AN EVALUATION OF AUTOMATED AND CONVENTIONAL RAIL TECHNOLOGY FOR THE CENTURY FREEWAY RAIL LINE

BY: **Richard Stanger**
DIRECTOR PROGRAM DEVELOPMENT

APTA

1987 RAPID TRANSIT CONFERENCE Toronto, Ontario
June 16, 1987 2:00–4:00 P.M.

LOS ANGELES COUNTY TRANSPORTATION COMMISSION

Transit Development in Los Angeles County

LOS ANGELES COUNTY TRANSPORTATION COMMISSION

AN EVALUATION OF AUTOMATED AND CONVENTIONAL RAIL TECHNOLOGY FOR THE CENTURY FREEWAY RAIL LINE

I. INTRODUCTION

The Century Rail Transit Line will be in the median of the Century Freeway now under construction in Los Angeles. It is oriented east-west for 17 miles between Norwalk and the Coast passing about 8 miles south of downtown Los Angeles (see Figure 1). At the Coast it branches north and south to serve major growth centers along the Coast. The first extension, to be completed in 1993 with the Century project, serves the large El Segundo aerospace employment center.

The Century-El Segundo rail line will be fully grade-separated. Given this circumstance, members of the Commission's Rail Construction Committee asked its staff, in mid 1986, to evaluate possible ways of improving the lines' performance, specifically by considering fully automated, or un-manned, operation. This paper summarizes this evaluation.

The paper has three parts. The first looks at possible ways of improving service short of fully automating the line. The second part looks at the benefits of full automation itself. The third part of the paper assumes automated operation and then evaluates the use of various vehicles. Its principal findings are these:

1. Neither increasing speed nor going to semi-automated operation (like most heavy rail systems use today) is economically justified.

2. Fully automating the Century Line appears to be justified.

3. Use of present light rail vehicle modified to allow unmanned operation should be an integral part of a decision to fully automate.

II. OPERATIONAL IMPROVEMENTS SHORT OF FULL AUTOMATION

A. Increasing Speed

Most user surveys rank reliability, frequency, and speed of service the most important attributes of a transit operation (typically in that order). 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 auto 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 pay the extra cost of the faster propulsion system.

A maximum speed of 65 mph would save a 3-car train, saving roughly $3.6 million in fleet costs. It would also reduce the estimated 28.5 minute travel time from Norwalk through El Segundo by 2 minutes. 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. A problem may exist stabilizing the vehicle at 65 mph at truck spacings of about 30 feet. 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 is 4% of the vehicle cost, or $2.5 million for the full fleet. This estimate does not address the possible truck redesign noted earlier.

Because a higher-speed vehicle draws more power, the capacity of the traction power transformers will also need to be increased, adding an estimated 5%, or $900,000, to the cost. Finally, automatic trip stops are required along the tracks when speeds of rail transit vehicles exceed 55 mph. The cost of adding these items is estimated to be $100,000. By coincidence, the cost savings from reducing the number of rail vehicles we will have to purchase if our rail cars had a maximum speed of 65 mph approximates the additional cost to make the remaining vehicles capable of operating at 65 mph.

The second way of reducing speed might be to have trains skip certain stations completely using express trains. To do this, a by-pass track in each direction, in addition to the normal two tracks serving the station, would be needed for each station to be skipped. Unfortunately, there is no room for such by-pass tracks (an additional 24'). What width was saved when the busway/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.

SUMMARY: Increasing Speed to 65 mph	
Pros:	**Cons:**
o 9% Faster travel times end-to-end (2 minutes)	o Increased vehicle and traction power costs ($3.5 million)
o Reduced fleet size ($3.6 million savings)	o Concern over ability of articulated vehicle and trucks to accommodate higher speed
Recommendation: Retain presently specified maximum speed of 55 mph.	

B. 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 (year 2000) is to have 3-car trains every 6 minutes, a total of 11 trains on the line. Instead, we could have 2-car trains every 4 minutes, or 1-car trains every 2 minutes.

Most new rail transit systems introduce semi-automated operation before sustained 3-minute headways are required. The benefit is operational: more consistent breaking and acceleration and tighter schedule adherence. The problem with semi-automation is that as many vehicle operators are required. One ends up having not only to maintain a more sophisticated signal system, but also to cover higher labor costs. Four-minute headways would require 17 operators instead of the 11 needed at 6-minute headways; 2-minute 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-minute headways all day with 2-car trains in the rush periods, 1-car trains off-peak. Evening and weekend operation would be with 1-car trains every 8 minutes. This would be equivalent service expected of a fully-automated system. The result is an increase of 21 vehicle operators and an annual cost increase of $695,500.

SUMMARY: Semi-Automated Operation	
Pros:	**Cons:**
o Better schedule adherence possible	o Higher labor costs with increasing frequency o Slight increase in maintenance cost o Increase in capital cost
Recommendation: No semi-automated operation	

III. FULL AUTOMATION

This section reviews the potential labor savings and capital costs we could expect with a decision to fully automate the Century-El Segundo Line.

A. Labor Costs

Table 1 compares the staffing levels of three guideway transit systems which 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 third is the San Diego Trolley. The two automated systems, although shorter and with rather close station spacings, attract 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 which minimizes the number of roving and security staff. (Some functions are contracted out, but none for major areas of work.) The vehicle itself also appears to either need less maintenance, or is maintained very efficiently. (For example, the workshop closes down at 5:00 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 AGT systems.* In this case, a decision has been made to have approximately one attendant per train throughout the day. These roving rapid transit attendants (RTA's) check fares, provide security, assist patrons and can operate the train should the automated operation falter. RTA's are paid operator's wages but have a broader job description.

---

* The London Docklands Light Railway will also utilize this philosophy.

TABLE 1:
COMPARISON OF AUTOMATED AND MANUAL STAFFING LEVELS OF SELECT SYSTEMS

System Characteristics:	Lille (VAL) 1985	Vancouver (UTDC) 1986 F	San Diego (LRT) 1985
Line Length (Miles)	8.5	13.3	15.9
Number of Stations	18	15	18
Daily Passengers	100,000+	100,000 +	16,400
Annual Passengers	28,700,000	30,000,000 F	5,975,000
Peak Hour Trains	18	21	6
Peak Hour Vehicles (Total)	72 (76)	84 (114)	18 (21)
Number of Employees:			
Administration	19	22	12
Operations:			
Vehicle Operators	-	-	36
Central	33	26	4
Roving	22	90 **	5 *
Other	-	3	6
Maintenance:			
Vehicle	32	76	19
Power and Comm.	21	28	13
Trackway	23	22	5
Other	9	33	3
Security	16	-	11 *
TOTAL	175	300	114
Employee Productivity:			
Annual Pass/Employee	164,000	95,000	52,400
O&VM&S Emp./Pk. Hr. Train	5.7	10.8	13.5
Maint. Emp./Line Mile	6.2	4.9	1.3
Maint. Emp./Vehicle	.5	0.9	1.1

* Contracted Forces
** Includes Security
F Forecast for 1986

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

Number of Employees:	MANUAL OPERATION *				AUTOMATED CENTURY			
	LB-LA (LB Yd)	Century (ElS.Yd)	Centrl Contrl	Total	LB-LA (LB Yd)	Century (ElS.Yd)	Centrl Contrl	Total
Administration:	-	-	12	12	-	-	12	12
Operations:								
Veh. Operators, Etc.	74	44	-	118	74	-	-	74
Central Control	-	-	35	35	-	-	35	35
Roving	13	9	-	22	13	9(35)**	-	22(48)
Other	5	5	-	10	5	5	-	10
SUBTOTAL	92	58	35	185	92	14(40)	35	141(167)
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)	5	79(69)
TOTAL	299	118	52	469	289	81(97)	52	422(438)

* Derived from Draft O&M Plan prepared for LB-LA and Century lines.
** Parentheses indicate staffing with train attendant philosophy.

The result is a roving force on Skytrain 2.5 times larger than that of VAL. One must admire the Lille transit management achievement. It is, however, debatable whether an automated system in Southern California could be so completely unattended.

Table 2 summarizes the staffing necessary for a Long Beach and Century-El Segundo system with the main yard in Long Beach and a satellite yard near El Segundo. 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. Three additional control technicians are necessary in the maintenance area with full automation. The automated line also requires no operators. However, the number of roving staff varies whether one assumes a VAL or a Skytrain staffing philosophy. On the one hand, we have kept the number of fare inspectors and transit police at the level of conventional operations. For this case, a net labor savings of $1,261,000 per year is possible. On the other hand, we have assumed that an RTA is assigned to each train. This also allows some savings in the number of transit police assigned to the automated Century line. A net labor savings of $509,000 can be achieved each year using the RTA concept. These levels of saving represent, 4.5% and 2%, 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. Perhaps ironically, automation can provide a more personal touch than is typical with conventional rail operations.

<u>SUMMARY</u>: Labor Costs

<u>Pros</u>:	<u>Cons</u>:
o Savings of $500,000 - $1,260,000/Year	
o Higher labor productivity	
o More operator/user contact with "train attendant" staffing philosophy	

B. <u>Capital Costs</u>

Assuming automation is achieved using a standard light rail vehicle without either linear induction motor or rubber tired technology, the introduction of automation is relatively straight-forward. Instead of a simple block signal system, a much more sophisticated system will have to be installed. It has two parts: (1) a relatively simple electronic component located on each vehicle, and (2) a wayside detection system linked to central control (capable of locating each vehicle precisely) plus a signal/control system (able to tell the vehicle to slow, stop or accelerate).

The carborne equipment is estimated to be $75,000 per vehicle if installed as part of the original order. For the 42-vehicle Century-El Segundo fleet, that cost totals $3.15 million. The wayside equipment is estimated to cost $48.5 million for the Century-El Segundo line. A non-automated signal system is estimated to cost $15 million for this line; thus the net increase in wayside equipment is $33.5 million.

Should a new technology be selected, the cost of the guideway could increase significantly. The MATRA system in Lille, France, uses a rubber-tired vehicle which needs a fairly complex concrete channel for guidance. The Lille system also uses platform doors (which were not costed here). The UTDC system in Vancouver is also built on a concrete slab at-grade, in part, because of the tolerance felt necessary for the linear induction motor (LIM) it utilizes. The LIM causes large rearward stresses on the guideway as the train accelerates. For both these reasons, it is not certain a conventional track structure with ties and ballast could be used throughout the system even though the vehicle uses steel wheels on steel rails.

It is estimated that the automated operation with short headways could save the future cost of having to expand the platforms to 4-car length, an estimated $1,000,000.

<u>SUMMARY:</u> Capital Costs

<u>Pros:</u>	<u>Cons:</u>
o Future savings of $1.0 million in platform lengthening costs.	o Additional $36.65 million cost for full automation signal and control system.

C. <u>Revenue Implications</u>

The VAL system in Lille and the Skytrain in Vancouver are successful because they have attracted a great number of users. In fact, ridership for both systems is well above expectations. 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 more ridership?"

This is a very difficult question to answer, though it is a pivotal one. Patronage models rely on home-based work-trip data which 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 demand. In discussions with both VAL and Skytrain officials about their ridership experience, it seems that while peak hour ridership is slightly higher than expected, the big surge in ridership occurred because of off-peak growth. There are three possible reasons for this. First, the corridors served in Lille and Vancouver are fairly high-density, active corridors. The Lille corridor connects a new town with the old downtown. A university generates a significant number of riders and several on-line stations serve strong all-day activity centers. The Skytrain system serves downtown, which has remained a strong retail center. Its outlying terminal station focuses on a number of commuter bus lines serving large bedroom communities. Several on-line stations serve large residential complexes. The corridor itself has been rapidly growing and increasingly congested along the few arterial streets. Both cities have a history of transit usage greater than is typical in the United States. In short, the land use pattern served fosters all-day trips.

Secondly, the Skytrain system has a strong feeder bus component so that the service is not so much a rail system overlaid on a bus network, but instead an integrated bus/rail system. It is easy to get to Skytrain mid-day because feeder buses (and trolley buses) are frequent and reliable.

The final reason the VAL and Skytrain service attracts off-peak riders in such large numbers is the frequent service throughout the day. Attended systems can run frequent trains mid-day as well, but usually don't because of added labor costs. (We estimate that cost in Section II-B at $695,000 more per year, amounting to 2.5% of the total systemwide O&M cost.) Automated systems are expected to run more frequently and do because labor costs may not increase with increased train frequency. The rapid transit attendant philosophy of one attendant per train, however, adds a marginal off-peak labor cost for Skytrain only somewhat less than for a manually driven system.

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 which is transit dependent. Experience with SCRTD buses also shows that only about 30% of its bus trips are work related, a very low percentage. SCRTD also experiences high mid-day and weekend demand for bus services, with much of its recent transit ridership growth during these periods. There appears to be a stronger than usual off-peak transit market in Los Angeles.

Whether through automation or not, the Century/Coast corridors should be able to support high frequency all-day rail transit service. If so, then high frequency Century/Coast Line would generate substantially more revenue and come closer to breaking even. 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¢, only 6,000 new daily riders (7.5% of expected Century Line patronage) would generate $1,000,000 more in annual revenues.

<u>SUMMARY</u>: Revenue Implication of Automated Operation

<u>Pros</u>:	<u>Cons</u>:
o Century/Coast corridor should be able to generate all-day ridership. o Potential for increased revenues good.	o Frequent service could be provided with additional labor (+$695,000/year) without automation.

IV. IMPACTS TO PRESENT BASIS OF DESIGN

This section reviews what changes in direction would be necessary if the decision was made to automate the Century-El Segundo line. The answer depends a great deal on whether or not our present light rail vehicle is used as the automated vehicle.

A. Vehicle Procurement

It would be possible to specify a new type of vehicle for an automated operation on the Century Line. The Vancouver UTDC vehicle comes first to mind, but there are several automated steel wheel-on-steel rail vehicles to choose from. These vehicles tend to be much smaller than our 90' vehicle - typically about 40' - yet cost 60-80% of the cost of a light rail vehicle. One drawback, then, is that the cost of the vehicle fleet could rise by as much as $12.6 million for the equivalent of our 42-vehicle fleet. Another is that it would introduce a third vehicle into the Los Angeles rail fleet after a Metro Rail and light rail car. A new spare parts inventory would be required; different maintenance equipment and tools would be required; and more training for maintenance staff would be required. On the positive side, a new vehicle would be already proven under automated operation although it is really the signal and control components that need to be proven under automated operation. Smaller vehicles would also be run two at a time for capacity reasons. A larger vehicle can be run as a single unit which might reduce system reliability.

It may be possible to make provisions for a carborne automated control unit on the vehicle being presently ordered. As noted earlier, adding the control unit now would add an estimated $75,000 per vehicle; retrofitting it later would cost $125,000 per vehicle.

One of the drawbacks of light rail vehicles on a grade-separated, aerial guideway is the overhead catenary system. The present vehicle could be adapted to have a "third rail" shoe which is retractable. The cost of adding this feature is about $25,000 per vehicle. There are some concerns about the dynamic performance of the shoe on a light rail vehicle which would have to be carefully evaluated. The added cost of a 3rd rail on the guideway is estimated to be less than $1,000,000.

<u>SUMMARY:</u> Vehicle Procurement (using present light rail vehicle)

<u>Pros:</u>
- o Systemwide light rail fleet remains compatible.
- o Systemwide maintenance cost is minimized.
- o Cost of required vehicle fleet is minimized by as much as $12.6 million.
- o Vehicle could operate manually as well.

<u>Cons:</u>
- o Full automation of a light rail vehicle is a new concept.
- o Single-car operation may be less reliable.
- o Purchase of Century vehicle may have to be deferred.
- o 3rd rail feature should be introduced at a cost of $1 million.

<u>Recommendation:</u> Use of present light rail vehicle modified to allow automated operation should be an integral part of a decision to automate.

B. Guideway Design

The present guideway design would not have to be redesigned if it was decided to operate an automated rail vehicle. The guideway would need to be further protected with a fence or an encroachment protection system (included in the estimated capital cost). As stated, the cost of the third rail would be $1 million over the cost of the overhead catenary system.

C. Maintenance Strategy

If the light rail vehicle is used for the automated vehicle, then no change in maintenance stragegy is necessary. If another vehicle is used, then the yard near El Segundo is not adequate and a new yard of larger size will be necessary. Experience shows finding such a yard will be a difficult task.

New automated systems use proprietary vehicles which are not only too small for our purposes, and quite expensive, but also will cause maintenance problems. The VAL vehicle cannot be manually driven at all, and the UTDC vehicle has only an emergency panel for manual drive. Thus vehicles needing servicing cannot be driven on their own to the Long Beach-Los Angeles yard where the heavy maintenance work for the fleet will take place. They will have to be towed and the wheel diameters, coupler heights and couplers of the vehicles are not compatible with LRV's. Maintenance equipment such as jacks and lifts, wheel truing machines, tools, etc., will probably be incompatible as well. From a maintenance standpoint, there is no benefit in having another vehicle type in the fleet.

SUMMARY: Vehicle Maintenance (using proprietary vehicle)

Pros:
- Some proprietary vehicle systems provide built-in diagnostics, etc., which lower maintenance requirements greatly.

Cons:
- Difficult at best to use LB-LA heavy maintenance shop.
- El Segundo yard not large enough for second heavy maintenance facility.
- Maintenance equipment is incompatible.
- Second spare parts inventory needed.
- Systemwide maintenance cost is increased.

Recommendation: Use of present light rail vehicle modified to allow automated operation should be an integral part of a decision to automate.

V. CONCLUSIONS

Given the circumstances of the Century Rail Transit Project, this evaluation indicated that full automation would be an attractive option if the presently-specified light rail vehicle - rather than a proprietary vehicle - was an integral part of the decision.

The report also concluded that a decision to fully automate the line would require the entire Coast Line to be within an exclusive guideway, principly on aerial structure. This appeared likely in any case, but would be a certainty. The extra cost was conceptually estimated to be an additional 40% over the estimated $500 million base cost.

The Committee in late 1986 decided not to pursue full automation but to design the Century-El Segundo project not to preclude its eventual introduction.