the train for the trees. In one farside location, the first few trees have been removed, because motorists complained about the trains darting out.

MODIFICATIONS TO NEW LIGHT RAIL CARS

The fleet of radically different light rail cars built by Breda in Pestoia, Italy, has been thoroughly described elsewhere in the literature (*2–4*). The cars went into service in 1981 and 1982. After some of the initial "glitches" had been worked out, the entire light rail service was operated with these cars. The remaining PCC cars saw their last emergency use in 1985, and all but four have been disposed of.

The new fleet still has major problems, and filling the service is only possible because the volume of ridership is far below predictions when 4,000 seats (working out to 48 cars) were specified in the 1975 agreement between Shaker Heights and RTA. Today 47 cars remain, car No. 849 being cobbled from the undamaged A and B halves of two other wrecked cars. However, the schedule calls for only 30 cars, providing

a shocking spare ratio of 56 percent! Only this surplus makes it possible to cope with two major problems.

The first problem to show up was the matter of powdery snow being ingested into the chopper control ventilation system far beyond any capability to filter it out (*2*). A host of solutions were tried, including spin filters, quick change filters, modifications to the ductwork, but all to small avail. The problem has become tolerable the past few winters because Cleveland and the Heights area have not experienced much powdery snow. Cars that overheated simply shut down and were taken out of service until the systems could be thawed out.

A proven "fix" has been developed that requires the chopper intake air to come in at the roof (the best location) rather than under the car (the worst location). However, ductwork must be run from floor to ceiling in the body of the car just ahead of the articulation area. It was necessary to remove two double seats, reducing seating capacity from 84 to 80 and gaining a little standing area. No one objected to this loss of capacity, even though the 4,000-seat requirement was violated. Sixteen cars have been modified, and retrofit kits are available to convert half the fleet. Eventually, all cars will have to be reworked. Cost of the kits to RTA will be near $1 million with installation being done in-house.

The second—and more serious problem—has been excessive wear and premature failure on the hypoid bevel gear trains, which convert longitudinal rotating motion of the monomotors to lateral axle turning power (*2*). The demands of Cleveland's light rail system may well be the most severe anywhere imposed on monomotor trucks. The difference in elevation from end to end is more than 500 ft, much of it concentrated in 3 mi of mostly tangent track with a few gentle curves. The desire to go fast downhill is very strong; after all, the line was called "rapid transit" before it was built and had better running time 60 years ago than it does today.

Gears began to fail within months after the cars were placed into service. It was quickly found that the hypoid offsets in the gearboxes were out of limit in most of the failures. The German gear supplier had subcontracted the gear cutting and assembly to an organization in Ontario, which had not satisfactorily observed quality requirements. When the trouble became acute, the supplier expressed amazement at the profile of the line and the sudden changes from high downhill speed to full service braking approaching stations, information that had been given to the carbuilder. (This high demand did not bother the original fleet built in 1914 and intended to be mere streetcars.)

After many experiments with different lubricants, greater frequency of servicing, and imposition of operating restrictions on speed and severity of braking, it was decided that 100 gearboxes would be overhauled by the gear supplier and fitted with new gears, using the facilities in Germany instead of those of a subcontractor. Cost of this work is about $1.4 million with RTA paying the bill. In the meantime, the operation is hard pressed to meet the schedule of 30 cars in service from a fleet of 47. At four gearsets per car, it is doubtful that many of the original 192 will still be in use by the time this report is published.

Some of the replacements made better to the same design are also showing problems, and the horrible conclusion is sinking in that the design may be simply inadequate for the service demand. One complete set of four gearboxes made by a different supplier for the Los Angeles cars will be tried as an experiment. In the end, it may be necessary to change to the largest possible gearbox that can be crammed into the space. With modern slip-slide control available, it is questionable whether monomotor trucks had enough advantage in the first place to justify their use in this rigorous application.

CONCLUSIONS

Virtually complete reconstruction of the old Shaker Heights Rapid Transit, carried out in the early 1980s, was by no means the end of the story. The great portion of change favorable to the passenger had already been achieved at that point, and riding volume improved to 19,000 per weekday. All this did was to bring the volume back to near the levels enjoyed before the disruption caused by rebuilding.

The later projects did very little for the rider and were justified by an assortment of unrelated values. At a cost of about $80 million (in the same league as the original reconstruction but in later, deflated dollars) the operation has been made safer, more attractive at the inner terminal, and seemingly less complicated.

At the same time, sacrifices have been made in capacity, speed of operation, and labor efficiency. A sophisticated signal system has been introduced that might in the long run prove more costly to maintain than its predecessor. Most significantly, riding volume, now down to 12,000 per weekday, may never return to the level enjoyed in 1979 before this renaissance began. Of course, things could not go on indefinitely in the old way, and fare increases of 1980, 1981, 1982, and finally again in 1991 had a lot to do with the poor results.

Nevertheless, the lesson can be drawn that enough may be too much. Improvements that degrade the running speed and have the potential to worsen delays should not be made without far greater justification than was shown here. Great expense devoted to creating a shopping palace and underground parking out of an old railroad terminal should not passed off as providing a transit benefit when it actually increases costs for the operating agency and robs it of terminal capacity enjoyed for 60 years. Certainly the last thing any rail transit system should want is more auto parking in its downtown terminal.

After more than a decade of disruptions, Cleveland's light rail system may now enjoy a period of relative calm, during which the management should be able to concentrate on trying to bring the riding volume back up to levels that will begin to justify the total investment since 1979 of around $180 million. Certainly the experience of earlier eras with this system showed that clockwork performance at good speed with a very high reliability level was the way to achieve a riding volume justifying rail operation in a low-density setting. Passenger amenities were of secondary or little importance for such short trips at rather high speed. That may no longer be true in today's market with competition from luxurious automobiles.

Those responsible for planning new light rail systems or for carrying out the reconstruction of old ones can learn much

from the experience in Cleveland. Negotiations with outside parties must always be done from a position of strength, insisting that the needs of the transit system always come first, now and in the future. Performance specifications for cars need constant follow-on to see that all components and systems meet demands. The sophistication level of equipment and appurtenances should be kept as low as can be to do the job needed. That old engineering lesson that less can be more must always be kept in view. Every dollar saved in this way may be a dollar available for expansion that otherwise could never be funded. Certainly the great spending in Cleveland with so little tangible result has put the damper on support for any expansion of the rail systems.

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