# An Evaluation of Automated and Conventional Rail Technology for the Century Freeway Rail Line

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The Century Rail Transit Line will operate for 17 mi in the median of the Century Freeway now under construction in Los Angeles. It will also extend initially for 3 mi on exclusive right-of-way into the large El Segundo aerospace employment center. In 1986 the Los Angeles County Transportation Commission staff evaluated the potential of fully automating this line. The paper summarizes this evaluation, looking first at improvements short of full automation, then at the benefits of full automation based on the experience of VAL and SkyTrain. It notes that the real benefit of full automation may come not so much from trade-offs between capital and operating costs, but from the revenue potential of frequent, all-day operation. The paper then compares the use of automated-guideway transit vehicles with a conventional light rail vehicle modified to be fully automated. It concludes that automating the Century Line appears to be justified, and that the use of conventional light rail vehicles modified to allow unmanned operation should be an integral part of a decision to automate.

THE CENTURY RAIL TRANSIT LINE will operate in the median of the Century Freeway now under construction in Los Angeles. It is oriented east-west for 17 mi between Norwalk and the coast, passing about 8 mi south of downtown Los Angeles. At the coast it branches out north and south to serve

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major growth centers. The first extension, to be completed in 1993 with the Century project, serves the large El Segundo aerospace employment center. The line is expected to cost $390 million in escalated dollars.

The Century-El Segundo rail line will be fully grade-separated. Given this circumstance, members of the Los Angeles County Transportation Commission (LACTC) asked the staff in mid-1986 to evaluate possible ways of improving the line's performance, specifically by considering fully automated, or unmanned, operation.

## BACKGROUND

Over the past 4 years two urban, public, unmanned transportation facilities have opened with convincing success. The first was the VAL system in Lille, France, an 8.5-mi line with 18 stations. On a typical weekday 120,000 riders use the system. Less than 3 years later the SkyTrain system opened in Vancouver, Canada, and carried 150,000 riders per day by summer 1986. Although much of this ridership was induced by Expo '86, it nevertheless showed the capability of the SkyTrain system, which now carries about 70,000 riders each day.

The technology has existed for some time to run fully automated trains; in fact most rapid transit systems since the Bay Area Rapid Transit (BART) system in San Francisco have employed the capability. Yet the step of removing the motorman remained. The contribution of the VAL and SkyTrain systems may be more in their taking this step in a full urban transport application than in proving the technology. It will now be easier for others to follow suit. The conversion of the Line D rapid transit in Lyon, France, to unmanned operation is a case in point.

## OPERATIONAL IMPROVEMENTS SHORT OF FULL AUTOMATION

Service can be improved short of full automation by increasing the maximum speed of the vehicles or by increasing the frequency of service by vehicles controlled by operators on a semiautomatic basis. Both of these tactics, however, have serious drawbacks.

### Increasing Speed

Because the Century rail project is in the median of a freeway and stops at relatively few stations, it will provide an impressive average operating speed of 37 mph, including stops. During rush hours, when parallel automobile speeds are expected to be quite slow, the rail speeds will be especially attractive.

Nevertheless, it is possible to increase the travel speed. There are two ways this might be done. First, a faster vehicle might be specified, that is, one with a higher maximum speed. If the speed is fast enough, the round-trip time could be reduced one headway. This would allow one train to be saved, which might offset the extra cost of the faster propulsion system.

A maximum speed of 65 mph would save a three-car train, saving roughly $3.6 million in fleet costs. It would also reduce the estimated 30-min travel time from Norwalk through El Segundo by 2 min. While not technically infeasible, there is no articulated light rail vehicle currently in existence operating at that speed, nor do the new automated systems operate above 55 mph. Vehicle engineers advise that problems may exist with stabilizing an articulated vehicle at 65 mph at truck spacings of about 30 ft. Changes in the truck design, perhaps with some risk, may be necessary.

The vehicle would also need bigger motors with forced-air ventilation, and similar control electronics design changes to handle the increased power rating. Other lower cost changes would also be needed on the vehicle. The estimated increase for these propulsion system changes was calculated to be 4 percent of the vehicle cost, or $2.5 million for the full fleet. This estimate does not address the possible truck redesign.

Because a higher-speed vehicle draws more power, the capacity of the traction power transformers would also need to be increased, adding up to an estimated 5 percent, or $900,000, to the cost. (The fact that a three-car train is saved may, however, reduce overall power consumption. This possibility was not pursued in detail.)

Finally, automatic trip stops are required along the tracks when speeds of rail transit vehicles exceed 55 mph. The cost of adding these items was estimated to be $100,000. By coincidence, the cost savings from reducing the number of rail vehicles if the rail cars had a maximum speed of 65 mph approximates the additional cost to make the remaining vehicles capable of operating at 65 mph. It should be noted, however, that the 7 percent speed increase could have an indeterminate, but positive, effect on revenues.

The second way to increase speed might be to have trains skip certain stations completely by using express trains. To do this in the best manner, properly located bypass tracks would be needed in addition to the usual two tracks serving the station. Unfortunately, there is no room for such bypass tracks. The width that was saved when the busway/high-occupancy vehicle (HOV) facility was changed to rail is now dedicated for carpool lanes. Although full express service is not possible, it is still possible to have certain stations skip-stopped in a modified express service.

In sum, increasing the speed to 65 mph would cut end-to-end travel time by 7 percent, or 2 min, and reduce the fleet size by one train for a savings of $3.6 million. However, it would increase vehicle and traction power costs by $3.5 million and raises concern about the ability of articulated vehicles and trucks to accommodate the high speed.

### Increased Frequency with Operator

Another way to increase the quality of service is to reduce the headway between trains so that waiting time is lessened. The present operating concept for the Century-El Segundo line during rush hours (in the year 2000) is to have three-car trains every 6 min, with a total of 11 trains on the line. Instead, two-car trains every 4 min, or one-car trains every 2 min, could be run.

Most new rail transit systems introduce semiautomated operation before sustained 3-min headways are reached. The supposed benefit is operational: more consistent braking and acceleration and tighter schedule adherence (although this is debatable). The problem with semiautomation is that it does not reduce the number of vehicle operators required. The system ends up having to not only maintain a more sophisticated signal system, but also cover higher labor costs. Four-min headways would require 17 operators instead of the 11 needed at 6-min headways; 2-min headways would require 33 operators. The benefits of high-frequency service can best be captured by converting to full automation. In that case, no operators would be needed for any operating plan.

As a point of reference, it would be useful to derive the cost of operating shorter headways with attended trains. We will assume 4-min headways all day with two-car trains in the rush periods, one-car trains off-peak. Evening and weekend operation would be with one-car trains every 8 min. This would be equivalent to service expected of a fully automated system. The result is an increase of 21 vehicle operators and an annual cost increase of $695,500. Semiautomated operation, therefore, cannot be justified.

## FINANCIAL BENEFITS OF FULL AUTOMATION

Fully automating the Century Line would mean labor costs could be cut along with the capital cost of building longer platforms needed to accommodate longer, nonautomated trains operating less frequently than the shorter, automated trains would. At the same time, full automation would mean installing an expensive signal and control system. But it also may mean significant ridership gains that could boost farebox revenues without adding to labor costs.

## Labor Costs

Table 1 compares the staffing levels of two guideway transit systems that make money or are close to doing so. The first is the automated VAL system developed by Matra in Lille, France. The second is the automated SkyTrain system developed by UTDC in Vancouver, Canada. The two automated systems, although shorter than the Century Line and with rather close station spacings, have attracted over 100,000 riders on a typical day. The high ridership depends a lot on the corridor being served; both cities have relatively dense corridors with good feeder bus services.

The labor productivity of the VAL system is very high, probably as high as any system anywhere. It appears to stem principally from a staffing philosophy that minimizes the number of roving and security staff. (Some functions are contracted out, but not for major areas of work.) The vehicle themselves

TABLE 1 STAFFING LEVELS OF SELECTED AUTOMATED SYSTEMS

| System Characteristics | Lille VAL 1987 | Vancouver SkyTrain 1987 |
|---|---|---|
| Line length (mi) | 8.5 | 13.3 |
| Number of stations | 18 | 15 |
| Daily passengers | 100,000+ | 70,000 |
| Annual passengers | 27,700,000 | 21,000,000 |
| Peak hour trains | 18 | 20 |
| Peak hour vehicles (total) | 76(108) | 80(114) |
| Number of employees | | |
| Administration | 26 | 22 |
| Operations | | |
| Vehicle operators | 0 | 0 |
| Central | 28 | 26 |
| Roving | 20 | 95[a] |
| Other | 0 | 3 |
| Maintenance | | |
| Vehicle | 31 | 76 |
| Power and comm. | 18 | 28 |
| Trackway | 24 | 22 |
| Other | 12 | 33 |
| Security | 26 | 0 |
| Total | 185 | 309 |

[a]Includes security.

also appear to either need less maintenance, or are maintained very efficiently. (For example, the workshop closes down at 5 p.m. weekdays and there is no vehicle or control system maintenance staff on duty during the night shift and on holidays.) The Lille system clearly takes full advantage of the automated concept.

The operation of the Vancouver SkyTrain represents another staffing philosophy employed by automated-guideway transit (AGT) systems. The new London Docklands Light Railway employs this concept as well. In this case, a decision has been made to have approximately one attendant per train throughout the day. These roving rapid transit attendants (RTAs) check fares, provide security, assist patrons, and can operate the train should the automated operation falter. RTAs are paid operator's wages but have a broader job description. The result is a roving force on SkyTrain 2.5 times larger than that of VAL.

Table 2 summarizes the staffing necessary for a combined Long Beach-Los Angeles and Century-El Segundo system with the main yard in Long Beach and a satellite yard near at the western terminus. The left side of the table assumes conventional light rail operation on both lines; the right side assumes the Century-El Segundo line is automated (either AGT or automated LRV). Because of the more sophisticated electronics, it is assumed that with full automation three additional control technicians are needed in the maintenance area.

The number of roving staff varies whether the VAL or the SkyTrain staffing philosophy is adopted. On the one hand, the number of fare inspectors and transit police has been kept to the level of conventional operations. A net labor savings of $1.261 million per year is possible if a VAL staffing philosophy is used. If an RTA is assigned to each train, a net labor savings of $509,000 can be achieved each year. These levels of saving represent, 4.5 percent and 2 percent, respectively, of the total estimated operating and maintenance costs of these two lines.

It should be noted that the shift from a train operator in the cab to an RTA provides both the transit authority and riding public with an employee capable of numerous tasks useful to the user. Because of this—and, perhaps, ironically—automation can provide a more personal touch than typical conventional rail operations.

## Capital Costs

Assuming automation is achieved using a standard rail vehicle without either linear induction motor or rubber tire technology, the introduction of automation on the Century-El Segundo Line would be relatively straightforward.

TABLE 2 ANALYSIS OF STAFFING WITH AND WITHOUT AN AUTOMATED CENTURY RAIL LINE

| | No. of Employees | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Manual Operation[a] | | | | Automated Century | | | |
| | LB-LA[b] | Century[c] | Central Control | Total | LB-LA[b] | Century[c] | Central Control | Total |
| Administration | – | – | 12 | 12 | – | – | 12 | 12 |
| Operations | | | | | | | | |
| Vehicle operators, etc. | 74 | 44 | – | 118 | 74 | – | – | 74 |
| Central control | – | – | 35 | 35 | – | – | 35 | 35 |
| Roving | 13 | 9 | – | 22 | 13 | 9 (35)[d] | – | 22 (48)[d] |
| Other | 5 | 5 | – | 10 | 5 | 5 | – | 10 |
| Subtotal | 92 | 58 | 35 | 185 | 92 | 14 (40)[d] | 35 | 141 (167)[d] |
| Maintenance | | | | | | | | |
| Vehicle | 80 | 25 | – | 105 | 70 | 30 | – | 100 |
| Power and comm. | 31 | – | – | 31 | 31 | – | – | 31 |
| Trackway | 17 | – | – | 17 | 17 | – | – | 17 |
| Other | 34 | 6 | – | 40 | 34 | 8 | – | 42 |
| Subtotal | 162 | 31 | – | 193 | 152 | 38 | – | 190 |
| Security | 45 | 29 | 5 | 79 | 45 | 29 (19)[d] | 5 | 79 (69)[d] |
| Total | 299 | 118 | 52 | 469 | 289 | 81 (97)[d] | 52 | 422 (438)[d] |

[a]Derived from draft O&M plan prepared for LB-LA and Century lines.
[b]Long Beach yard.
[c]El Segundo yard.
[d]Parentheses indicate staffing with train attendant philosophy.

After assessing the cost of a standard wayside-based train control system, it was decided to opt for a moving block system. This lowered the cost estimate by a factor of two. The total cost estimate for the train control system was $21.4 million. A train control system compatible with the cab signal system of the Long Beach-Los Angeles line was estimated to cost $19 million for the Century-El Segundo line; thus the net increase in wayside equipment is $2.4 million.

Costs were not derived for the rubber-tired technology used by the VAL system. Should a new technology be selected, the cost of the guideway could increase significantly. The Matra system in Lille uses a rubber-tired vehicle that needs a fairly complex concrete channel for guidance. The Lille system also uses platform doors (which were not costed here).

It is estimated that the automated operation with short headways could also save the future cost of having to expand the platforms to accommodate four-car trains, an estimated $1 million.

## Revenue Implications

The VAL and SkyTrain systems are successful because they have attracted a significant number of users. The more ridership a system attracts, the more revenue is generated at the farebox and the less operating subsidy is required. The capital and labor cost trade-off, reviewed above, is then only half of the picture. As important is the question: Do automated systems—simply because they are automated—attract greater ridership?

This is a very difficult question to answer, although it is a pivotal one. In Los Angeles, patronage models rely on home-based work-trip data that do not reflect other types of trips, such as school, shopping, or recreational trips. Instead, factors are used to increase work trips to daily trips and these factors are derived from existing transit experience; but transit systems do not run frequent off-peak service because of costs or apparent lack of demand.

New automated systems appear to have tapped this latent off-peak demand. In discussions with VAL officials it emerges that while peak hour ridership is slightly higher than expected, the big surge in ridership occurred because of off-peak growth. One reason is the frequent service throughout the day. Attended systems can run frequent trains midday as well, but usually do not because of added labor costs.

Do these same conditions hold for the Century/Coast Line? The Coast Line, in particular, has a diversified land use distribution with major activity centers capable of generating off-peak trips. The Century corridor does not have this land use pattern but does have good north-south feeder bus services along major arterials and a population that is transit-dependent. Experience with buses also shows that only about 30 percent of trips are work-related, a very low percentage. Bus services also have high midday and weekend demand, with much of the recent transit ridership growth occurring during these periods. There appears to be a stronger-than-usual off-peak transit market in Los Angeles. The Century/Coast corridors should be able to support high-frequency, all-day rail transit service. If so, then a high-frequency Century/Coast Line should generate substantially more revenue. This would lower operating subsidies as effectively as would lowering labor costs. Precisely how much is too difficult to say. At an average fare of 50 cents, only 6,000 new daily riders (7.5 percent of expected Century Line patronage) would generate $1 million more in annual revenues.

## CHOICE OF VEHICLE, ASSUMING FULL AUTOMATION

Assuming the decision to fully automate has been made, the next decision is whether to stay with a conventional light rail vehicle (LRV) or to procure AGT vehicles. Each offers benefits and drawbacks.

### Vehicle Type

AGT vehicles are much smaller than the 90 ft Long Beach-Los Angeles LRV. Typically about 40 ft long, AGT vehicles still cost 60 to 80 percent of what LRVs do. Because of this, assembling a 42-vehicle Century-El Segundo fleet would cost $12.6 million more if AGT vehicles were chosen. Procuring AGT vehicles would also introduce a third vehicle into the Los Angeles rail fleet already using Metro Rail and light rail cars. A new spare parts inventory would be required as would different maintenance equipment, tools, and more training for maintenance staff.

On the positive side, an AGT vehicle would come packaged with its control system, and this package would more than likely be already proven under automated operation. The same cannot be said of LRVs used as automated vehicles. Smaller vehicles would also be run two at a time for capacity reasons. A larger vehicle can be run only as single unit, which might reduce system reliability.

### Vehicle Maintenance

If the system's present LRV is used as an automated vehicle, then no change in maintenance strategy is necessary. Anything but light maintenance can be done by taking the LRV to the Long Beach-Los Angeles Line's central yard. If an AGT vehicle is used, the yard near El Segundo might not be adequate. A new yard of larger size might be necessary, but finding such a site would be a difficult task.

The AGT vehicles have at most an emergency panel for manual drive. Thus vehicles needing service could not be driven to the Long Beach-Los Angeles yard where the heavy maintenance work for the fleet is located. They would have to be towed. Their wheel diameters, coupler heights, and design, however, are not compatible with LRVs. Maintenance equipment, such as jacks and lifts, wheel truing machines, and tools, will probably be incompatible as well. From a maintenance standpoint, there is no benefit in having another type of vehicle in the fleet.

On the other hand, suppliers of proprietary vehicles emphasize their elaborate built-in diagnostic systems, which conventional rail vehicles do not have. As a result, maintenance is more preventive with less shop time required. New systems also rely more on component change-out, which lowers shop time.

## CONCLUSIONS

Based on this evaluation, the conclusion is that full automation of the Century-El Segundo line may be an attractive option, but only if conventional light rail technology is used that is compatible with the Long Beach-Los Angeles Line. Automation seemed justified because potential labor cost savings and possible higher revenues generated by frequent, all-day service outweighed the one-time extra capital cost. Conventional light rail technology seemed better than proprietary AGT technology for reasons of system compatibility and fleet cost.

In early 1988, LACTC voted to automate the Century-El Segundo Line. It did so with the provision that an LRV be used—a 90-ft articulated vehicle. However, the vehicle is to be modified in several ways. First, third-rail power collection will be used. Second, the vehicle speed is to be increased to 65 mph. Third, the vehicle is to be made lighter by the use of stainless steel or aluminum, rather than the rolled steel of the Long Beach-Los Angeles LRV. All three of these changes were made because the right-of-way is now 100 percent exclusive. The catenary was felt to be unaesthetic; the steel body, useful for ease of collision repair, no longer necessary; and the higher speed primarily the result of the lighter vehicle. The Century-El Segundo Line will open for operation in late 1993.

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