

Line Evaluation Criteria for Electric Trolleybus Application

ELIANE GUILLOT AND SUSAN PHIFER

The method used to evaluate candidate electric trolleybus lines in Los Angeles is described. The effort was aimed at defining which lines should first be implemented, in support of the regional air quality mandate. Some may view electrification as a capital enhancement to an existing motor coach plant, but this intense 3-month evaluation phase focused on its operations and maintenance aspects. The evaluation team analyzed data for packages of three to four lines and looked at the future network layout and ensured trolleybus compatibility with transit maintenance facilities plans. The review culminated with a formal screening, followed by further refinement of the top-rated packages. About a third of the original packages were recommended for inclusion in the draft environmental impact statement. Operations issues covered the ridership impacts of potential line truncations if only the core leg of a regional route is electrified. Also examined was how future electric trolleybus lines might interface with other modes: express bus, commuter rail, and urban rail transit. The key package selection criteria are displayed in a sample evaluation matrix. These criteria were first tailored to the Los Angeles planning context. The evaluation framework is broadened for transferability to other cities, enabling the densest segments of local bus lines to be upgraded.

The team approach used in early 1992 to select the most viable motor coach lines for near- to mid-term electrification in Los Angeles is summarized. The paper presents the process used by the Route Selection Task Force in defining, fine-tuning, and testing evaluation criteria. Throughout the route selection phase, the multidisciplinary nature of the team was a strong catalyst in reaching a consensus. This was a critical path approach, chosen to fit within the very short time span of this intense effort and facilitate scoping for the subsequent engineering and environmental reviews.

The evaluation team had approximately 20 members, including the following participants:

1. Planning, operations, scheduling, and maintenance facilities representatives from the Southern California Rapid Transit District (SCRTD), since merged with the regional agency funding this effort [Los Angeles County Transportation Commission (LACTC)] into a new agency, called the Los Angeles County Metropolitan Transportation Authority, hereby referred to as MTA;
2. Planning staff from the Long Beach (Public) Transit System and the Montebello Municipal Bus Lines, two municipal operators involved in this project, and resulting from a survey of the nine municipal fixed-route systems run in Los Angeles county;
3. Programming staff and public participation specialists from the LACTC and the SCRTD, since combined within the new MTA structure;

4. Electrical engineering, vehicle procurement specialists from the consulting team, led by ICF Kaiser Engineers with operation, planning, and base conversion support supplied by Parsons Brinckerhoff; and

5. Environmental and urban design subconsultants to ICF Kaiser Engineers, who first reviewed alternatives to be studied, then gave technical and field support to the 9-month development of the draft environmental impact report.

EVALUATION APPROACH

Overview

The approach was tested over a very short time span (less than 3 months) and within the unique operating and funding context of Los Angeles. Still, it is expected to be transferable to other North American cities. The framework can help other transit planning and operating bodies in their local decision making about the potential for placing the overhead wire, electric trolleybus technology along corridors already served by motor coach lines. Many factors were addressed in the Los Angeles setting. Not all these factors may directly pertain to other places with either smaller urban areas or less dense local transit corridors.

First, the trolleybus route selection criteria developed in Los Angeles were drawn from performance measures used in transit service planning, route evaluation, or line restructuring (1). Quantitative measures already exist for most of these familiar transit concepts and apply equally to other vehicle technologies in fixed-route bus line applications. The measures ease the data collection and analysis. Adopted standards already used by the operator provide explicit values for target or threshold levels. In most cases, they also simplify the interpretation of the quantitative results, since the corresponding measures are monitored regularly.

Some line-level quantitative measures needed refinement. This occurred when only a portion of a line was proposed (a segment within a longer line, or only the local portion of a route combining local and express services along the same corridor). In some cases several lines, serving the same geographical sector and linked to a common operating and maintenance base, needed to be studied together. This was done by examining "packages" of lines instead of single lines.

Also found were elements, relevant to electrification potential or merit, that could not be quantified. Several lines were evaluated in the broad domain of public acceptance, goodwill from the local jurisdictions expected to be involved along the candidate lines, and local and regional consensus building—all of which factors were much more qualitative in nature. Overall, a careful compromise was needed to weigh the pros and cons of recommending a

E. Guillot, Parsons Brinckerhoff Quade & Douglas, 505 South Main Street, Suite 900, Orange, Calif. 92668. S. Phifer, Planning Department, Metropolitan Transportation Authority, 425 South Main Street, Fifth Floor, Los Angeles, Calif. 90013.

single line or phasing an optimal package of the most promising lines.

The main theme was to maximize opportunities for near-term electrification in line with regional air quality control measures. Such measures are regionally established by the Southern California Air Quality Management District. In response to the control measures, the team was directed to assess where the most promising line grouping might be, as well as which ones (or which core parts) would lend themselves most easily to an initial deployment of trolleybuses in Los Angeles. Other cities might be less eager to proceed at such a fast pace, partly because of their less pressing air quality issues—issues worsened in Los Angeles by massive urban sprawl and natural topography. They also may be less eager because of a local preference for low-polluting, alternative-fuel technologies over electric trolleybuses.

Objectives

The objectives of the route selection phase (2) were as follows:

- Identify major opportunities for (or potential obstacles to) the near-term electrification of the candidate lines or line segments and assess the level of community acceptance for this program via an extensive outreach effort targeted to the cities and communities affected by the proposed lines.
- Consolidate 20 candidate lines into several packages composed of two to four lines each and thus facilitate the review of their cumulative potential for near-term or future electrification. The purposes of combining routes into packages were to assess the overall performance of each package relative to isolated lines and to maximize opportunities for an optimal trolleybus network, capable of phased implementation and cost-effective operations.
- Define conceptually the key operating and physical parameters for each package. This aspect of the route selection phase required development of preliminary service plans and scheduling and coach assignment simulations for those packages that required major service restructuring instead of minor revisions to existing services.
- Compare the performance of the packages according to a set of agreed-on criteria and state the main reasons for recommending the most promising packages. The next step was to select which parts of the lines, identified within such packages, would be most suitable for the start-up phase of the Los Angeles demonstration.

Screening Criteria for Line Electrification

The evaluation criteria agreed on by the Route Selection Task Force and the Electric Trolleybus Coordinating Committee were the following:

- *Weekday headways of 15 min or less*: these represent current headways at peak and base periods on the candidate lines. If a line needed to be truncated or modified, the remaining trolley and non-trolley segments were assumed to operate with headways similar to current timetables on each leg.
- *Vehicle service hours per route mile*: the trolleybus service intensity or density indicated which lines would remove the maximum number of diesel bus trips from the road, especially those trips with many stops and starts resulting in slower speeds (or

more service hours). The slower progression would result from traffic congestion as well as long dwell times at zones with high numbers of passenger boardings and alightings.

- *Cost-effectiveness relative to air quality benefits*: this was measured by the incremental annualized cost per pound of total emissions reduced—that is, when comparing the proposed trolleybus improvements to methanol-powered coach replacement on the candidate lines and reflecting some inherent savings (or added costs) due to the changes warranted by grouping lines in a package. If some non-trolleybus component was still needed, its contribution in pollutants emitted was treated as a disbenefit and any operations and maintenance costs above current operations were taken into account.

- *Geographic coverage*: the areas served and the general orientation of each line in a package were identified and mapped. The objective was to ensure a broad geographic coverage, itself a policy-oriented concern expected to prevail in a very large urbanized area like greater Los Angeles.

- *Scheduling and operations*: this looked at several operational and routing parameters as well as aspects unique to some lines. These parameters included current layout of the lines for their suitability or lack of suitability for trolleybus conversion (example: circuitous path, multiple branches, intermittent closures of route along current alignment for special events accommodations); potential for creating 100 percent trolleybus lines and maximizing the use of common wire segments in the Los Angeles central business district (LACBD) or other activity centers; current mix of local and limited services and their accommodation under the trolleybus program; lack of compatibility with freeway express running, limiting the initial phase of electrification to nonfreeway segments.

- *Impact on patronage*: the main focus at the route selection phase was to quantify the potential effects of forced transfers between trolley and non-trolley services as imposed by the rule of first electrifying only within a nonfreeway environment. The lines where a forced transfer would not occur as a result of electrification were generally expected to attract new riders on the previous motor coach service.

- *Proximity to operating base*: the intent was to minimize the need to install long stretches of nonrevenue wire while not adding to current deadhead distances with the introduction of trolleybus service. As much as feasible, the authors tried to minimize any marked increase in deadhead time over the current motor coach service plan. Lines identified in the same package tended to overlap in the core of the geographical sector served; this facilitated sharing a common division and nonrevenue wire segment for local site access and egress. The detailed routing plans for the preliminary engineering phase will need to optimize such site-specific assumptions. No attempt was made at testing potential savings in annualized costs associated with optimal routing paths among nonrevenue legs of lines in the same package. Such issues become more crucial for phasing the gradual implementation of the project.

- *Other factors*: the miscellaneous category included unavoidable conflicts (requiring periodic detours) with major events, interface and local feeder potential with existing or committed rail stations, as well as a corridor-level assessment of compatibility with other public works, roadway, or utility upgrade projects. In addition, community support from local jurisdictions was included. Relevant to gauging the local acceptance by affected jurisdictions were the types of support contemplated, for instance,

local commitment of financial support as well as local improvements supportive of transit service delivery such as preferential treatment for trolleybuses along streets and arterials proposed for electrification, urban design features along bordering sidewalks or street medians, or other operational measures facilitating bus stop or transit center layout.

DESIGN OF LINE PACKAGES

Sixteen packages were developed using various combinations of the 20 candidate lines. The review of these packages was based on the line evaluation criteria just given. In sorting among these candidate lines, the cumulative benefits of grouping specific lines or line segments were assessed. Several opportunities arose for major line restructuring as well as for potential service increases along some line segments. Typically, the proposed trolleybus services were defined to maintain service levels (i.e., coverage and typical weekday headways) equivalent to current levels on the affected motor coach lines.

The proposed grouping of the candidate lines into different packages responded to the following planning objectives:

- Strive for line proximity to one or more active operating division(s) expected to be retrofitted for trolleybus service, inspection, heavy maintenance, storage, and operations and dispatch. Assess the ability of lines in the same package to share the same division, even if it means reassigning an existing line to a new site (i.e., a change in current practice).

- Look for opportunities among lines in the same package to share overhead wire systems in revenue service, both within and outside LACBD. The greater the number of lines with a common segment, the more economical the construction and the maintenance of their overhead catenary system relative to the total length of the package. Preliminary paths of nonrevenue wire needs were laid out for sharing nonrevenue segments among lines in the same package.

- Analyze the proposed conversion of limited service (i.e., skip stop running on designated segments of major arterials) to local service. This change was tempered by the potential disbenefit of causing noticeable travel time increases at peak or midday hours along key route segments. In such cases, maintaining the integrity of the limited service was deemed to warrant the provision of double wire for reliable trolleybus passing. In other cases, the proposed electrification would affect only the local service components, whereas the limited service would rely on nontrolley technology.

- Minimize the potential to lower interline savings (in number of peak coaches), currently achieved via shared coach and driver assignments among different lines close to each other. This was considered explicitly for several packages, whether a candidate trolleybus line was interlined with another motor coach-only line or whether the limited portion of a route was not proposed for electrification (while the local portion was a promising candidate). Conversion to methanol-powered coaches offers more operational flexibility in this regard, as long as fueling provisions are made at all affected divisions.

- Compare the known capacities of active operating divisions with the estimated number of active trolleybuses in each package. This early assessment assumed compatibility between trolleybus and nontrolleybus fleets or the ability to mix technologies at the

same maintenance site. Also assumed at this conceptual phase was the uniform use of standard-length (40-ft) trolleybus coaches among all the packages.

- Optimize intermodal connections with existing and programmed light rail, heavy rail, commuter rail, and other municipal or regional bus and rail transit services. This was reflected in the recommended trolleybus routings or route deviations for enhanced transfer opportunities.

DEFINITION OF SELECTED PACKAGES

Now the trolleybus evaluation is illustrated for three distinct packages. Highlighted are routing definition, service parameters, and local land uses along their respective lines (3). Briefly stated are unique aspects of each package and special issues raised by operations, maintenance, or multimodal integration. Such points supplement the quantitative results by placing the findings in the Los Angeles context. If one applied the same criteria elsewhere, a somewhat different interpretation might prevail to reflect local issues.

Package P-5: Description of MTA Lines 30/31 and 45

Package P-5 combines two lines with a common path through the LACBD; it covers 26 mi. Each line operating plan is summarized here.

As shown in Figure 1, Lines 30/31 follow West Pico Boulevard in West Los Angeles. Land uses are almost exclusively retail in

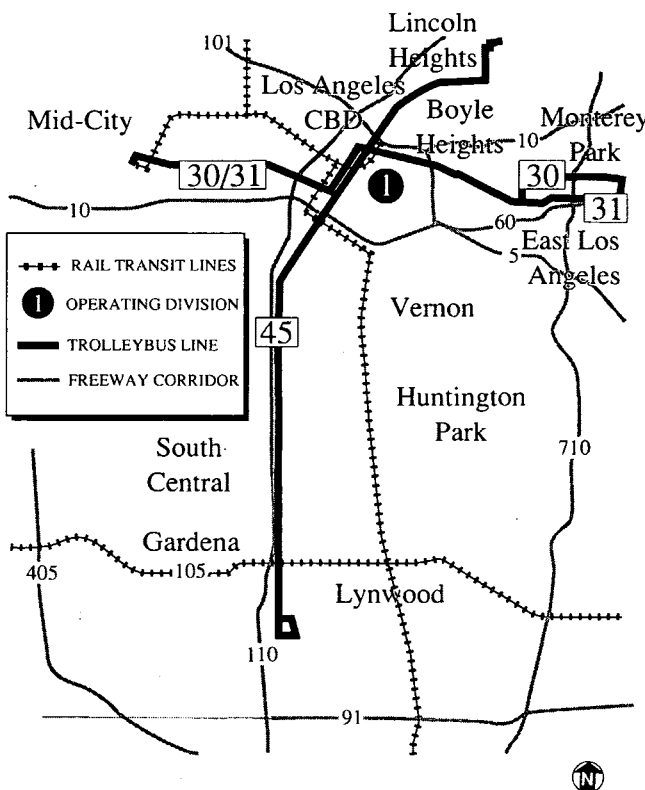


FIGURE 1 Package P-5 layout.

this segment of the route common to Lines 30 and 31. Through the LACBD, both lines follow the same path along Broadway (north-south penetration of the LACBD) between Pico Boulevard and First Street. The downtown segment still has a strong retail element with a mix of institutional, commercial, and office buildings, in the core part of Broadway.

To the east of the LACBD, Line 31 runs east-west along East First Street and terminates via a short loop along Atlantic Avenue, Floral Drive, Collegian Way, and Riggin Street. Land uses in the Boyle Heights community consist of small lots with a mix of residential, neighborhood retail, and open space. Within the unincorporated part of East Los Angeles and the city of Monterey Park, land uses are mostly residential. Line 30 follows an alternative branch from the trunk route on First Street to the east of Rowan Avenue via Hammel Street, Brannick Avenue, and Floral Drive. Both lines were proposed for electrification, even though the Floral Drive branch of Line 30 had somewhat higher boardings than the eastern leg of Line 31.

The weekday service span of Lines 30/31 is about 23 hr (from 4:30 a.m. to 3:40 a.m.), with peak headways of 7 min and base headways of approximately 15 min. The peak pullout requirement is 42 buses.

Lines 45/46/345 operate north-south along the Broadway corridor. Line 45 follows Broadway as far south as Rosecrans Avenue, with the Line 345 limited runs (peak period only) between Imperial Highway and the LACBD. Current travel time savings between Imperial and Pico Boulevard are approximately 9 min for the limited over the local trips. For this package, the Line 345 service was assumed to continue in nonrolleybus mode, thus electrifying only the Line 45 local service.

To the north of the LACBD, Line 46 currently uses the same path as Line 45 to the intersection of North Broadway and Griffin. The Line 46 branch, running through the Montecito Heights neighborhood, was not assumed to be electrified, with the local part of the service along Griffin replaced by an existing Line 255. Patrons bound for the LACBD would transfer to the Line 45 trolleybus service on North Broadway. The northernmost leg of Line 45 would be electrified along Lincoln Park Drive, Flora Avenue, Sierra Street, Mercury Avenue, and, turning around, at Collis Avenue and Huntington Drive, a major bus transfer node. Although this leg of Line 45 is quite circuitous, the very productive segment was considered worthy of electrification.

The Line 45 service span is slightly less than 24 hr, with peak headways of 7 min and base headways of approximately 15 min. The peak pullout requirement for Line 45 only is 24 buses.

As shown in Figure 1, Line 45 follows Broadway in each direction. The same LACBD path as now used was assumed for this package with common wire along the full length of Broadway between Pico Boulevard and First Street.

This package raises service development issues along the future rail extension corridors. The western terminus of Lines 30/31 is adjacent to the proposed Red Line interim terminus at Pico and San Vicente Boulevards. This may result in a shift of current bus riders to the rail service for a faster access to the LACBD area, as well as possibly a need to shorten base headways (from the current 15-min service) to provide more convenient feeder bus connections in the base period. The East Los Angeles routing of Lines 30/31 follows First Street, which parallels one of the rail alternative alignments (between Union Station and Indiana Avenue) defined by the recent MetroRail Eastside Extension AA/DEIS. Thus, the implementation of this subway extension

may affect the future routing and service headways of Lines 30/31 along First Street.

Line 45 is expected to warrant change in its southernmost routing for feeder access to the 117th Street Green Line station and the Harbor Transitway. Ending the electrified route at this bus-rail transfer node is one service design option. Another option is to divert Line 45 from Broadway to an off-street transfer location west of Broadway. Current bus headways along this portion of the line may need to be shortened for more convenient local feeder bus access to both new regional transit facilities.

Package P-8: Description of MTA Lines 40 and 204.

Package P-8 combines two north-south lines, only one of which serves the LACBD. It covers a total of 30 mi. Each line operating plan is summarized here.

As shown in Figure 2, Line 40 follows Martin Luther King Jr. Boulevard, Crenshaw Boulevard, and Hawthorne Boulevard. It connects the LACBD (via the north-south Broadway corridor) with a mix of industrial, commercial, and small office buildings along the middle part of the route. Pockets of residential areas are served near the southern terminus at the South Bay Galleria Transit Center, part of a regional shopping mall in the city of Redondo Beach.

The weekday service span on Line 40 is 24 hr, with peak headways of 9 min and base headways of approximately 12 min. The peak pullout requirement for Line 40 is 55 buses.

As shown in Figure 2, Line 204 currently runs north-south on Vermont Avenue from Imperial Highway in the South Bay area

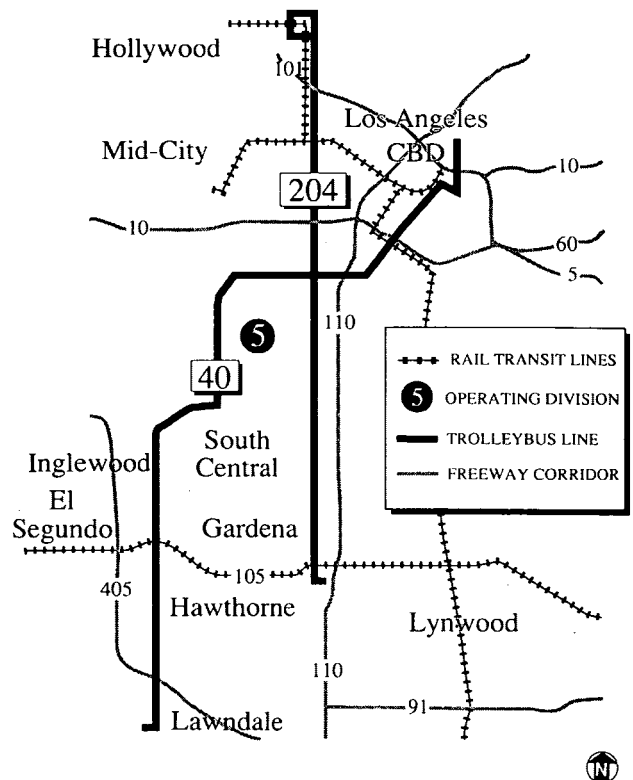


FIGURE 2 Package P-8 layout.

to Hollywood Boulevard in Hollywood. Line 204 does not serve LACBD directly, although transfers to the future Red Line subway stations along Vermont Avenue would provide convenient access to downtown from the northern part of this trolley corridor. The north-south corridor is bordered mostly by retail land uses, sparsely mixed with small pockets of residential and open space and commercial activities.

Besides the local 204 motor coach service, Line 354 currently provides limited-stop service along Vermont from Melrose to Manchester Avenue. Current travel time savings between these two limited stops is approximately 8 min for the limited over local trips. For this stage of route refinement, the limited 354 service was assumed to be electrified and converted to local service. This change was estimated to require an extra two peak coaches over current weekday needs.

Line 204 will feed the Red Line at future subway stations located at Vermont Avenue and Wilshire, Beverly, Santa Monica, and Sunset Boulevards. Under the proposed rail feeder plan, there is no change to Line 204 routing, whose northern path was already altered for permanent feeder bus access to this leg of the heavy rail network.

The Line 204 weekday service span is 24 hr, with peak headways of 6 min and base headways of approximately 10 min. The peak pullout requirement for Line 204 is 39 buses.

This package can be integrated with the near-term development of the initial Green Line east-west corridor along the new Century Freeway median. Line 204 will serve the Green Line station near 117th Street and Vermont Avenue. Line 40 will also feed the Green Line near Imperial Highway and Hawthorne Boulevard. Line 40 current peak headways of 12 min may need to be shortened for more convenient feeder service to the regional rail system. Long-term opportunities for a southern extension of the Green Line along Hawthorne Boulevard might point to the need for first electrifying Line 40 only as far south as Imperial Highway.

Package P-9: Description of MTA Lines 70 and 92/93

Package P-9 combines two local lines and covers a total of 35 mi. Each line operating plan is summarized here.

As shown in Figure 3, Line 70 begins in the LACBD and uses a circuitous path through the Boyle Heights and City Terrace communities. The predominant land uses in this initial leg are residential. The line then runs east-west along the Garvey Avenue corridor, which parallels the San Bernardino Freeway up to the eastern terminus at the El Monte Busway Station. Land uses along Garvey Avenue are mostly neighborhood retail, especially east of Fremont Avenue.

Within the LACBD, this line follows the north-south Spring Street corridor (parallel to Broadway) between Sunset Boulevard and 12th Street. A loop at the southern edge of the LACBD serves the convention center and the Blue Line Station at Pico Boulevard and Flower Street. At this stage of development, the loop was assumed to be electrified, although the environmental review of potential traffic conflicts with convention center activities has since led to proposing a relocation of the loop to a more remote site.

Line 70 weekday service span is 24 hr with peak and base headways of 10 min. The peak pullout requirement for Line 70 is 22 buses.

As shown in Figure 3, Lines 92/93 currently operate from LACBD north to the city of Glendale along Glendale Boulevard. They continue north along Brand and Glenoaks Boulevards through the cities of Sun Valley and San Fernando. Then Line 93 deviates from Line 92 along a branch on Allesandro Street and Riverside Drive, to the south of the Golden State Freeway in the Silverlake neighborhood of Los Angeles.

In view of the extensive coverage of this line (full length at more than 26 mi between the LACBD and the north terminus), only the southernmost portion to Olive and Glenoaks in Burbank was originally studied as a viable trolleybus candidate. Yet in or-

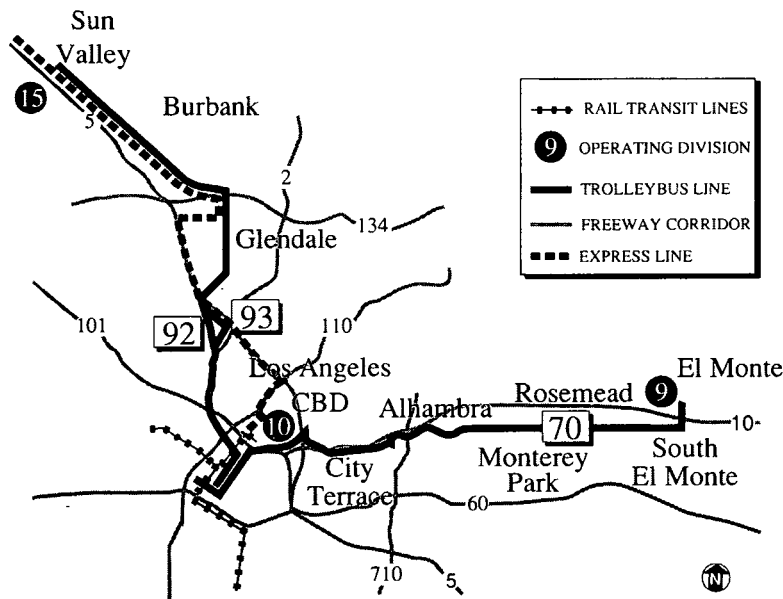


FIGURE 3 Package P-9 layout.

der to use an existing operating division along the corridor, the authors opted to extend the proposed trolleybus coverage further north. This resulted in a net line coverage of 20.7 mi for the proposed trolleybus service.

The service span of Lines 92/93 is 24 hr with peak headways of 10 min and base headways of 15 min, south of the Burbank CBD. Current base headways on Lines 92/93 to the north of Burbank are approximately 24 min, with current peak-period headways on Line 410 in the range of 15 to 30 min. Peak pull-out requirements for truncated Lines 92/93 are 16 coaches.

The proposed truncation of Lines 92/93 would be mitigated by an increase in current service levels along Line 410. This line follows the same Glenoaks Boulevard corridor as Lines 92/93 within the San Fernando Valley and becomes an express line along the I-5 freeway from Colorado Street near Griffith Park to the LACBD. Although current service on Line 410 runs only in the peak periods, the trolleybus conversion would introduce all-day, nontrolley service along Glenoaks Boulevard between Hubbard Street in San Fernando and Colorado Street in Glendale to replace local service deleted on the shorter Lines 92/93 runs. Yet, this extension of the service span for Line 410 results in a net increase of six extra a.m. peak and four extra p.m. peak coaches for the new service (i.e., combined trolley along shorter Lines 92/93 and nontrolley along all-day Line 410). This change would warrant an additional 104 platform hours on a typical weekday for the family of Lines 92/93/410, or a 38 percent increase over current service supply without offering any more frequent runs than today.

In the LACBD, Lines 92/93 operate on Temple, Spring, and Main Streets in a counterclockwise loop. Under this package, the future trolleybuses would operate in each direction on Spring Street. The LACBD trolleybus revenue wire shared by Lines 70, 92 and 93 would follow Spring Street between Pico and Sunset Boulevards.

Summary of Results for Selected Packages

Table 1 presents a summary of the evaluation results for each of these packages. It shows the composition and length of each pack-

age as well as the planning assumptions made on operating division assignments. Current weekday service levels are given for peak and base headways by line. On the basis of these current service levels, the corresponding service intensities in weekday vehicle hours per route mile are shown. Also given in Table 1 are the net cost per pound of emissions reduced, an abbreviated label for geographic coverage, and estimates of peak trolleybus coaches, active fleet sizes, and anticipated effects on patronage.

INTERPRETATION OF TECHNICAL FINDINGS

The evaluation team reviewed all the technical findings, compared results among the 16 packages, and recommended a total of 5 to 6 packages. The recommendations were made for the environmental analysis to focus on those packages contemplated for the first phase of the trolleybus program (4). Results of the team review are summarized for the three packages just described.

Package P-8

Package P-8, which consists of MTA Lines 40 and 204 in full, was strongly recommended for the first phase. The indicators for service intensity and cost-effectiveness were both high relative to the full set of packages. Table 2 indicates that P-8 ranks third in service intensity and fourth in cost-effectiveness. Both lines serve heavily used transit corridors along major north-south arterials, which connect several sectors of the MTA service area. Both lines could share the same operating division in the South Bay. When the Green Line trains begin in revenue service, there will be potential to increase local service frequency along the Hawthorne Boulevard segment of Line 40. This would further increase the indicator for service intensity. In view of those strengths, neither the lack of common revenue wire among both lines nor the proposed replacement of limited service by local service along Vermont Avenue (Line 354 becomes same as Line 204) were judged to be significant weaknesses.

TABLE 1 Electric Trolleybus Route Selection: Aggregate Data for Selected Packages (2)

	Package Composition (Length of full package)	Current Service Levels Weekday Headways By Line			Weekday Vehicle Hours Per Route Mile	Net Cost Per Pound Of Emissions Reduced	Geographic Coverage
		Line	Base (Minutes)	Peak			
P5	MTA 30/31, and 45 (26.2 miles)	30/31 45 345	15 15	7 7 7 to 8	30.7 (gross) 32.6 (with shared wire)	\$29	LACBD, SGV, Southeast, Westside, East LA
P6	MTA 30/31, 40 and 45 (39.0 miles)	30/31 40 45 345	15 12 15	7 9 7 7 to 8	32.7 (gross) 37.8 (with shared wire)	\$29	LACBD, East LA, SGV, Southeast, Westside, South Bay
P8	MTA 204 and 40 (29.7 miles)	204 40	10 12	6 9	35.8 (gross)	\$32	LACBD, Westside, South Bay
P9	MTA 92/93 and 70 (34.9 miles)	92/93 410 70	15 10	10 15 to 30 10	13.2 (with shared wire)	\$104	LACBD, SGV, SFV
P10	MTA 30/31 and 70 (26.4 miles)	30/31 70	15 10	7 10	26.1 (gross) 27.8 (with shared wire)	\$38	LACBD, SGV, Westside, East LA

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TABLE 1 (continued)

	Package Composition (Length of full package)	Operating Division Number (Rated Capacity in Number of Coaches)	Peak Trolley Coaches	Active Coaches Estimate (% of Division Capacity)	Impact Upon Patronage (Based on current weekday segment level counts)	Average Distance To Operating Division (Miles)
P5	MTA 30/31, and 45 (26.2 miles)	MTA Division 1 at Sixth and Central (170)	66	76 (45%)	Potential for reduction along Westside leg along Pico with future opening of proposed Pico/San Vicente Red Line interim terminus.	0.85
P6	MTA 30/31, 40 and 45 (39.0 miles)	MTA Division 1 at Sixth and Central (170) and MTA Division 10 at Macy and Mission (238)	123	150 (30% for both combined)	Similar to P-5, plus potential for reduction with 46 leg replacement by 255 local and transfer to LACBD bound trolleys at North Broadway.	0.75
P8	MTA 204 and 40 (29.7 miles)	MTA Division 5 at 54th and Van Ness (235)	94	108 (46%)	Potential for reduction with 354 replacement by local only trolleybus runs.	1.13
P9	MTA 92/93 and 70 (34.9 miles)	MTA Division 10 at Macy and Mission (238) and small part of MTA Division 9 at Santa Anita and Ramona (near El Monte Station)	38	44 (17%)	Approximately 510 (8% of NB riders) and 890 (14% of SB riders) patrons forced to transfer in Sunland along Line 92/93.	0.88
P10	MTA 30/31 and 70 (26.4 miles)		64	74 (31%)	Positive, except for Westside leg along Pico with future opening of proposed Pico/San Vicente Red Line interim terminus.	0.75

Package P-5

Package P-5, which consists of MTA Lines 30/31 and 45, was only recommended as part of a larger Package P-6. As indicated in Table 1, P-6 combines the two lines, defined for package P-5, with Line 40 (also part of the package P-8). Per Table 2 estimates of shared wire, the service intensity indicator increased from 32.6 to 37.8 vehicle service hours per route mile, when adding Line 40 to P-5. But P-5 by itself was found to be equally cost-effective to P-6 as a whole. Overall P-6 ranked second (service intensity), while P-5 ranked fifth; P-6 and P-5 ranked first for cost-

effectiveness. Without using constraints on capital funds for the trolleybus project, the larger Package P-6 would have greater air quality benefits than P-5. P-6 would give access options to a zero-polluting fleet to a greater number of transit riders.

Looking at smaller differences between Packages P-5 and P-6, the three lines proposed for P-6 would share 6.0 mi of revenue wire along Broadway within and south of the LACBD. This common wire benefit is reduced to 1.5 mi among the two lines proposed for P-5. Trolleybuses under P-5 only could share a single operating division east of the LACBD. The larger fleet size for P-6 (i.e., about twice the P-5 active fleet) would warrant a split

TABLE 2 Overall Ranking of Aggregate Measures (2)

Trolley Revenue Service Intensity Rank (in VSH*/Rte Mile)	Package	VSH*/RteMile Value	Possible Clusters	Cost Effectiveness Relative to Air Quality Rank (in Incremental \$/Lbs Reduced) (1)	Package(s)	Cost Effectiveness Value (\$)	Possible Clusters
1	P-4	48.1		1, 2, 3	P-4, P-5,	29	
2	P-6	37.8	30		P-6		\$35
3	P-8	35.8	or	4	P-8	32	or
4	P-7	33.9	more	5, 6	P-3, P-16	35	less
5	P-5	32.6		7	P-10	36	
6	P-1	29.6		8, 9	P-7, P-12	37	
7	P-3	29.4		10	P-11	38	\$36
8	P-16	28.6	25	11	P-2	39	to
9	P-2	27.2	to	12	P-1	40	\$75
10	P-10	26.1	30	13	P-15	45	
11	P-11	25.5		14	P-9	104	\$75 to
12	P-12	21.8	20 to below 25	15	P-14	109	\$115
13	P-14	19.5		16	P-13	169	\$116 or more
14	P-13	16.8	below				
15	P-15	16.3	20				
16	P-9	13.2					

(1) Ties between packages correspond to multiple ranks on the same row.

* VSH stands for Vehicle Service Hours

TABLE 3 Grouping by Fleet Size, Division Access, and Coverage

Active Fleet Size Preliminary Estimates of Active Trolleybuses			
below 50	50 to 100	above 100	
P-9, P-13, P-16	P-2, P-3, P-4, P-5, P-7, P-10, P-11, P-12, P-14, P-15	P-1, P-6, P-8	
Average Distance to Operating Division(s)			
less than <u> </u> mile	<u> </u> to less than <u> </u> mile	<u> </u> to 1.0 mile	greater than 1.0 mile
P-2, P-3	P-1, P-11, P-16 P-10, P-12, P-14, P-15	P-4, P-5, P-6, P-9,	P-7, P-8, P-13
Coverage of Trolley Bus Network (one-way route miles)			
less than 25 miles	25 to less than 27 miles	27 to 30 miles	above 30 miles
P-16, P-2, P-13, P-4	P-5, P-7 P-10, P-11, P-15	P-3, P-8, P-12	P-1, P-6, P-9, P-14

assignment among two separate divisions because of capacity constraints and limited expansion potential at existing divisions. Package P-6, being much larger, would present more opportunities for shared nonrevenue wire segments than P-5 as defined. Those points show some of the trade-offs expected in expanding from one package to another rather than adding a different package altogether (no common lines).

The future opening of the Pico/San Vicente Red Line interim terminus on the Westside might also modify current ridership patterns along Lines 30/31. Some bus patrons bound for the LACBD and East Los Angeles might shift to the Red Line trains and away from the Line 30/31 trolleybus service. Yet the new feeder function of this east-west local line would most likely draw new riders to the same West Pico Boulevard segment proposed for electrification.

Package P-9

Package P-9, which consists of MTA Lines 70 and 92/93, was not recommended for the first phase, although the central portion of Lines 92/93 may need to be restudied at a later phase. This package ranked very low for the two quantitative indicators in Table 2. It ranked last for service intensity and third to last for cost-effectiveness. Since current base headways on Lines 92/93 to the north of Burbank are much longer than 15 min, truncating both lines in Burbank seemed consistent with the screening criteria. The spreading between the central San Gabriel Valley (Line j70 eastern terminus) and the north San Fernando Valley (Lines 92/93 northern terminus, if trolleybus were to run north of Burbank) brings too many operational disbenefits. The incremental cost of adding midday service on Line 410 outer leg is also counterproductive. As an added disbenefit for this package, long dead-head trips to and from the proposed shared operating division (adjacent to the LACBD legs of both routes) warrant partial conversions of two outer divisions to trolleybus storage.

Dropping a given package from the first phase does not always imply that another package, using some of its lines, might not be a candidate for near-term electrification. As indicated in Table 1, associating Line 70 (part of P-9 above) with Lines 30/31 (part of

P-5 and P-6 above) makes a much stronger candidate P-10 than the P-9 combination. Per Table 2 results, P-10 ranked seventh in cost-effectiveness and tenth in service intensity. Package P-10 was indeed recommended for the first phase of the project.

CLUSTER CONCEPTS

One advantage of working with packages was to help frame the options for coach assignments to viable operating divisions. This is one aspect of the trolleybus program development in need of coordination with methanol-powered fleet expansion by MTA. Another advantage of evaluating packages (rather than focusing on individual lines) was to have a more manageable data set with which to deal. (Table 3 gives groupings that are based on fleet size, division access, and coverage.) The Electric Trolleybus Coordinating Committee also endorsed the approach of relying on unweighted criteria in summarizing the results and making recommendations. No predetermined "acceptable" range was set before the quantitative results were compiled among the various packages.

The overall evaluation did reflect the solid framework tied to the two quantitative measures, given in Table 2: the service intensity (i.e., vehicle service hours per route mile of line to be electrified) and the overall cost-effectiveness (relative to the air quality benefits over running methanol-powered coaches along the same paths and with comparable headways). As shown, there are few major ranking contrasts among these two primary indicators.

The definition of viable (numerical) clusters was then based on this unique set of packages. The authors could not recommend transferring those values to other systems, since such quantitative benchmarks depend on local operating practices. However, the same concept is valid for other transit agencies involved in an areawide review of candidate trolleybus corridors.

CONCLUSION

The evaluation approach used in Los Angeles proved to be a thorough and technically sound way to select the most viable corridor

segments for near- to mid-term electrification. Although the impetus came from regional air control measures, some constraints to a fast-track implementation were indeed encountered. Such constraints are not expected to be unique to Los Angeles. They included the challenge of a fast-track vehicle procurement, when a limited market still exists for electric trolleybus fleet acquisition or development in North America, and the shortage of capital moneys to carry out the more attractive option of a full package instead of a partial one as a startup.

The trolleybus concept may not lend itself to support the rationale for a brand new service, for which local market demand has not yet been tested. This reinforces the original framework of focusing the first phase evaluation on local, nonfreeway lines carrying a stable ridership within the most densely traveled of the transit network. This is well worth emphasizing in view of the permanent location of overhead trolleybus revenue wire and associated facilities (power substations, nonrevenue wire to operating divisions). It also points to the relative merit of deploying

alternative fuel-powered vehicles, such as methanol-powered coaches, in areas with emerging transit markets or likely changes in the coverage of their local transit lines—as often expected for corridors with programmed rail transit or express bus improvements.

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