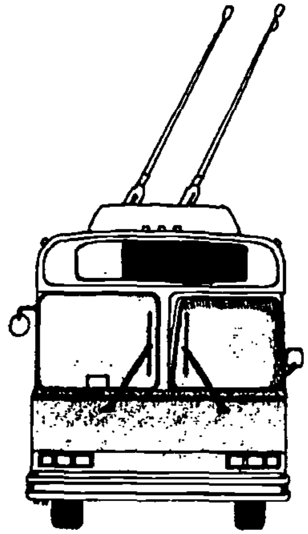
FINAL Report
Part A
ELECTRIC TROLLEY BUS STUDY FOR RTD AND THE LACTC



RTD

LACTC

ART LEAHY

June 1991

by

BOOZ·ALLEN & HAMILTON Inc.

In Association with

Morrison Knudsen Engineers
Cordoba Corporation
Gruen & Associates
Sharon Clark Associates

ABSTRACT

This report has been prepared for the Southern California Regional Transit District and the Los Angeles County Transportation Commission to evaluate implementation issues, costs, and benefits associated with converting bus routes in RTD's system to electric trolley operation. The "Electric Trolley Bus Study" is divided into two parts: Part A focuses on evaluating selected routes for early implementation and comparing costs and emission characteristics with alternative fuel bus operation; Part B of the study is focused on evaluating RTD's entire bus route system as well as MUNI operations in Southern California to structure long term electrification system options for the region. Part B of the study also evaluates the practicality of other "zero emission" propulsion technologies such as fuel cells, inductive coupling, and battery powered vehicles.

<u>This report (Part A) is a Summary report.</u> It is supported by more detailed Task Reports organized as follows:

Task 1 – Trolley Bus and Overhead Wire Technology Evaluation

Task 2 – Route Selection

Task 3 – Comparative Analyses of Low Emission Transit Alternatives

Task 4 – Environmental and Energy Considerations

Task 5 – Aesthetic Considerations

Task 6 – Community Acceptance

Task 7 – Financing Options

PREFACE

The development of this report focused on gathering, organizing, and interpreting information from many sources to evaluate the conversion of motor bus routes in RTD's system to trolley operation.

The task was not an easy one. New "clean fuel" alternatives are just now emerging in the marketplace and uncertainties exist regarding a variety of operational issues as well as costs. Trolley system technology (both vehicle designs and overhead wire systems) are also changing. Existing trolley systems have experienced varying degrees of success at different cities throughout North America depending on route structure, geography, topography, system patronage and service levels, energy costs and numerous other factors. RTD's situation is unique and a review of operations in other cities will not provide all the answers. Finally, RTD is in the unique position of having the opportunity to establish the first all new trolley system in North America in the last 3 decades. All these factors combine to make this an exciting and challenging study. Booz·Allen and its subcontractors are proud of our work on this report. We believe it represents a comprehensive assessment of trolley bus operations and provides RTD/LACTC with the necessary foundation to confidently move forward with the selection of routes and implementation plans for trolley bus conversion.

BOOZ·ALLEN & HAMILTON Inc.

Robert Kreeb
Project Manager

ACKNOWLEDGEMENTS

The Booz·Allen team wishes to acknowledge the contributions of the following individuals and organizations who provided data, information, and research for the study. Their experience and insight was invaluable in completing the analyses of trolley buses and other clean fuel alternatives.

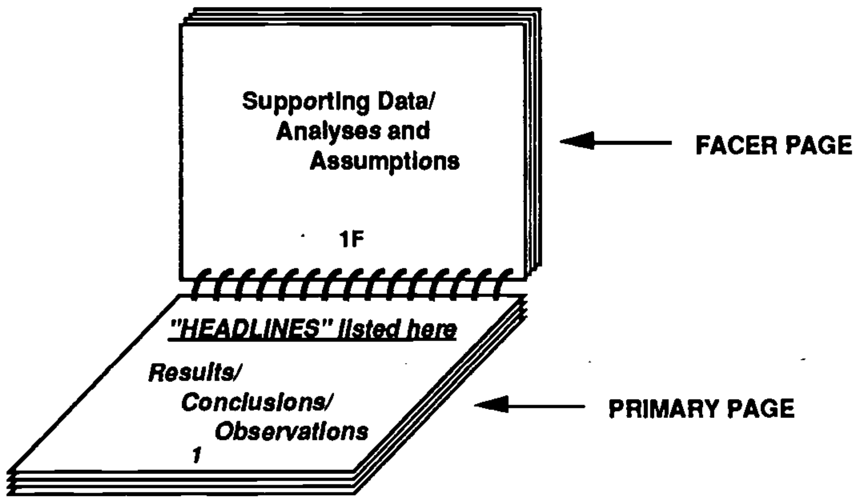
RTD STAFF
LACTC STAFF
Southern California Edison
Los Angeles Dept. of Water and Power
The South Coast Air Quality Management District
The California Air Resources Board
The California Energy Commission
Transit Properties:
- San Francisco Municipal Railway
- Seattle Metro
- BC Transit: Vancouver
- SEPTA: Philadelphia
- MVRTA: Dayton
- Hamilton Street Railway
- Toronto Transit
- MBTA: Boston

Environmental Protection Agency
U.S. Dept. of Energy
Urban Mass Transit Association
American Public Transit Association
L.A. Fire Department
Southwest Research Institute
Detroit Diesel Corporation
Cummins Engine Company
Flyer Industries
Flexible Corp.
TMC
Methanol Producers Association
Celenese Corp.
Chevron Research

In particular, we wish to acknowledge the efforts of RTD staff members Mr. Al Perdon and Mr. Nadeem Tahir who provided guidance throughout the study.

REPORT FORMAT

In completing other studies of this type, where large amounts of data are generated and reported, Booz·Allen has found that a horizontal or presentation style report is more efficient for conveying information. This format is results/recommendations driven, meaning the reader gains a quicker insight into the findings of each task. The exhibit below illustrates the style of this report. The "primary" page presents the reader with a key observation, conclusion, result, or idea. The "facer" page simply list additional data, analyses, charts, and diagrams that support the main point or idea listed on the primary page. The facer also serves as a convenient location for footnotes, references, and assumptions supporting the primary page. As the reader flips through the report, the primary page should always be read first. The "headlines" on each primary page of a particular section flow together in a story-line format to convey the main message(s) of that section. Facer pages need not be read to gain an understanding of the subject matter (although they provide an added level of detail).



GRAPHIC 58

Not all primary pages have a support facer page if/when the main message can be adequately conveyed or supported on the primary page.

PRES/RCC - 03

RTD AND LACTC HAVE INITIATED THIS STUDY TO EXAMINE THE ENVIRONMENTAL AND OPERATIONAL IMPLICATIONS OF TROLLEY BUS USE. . . THE STUDY IS DIVIDED INTO TWO PARTS

PART A

- Determine air quality and other user benefits from trolley operations
- Identify any operational complexities or special concerns associated with trolleys
- Assess community acceptance and initiate a public awareness program
- Compare capital and operating costs with other alternative fuel technologies
- Review and recommend an appropriate trolley vehicle technology . . . and overhead wire power distribution system
- Select a small subset of routes for early conversion and develop an implementation plan
- Develop a preliminary financing plan and cash flow projections

PART B

- Determine the extent to which RTD's system can be converted to trolley operation in a practical, effective manner
- Establish a route-specific operating plan for RTD's entire system . . . as well as for MUNI's
- Develop a preliminary implementation plan for converting the remaining routes
- Review the commercialization potential of "advanced" vehicle technologies such as fuel cell and roadway powered propulsion systems

UPON APPROVAL FROM LACTC AND RTD BOARDS' OF DIRECTORS TO MOVE AHEAD WITH THE PROJECT, THIS STUDY WILL BE FOLLOWED BY A MORE DETAILED PRELIMINARY ENGINEERING AND IMPLEMENTATION PLAN

- Route refinement
  - Route restructuring (as required)
  - Power needs assessment
  - Overhead wire design (pole-use, special work, etc.)
  - R.O.W. modifications (as required)
- Facilities plans
  - Finalize route assignments by division
  - Working with system planners (RTD and LACTC) to establish need for (and possible locations of) new trolley bus divisions
  - Detail modifications needed to operate mixed-use divisions (costs, maintenance equipment lists, storage, catenary requirements inside each of the targeted divisions, etc.)
- Environmental analyses along selected routes
- Vehicle specifications (including use of ARTIC vs. 40 ft. coaches on a route-by-route basis)
- Detailed project costs estimates and work scheduling
- Financing and cash flow plans
- Community Outreach program

THE REMAINING SECTIONS OF THIS REPORT ARE ORGANIZED AS FOLLOWS:

- **Introduction and Background**
- **Study Methodology**
- **Summary Conclusions**
- **Overview of Trolley Bus Systems**
- **Trolley Bus Benefits**
- **Operations and Maintenance Considerations**
- **Review of Trolley Systems in Other Cities**
- **Electric Power Source Profile for Southern California**
- **Community Awareness Program**
- **Vehicle Technology**
- **Overhead Wire and Power Distribution System Design**
- **Aesthetic Considerations for Catenary Systems**
- **Fuel Price Issues**
- **Alternatives Technology Analyses**
- **Alternatives Cost Comparison**
- **Route Selection**
- **Implementation Plan**
- **Financing Plan**

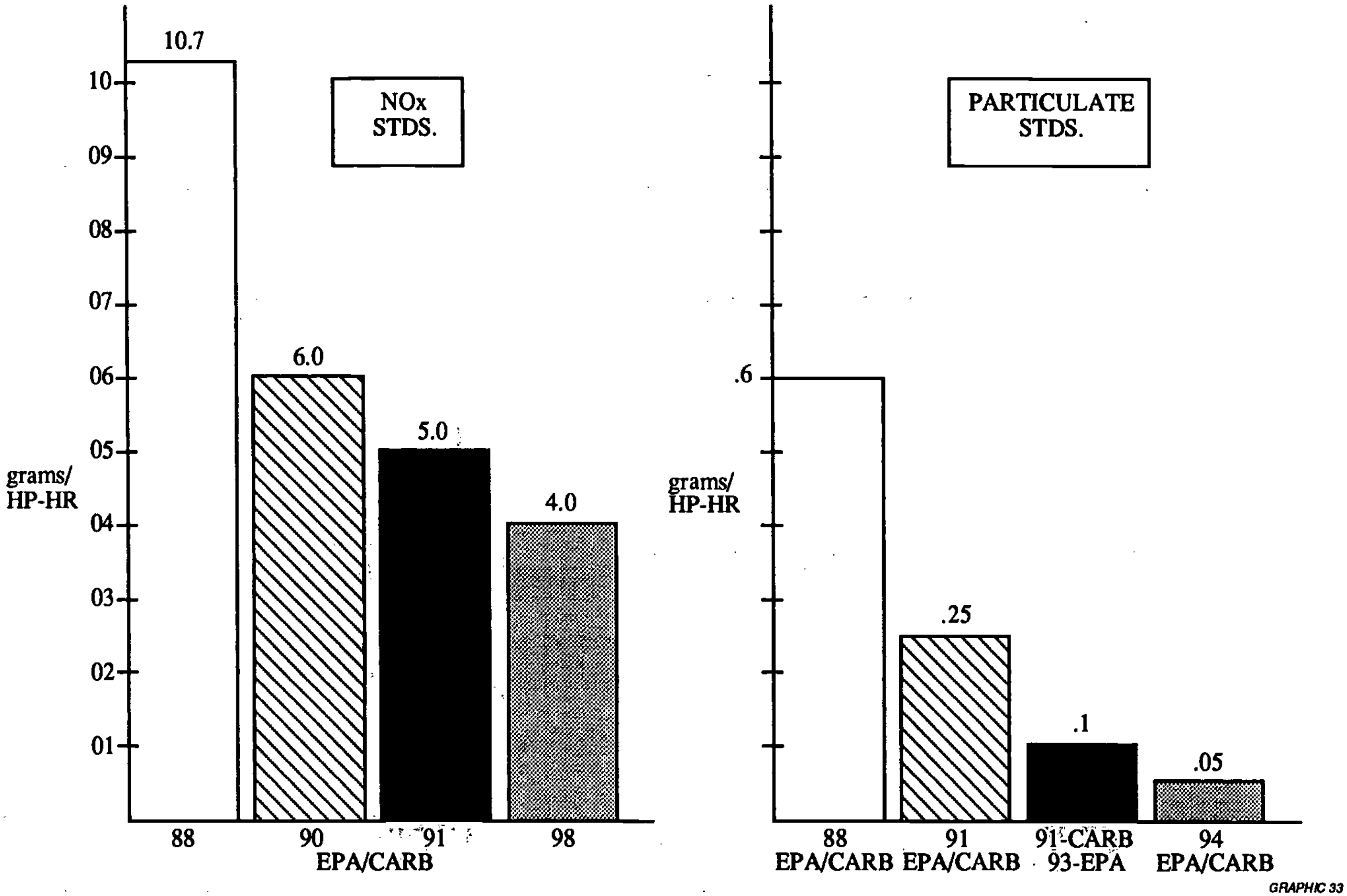
INTRODUCTION AND BACKGROUND

WORKING AS PARTNERS, THE RTD AND LACTC ARE EXPANDING AND DIVERSIFYING THE PUBLIC TRANSIT SYSTEM IN SOUTHERN CALIFORNIA

Light Rail:	**Blue Line open July 1990; major expansions planned**
Heavy Rail:	**Red Line opens 1993; major expansions planned**
Commuter Rail:	**Numerous lines opening over next 5 years**
Alternative Fuel Coaches:	**Largest fleet in U.S.; major expansions planned**
Electric Trolley Coaches:	***THE ISSUE AT HAND TODAY***

THE FOCUS OF THESE EFFORTS IS INCREASED RIDERSHIP, IMPROVED SERVICE, AND A REDUCTION IN TRANSIT-GENERATED AIR POLLUTION

BUS EMISSION STANDARDS



Source: ***EPA Standards – U.S. Clean Air Act of 1990; Transit Bus Emissions***
CARB Standards – Title 13, Chapter 3, California Code of Regulations

TRANSIT BUS EMISSION STANDARDS ARE GROWING INCREASINGLY STRINGENT - - - AND DIFFICULT TO MEET WITH CONVENTIONAL DIESEL BUS TECHNOLOGY

	Environmental Protection Agency (EPA)		California Air Resources Board (CARB)	
	NOx	PM	NOx	PM
1988	10.7	.6	10.7	.6
1990	6.0	.6	6.0	.6
1991	5.0	.25	5.0	.1
1993	5.0	.10	5.0	.1 *
1994	5.0	.05(1)	5.0	.05(1)
1998	4.0	.05	4.0	.05

* CARB is scheduled to establish new standards for heavy duty vehicles in 1992

(1) EPA has the authority to relax this standard to .07 if .05 is determined to be infeasible for in-service vehicles.

NOTES/ASSUMPTIONS

1) Personal communications with Dr. Vinod Duggal (Cummins) and Mr. Stan Miller (DDC)

2) Operating experience as described by SCRTD alternative fuels section staff, and by other properties operating partculate trap coaches

3) Diesel transit engines equipped with traps have demonstrated particulate emissions as low as 0.05 grams per HP-HR and NOx emissions in the 4.0 to 5.0 grams per HP-HR range on new engines. The majority of industry experts interviewed for this study stated that the 1998 EPA standards of 4.0 g/HP-HR NOx and 0.05 g/HP-HR particulates would be extremely difficult to meet at the 290,000 mile in-service test point required for EPA certification (See Task Report #3, Low Emission Transit Alternatives, for more information on particulate traps).

4) Booz·Allen interviews with the California Air Resources Board suggest that on-road heavy duty vehicle NOx standard to be established in 1992 and take effect sometime in the last half of this decade will be below 4.0 grams per HP-HR - - - at least for vehicles operating in fleets that are centrally fueled and traveling within a city's consolidated metropolitan statistical area.

THESE REGULATIONS WILL LIKELY MANDATE THE USE OF ALTERNATIVE FUELS - - - AND/OR ELECTRIC TROLLEY BUSES

- **Diesel buses cannot meet 1991 California Air Resource Board standards unless equipped with a particulate trap**
  - **California certified particulate trap buses will not be available until late 1992**[1]
  - **Reliability of particulate trap buses has been poor but is improving**[2]
- **Even with a particulate trap, diesel fueled buses are not anticipated to be able to meet federal regulations for 1998 and beyond**[3]
- **It is possible - - - and in fact probable - - - that California Heavy Duty Regulations to be established in 1992/1993 (and to take effect in the 1996 to 1998 timeframe) will pre-empt Federal Standards and thus prohibit the sale of Diesel Buses**[4]

THIS DECADE WILL LIKELY SEE THE END OF THE DIESEL POWERED BUS ERA - - - PARTICULARLY IN CALIFORNIA.

RTD IS AGGRESSIVELY MOVING TOWARD IMPLEMENTATION OF ALTERNATIVELY FUELED MOTOR COACHES - - - BUT AT A SUBSTANTIAL INCREASE IN COST COMPARED TO TODAY'S DIESEL OPERATIONS

- Capital Costs
  - Vehicles – $20,000 to $50,000 premium per bus
  - Fuel Facilities – Up to $2,000,000 conversion cost per facility, depending on fuel type
  - Maintenance Facilities – Up to $200,000 per facility for safety related improvements, depending on facility conditions

- Operating Costs
  - Fuel Costs – Up to 100 percent increase over diesel buses – depending on fuel type
  - Maintenance Costs – 10 to 20 percent increase over diesel buses
  - Spares Ratio – potentially higher than diesel fleet

Note: ***See "Alternative Technology Analyses" section for details on capital and operating cost data***

DURABILITY AND RELIABILITY OF ALTERNATIVELY FUELED COACHES IS IMPROVING, BUT STILL FALLS SHORT OF A CONVENTIONAL DIESEL FLEET.

FROM THE 1991 SOUTH COAST AQMP, APPENDIX G. (CM #90-M-G-1)

SUMMARY

Source Category: Urban Bus

Control Methods: Electrification of Transit Buses Using Conventional Technology

Emissions (Tons/Day)	**Year 1987**	**Year 2000**	**Year 2010**
Annual Average			
ROG Inventory	1.7	1.9	2.3
ROG Reduction	—	0.6	0.7
ROG Remaining	—	1.3	1.6
NOx Inventory	12.8	9.5	10.4
NOx Reduction	—	2.9	3.1
NOx Remaining	—	6.6	7.3
CO Inventory	6.3	9.3	11.2
CO Reduction	—	2.8	3.4
CO Remaining	—	6.5	7.8
PM10 Inventory	1.6	1.3	1.1
PM10 Reduction	—	0.4	0.3
PM 10 Remaining	—	0.9	0.8

Control Cost: $30,000/Ton of ROG, NOx, CO, and PM10

Implementing Agency: District

Other Impacts: Increased Demand for Electricity, Reduced Noise Pollution

THE SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT HAS INCLUDED IN THEIR DRAFT 1991 AIR QUALITY MANAGEMENT PLAN PROVISIONS FOR CONVERTING MOTOR BUS ROUTES OPERATING IN THE SOUTH COAST AIR BASIN TO ELECTRIC TROLLEY BUS OPERATION

From the 1991 South Coast AQMP, Appendix G; pertaining to Control Measure #90M-G-1 "Urban Bus System Electrification"

PROPOSED METHOD OF CONTROL

The proposed method of control is to install overhead trolley wires for power transmission to transit buses operating along major fixed routes. Services that run continuously along major arterials at intervals of 15 minutes or less would be candidates for conversion from diesel operation directly to electric operation. In 1988 the LACTC estimated the number of trolley coaches required to operate on headways of 15 minutes or less in Los Angeles County as follows: District – 1044; Culvert City – 7; Long Beach – 30; Los Angeles – 23; Santa Monica – 75. The corresponding route-miles to be electrified are: SCRTD – 740; Culvert City – 10.7; Long Beach – 7.5; Los Angeles – 4.3; Santa Monica – 85. These figures may increase in the 1994 AQMP revision pending results from the LACTC/RTD study.

Transit operators would acquire the electric buses and operate them along these lines. Routes that run infrequently, or on very circuitous routes would not be electrified but would convert to clean fuels.

EMISSIONS REDUCTION

The emission impact from this control measure would be equivalent to reducing the emission levels from 30 percent of the bus transit fleet (30 percent of about 3,000 buses) to near zero levels. Electrified buses would be those that operate on 15-minute headways or less. This emission reduction assumes that the additional power required would be generated from in-Basin, non-polluting sources, or imported from out-of-Basin. Replacement of heavy-duty diesel buses by electric buses would reduce ROG, CO, NOx, and PM10 levels from this source to virtually zero. The associated emissions inventory and reductions are listed in the summary table.

THE AQMP CONTROL MEASURE CALLS FOR COMPLETION OF THE ELECTRIC TROLLEY BUS CONVERSION BY YEAR 2000 AND APPLIES TO SCRTD AND THE MUNI'S OPERATING WITHIN AIR BASIN BOUNDARIES.

AS DEMONSTRATED BY OPERATIONS IN OTHER CITIES, TROLLEY BUSES CAN OFFER SEVERAL ADVANTAGES TO THE COMMUNITY, BUS RIDERS AND RTD IN MEETING THEIR SERVICE OBJECTIVES

COMMUNITY BENEFITS	RTD BENEFITS
• LOW POLLUTING	• REDUCED VEHICLE MAINTENANCE
• MORE ENERGY EFFICIENT (CONSERVES NATURAL RESOURCES)	• LONGER VEHICLE LIFE
• LESS NOISE	• REDUCED ENVIRONMENTAL CONCERNS WITH NEW FACILITY EXPANSION PLANS
• SMOOTHER RIDE	• A PROVEN TECHNOLOGY

GRAPHIC 2

BECAUSE OF THESE BENEFITS, EVIDENCE FROM OTHER CITIES INDICATES THAT TROLLEY BUS LINES MAY ATTRACT <u>NEW</u> RIDERS

A MIXED FLEET OF BOTH ELECTRIC TROLLEYS AND ALTERNATIVELY FUELED MOTOR COACHES CAN BE PART OF AN INTEGRATED SOLUTION TO SOUTHERN CALIFORNIA'S PUBLIC TRANSIT SYSTEM NEEDS

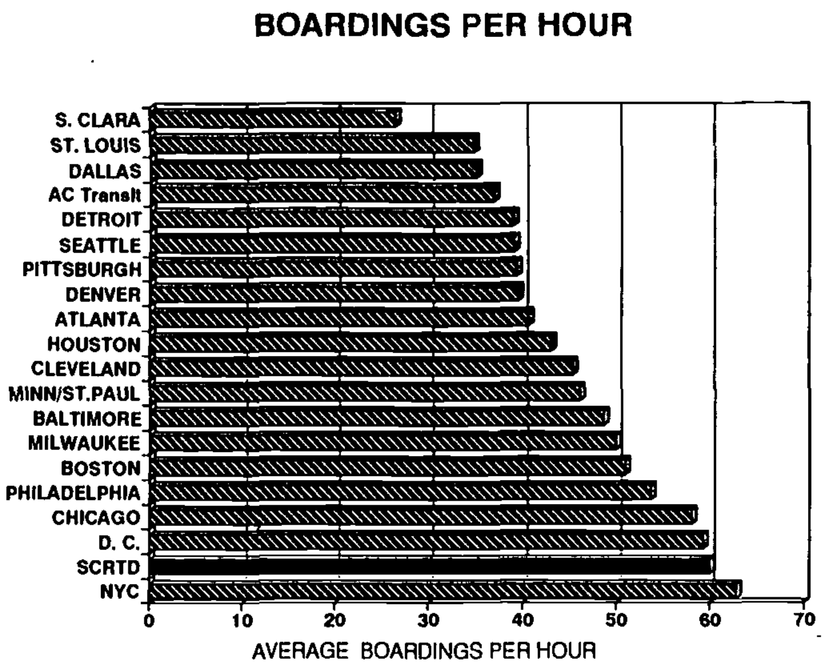
TROLLEY BUS TARGET ROUTES

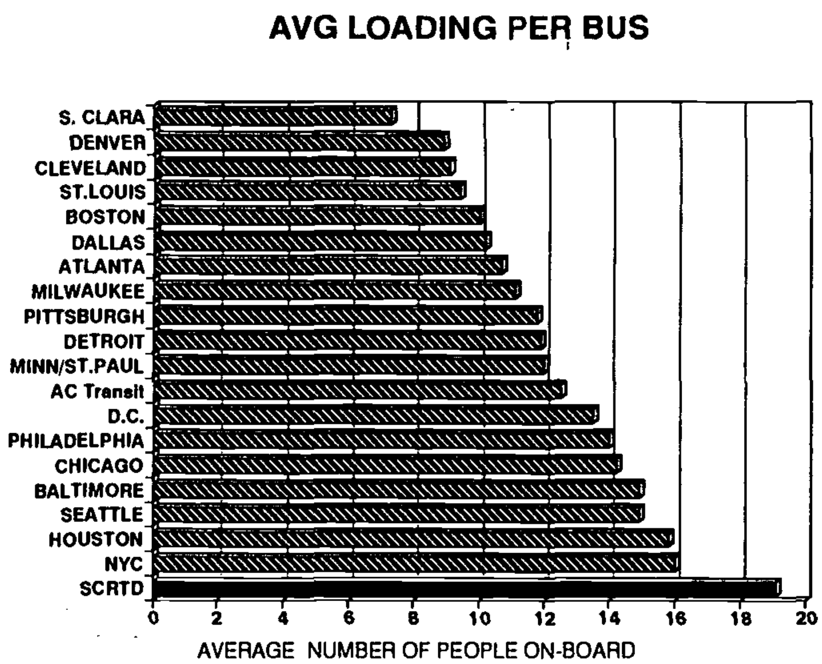
- Capital costs associated with establishing the overhead wire system suggests that trolley buses will be most cost effective on heavily travelled routes - - - where utilization of the overhead wire system is high
- Along routes where reduced noise and smoke levels are highly valued
- On routes where the community is anxious to compliment RTD's efforts to improve the streetscape and mitigate overhead wire visibility

MOTOR BUS TARGET ROUTES

- Routes with low to intermediate service levels
- High speed routes that include freeway operation
- "Complex" routes with numerous branch lines and interlining (thus increasing the costs of converting the route to trolley operation)
- Routes where overhead wire installation is difficult or visual intrusion of the wire is considered unacceptable by local community

RTD'S BUS SYSTEM IS ONE OF THE MOST HEAVILY USED IN THE NATION - - - SUGGESTING THAT SEVERAL ROUTES COULD BE GOOD CANDIDATES FOR TROLLEY BUS CONVERSION - - -





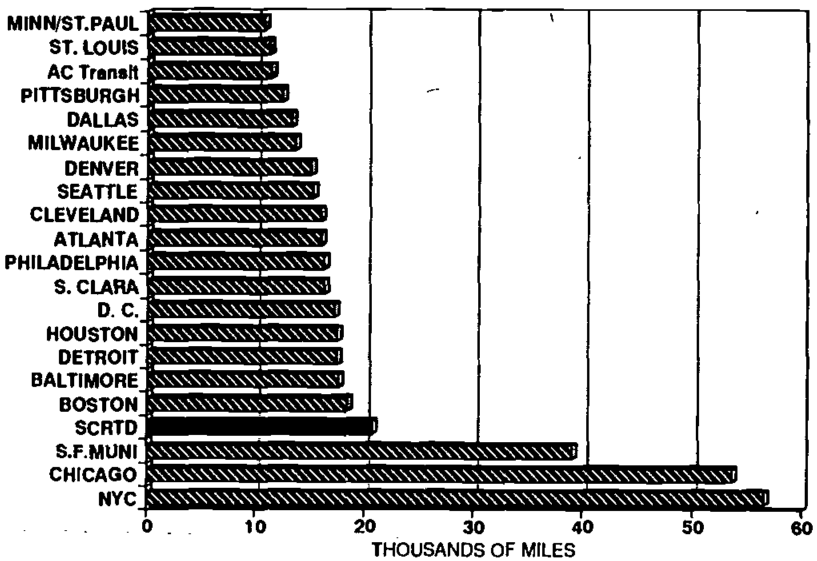
Source: APTA 1990 Transit Operating and Financial Statistics

Property	Total Directional Route Miles	PM Peak Vehicles	Total Annual Vehicle Miles
RTD	4,897	1,826	101,106,656
NYC	1,839	2,858	104,039,383
WMMATA (Wash. D.C.)	2,844	1,331	49,008,256
CTA (Chicago)	1,386	1,786	74,285,314
SEPTA (Philadelphia)	2,552	1,058	41,436,924
MBTA (Boston)	1,422	693	26,179,923
Milwaukee	1,374	415	18,648,964
Baltimore	1,387	654	24,443,443
MTC (Minneapolis/St. Paul)	2,548	821	27,614,653
Cleveland	1,450	572	23,018,510
Houston	1,992	690	34,793,684
MARTA (Atlanta)	1,826	565	26,424,141
Denver	1,754	565	26,424,141
PAT	2,483	664	30,871,506
METRO (Seattle)	2,085	832	31,781,185
AC Transit	2,187	604	24,991,662
Dart (Dallas)	1,511	509	19,981,872
Bi-State (St. Louis)	2,163	553	24,474,783
Santa Clara	1,396	417	22,742,640
S.F. MUNI	573	634	22,328,177

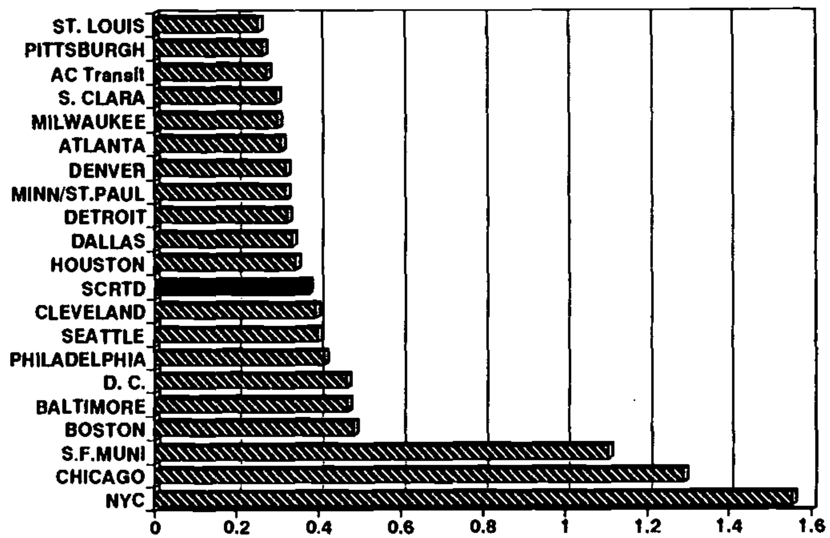
Source: APTA 1990 Transit Operating and Financial Statistics

- - - ON THE DOWNSIDE, MANY OF RTD'S ROUTES ARE COMPARATIVELY LONG, THUS INCREASING THE INITIAL CONVERSION COSTS

VEHICLE MILES PER ROUTE MILE



PEAK VEHICLES/ DIRECTIONAL ROUTE MILE



Source: APTA 1990 Transit Operating and Financial Statistics

WHILE TROLLEY BUSES CAN OFFER SEVERAL ADVANTAGES, FACTORS THAT MUST BE ADDRESSED AS THE PROGRAM PROCEEDS INCLUDE:

- **Overhead Wire Maintenance**
- **Off-wire Maneuverability**
- **Visual Impact of Overhead Catenary and Community Acceptance**
- **Safety Issues Associated With Overhead Wire And Power Distribution System**
- **Integration Into Existing Motor Coach Fleet (Maintenance, Operations, and Facilities)**
- **Other implementation issues including feasibility and costs of mixed diesel/trolley operating divisions; use of articulated coaches on RTD's routes; increased spares requirements due to reduced homogeneity of fleet; and increased driver and mechanic training.**

STUDY METHODOLOGY

THE INFORMATION AND DATA USED IN COMPILING THIS REPORT WERE ACQUIRED FROM SEVERAL SOURCES

- Previous trolley bus studies at San Francisco, Dayton, Seattle, and Vancouver
- UMTA and APTA trolley bus vs. diesel comparative studies
- Section 15 data from properties operating trolley coaches
- Extensive personal interviews with maintenance, operations, and scheduling personnel at transit properties in North America operating trolley coaches; survey data from these same properties
- RTD alternative fuel studies/reports
- Interviews with RTD maintenance, operations, facilities, and scheduling personnel
- Prior Booz·Allen trolley vehicle technology and maintenance studies at San Francisco MUNI
- Interviews with overhead wire equipment suppliers, bus builders, engine manufacturers, and electric propulsion equipment suppliers
- Power generation and emission factor data supplied by local utility companies
- Data and interviews with regulatory agencies
- Data and interviews from various city and county public works departments

A BIBLIOGRAPHY OF THE MAJOR REFERENCES USED IN THIS STUDY IS LISTED AT THE END OF THE REPORT.

KEY PERSONNEL AT TRANSIT PROPERTIES OPERATING TROLLEYS WERE INTERVIEWED

NAME	DEPARTMENT/TITLE	ORGANIZATION
ROBERT HIGHFILL	EQUIPMENT/ENGINEERING	MUNI
CARL NATVIG	OPERATIONS PLANNING	MUNI
PETER STRAUSS	TRANSPORTATION DEPT.	MUNI
MIKE VORIS	EQUIPMENT/ENGINEERING	SEATTLE METRO
MIKE BERGMAN	SERVICE DEVELOPMENT	SEATTLE METRO
EDDIE TATE	CONSTRUCTION MANAGEMENT	SEATTLE METRO
BRIAN KELLY	MANAGER – OAKRIDGE TRANSIT CENTRE	BC TRANSIT
JOHN MILLS	OPERATIONS/PLANNING	BC TRANSIT
JOE FERETTI	EQUIPMENT/ENGINEERING	BOSTON MBTA
FOREST SWIFT	EXECUTIVE DIRECTOR	DAYTON
DHRIEN CHAKROBORTY	EQUIPMENT MAINTENANCE	SEPTA
R.W. DUNCAN	EQUIPMENT/ENGINEERING	HAMILTON STREET RAILWAY
DOUG KENNEDY	MAINTENANCE MANAGER	TORONTO TRANSIT
OVI CALIVENCHENZO	ENGINEERING	ONTARIO MINISTRY OF TRANSPORT
JEFF TURNER	ADVANCED TECHNOLOGY	ONTARIO MINISTRY OF TRANSPORT
GLENN ANDERSON	MAINTENANCE/ENGINEERING (RETIRED)	CHICAGO

GRAPHIC 55

EQUIPMENT AND FUEL SUPPLIERS ALSO SUPPLIED DATA FOR THE STUDY AND WERE INTERVIEWED REGARDING FUTURE PRODUCT PERFORMANCE, COST, RELIABILITY, AVAILABILITY, AND A RANGE OF OTHER ISSUES

Coach Manufacturers

Flyer: Bob Bevis – Engineering/Sales VP
Flexible: Ed Kravitz – President
TMC: Dave Mikoryak and Scott Mentler – VP Engineering/Sales

Engine Manufacturers

DDC: Stan Miller – Manager Alternative Fuels
Doug Grahm – Director Applications Engineering
Jim Bennethum – Director, Advanced Engineering

Cummins: Carl Koontz – Service Director
Clark Ahrens – Director, Bus Business
Dr. Vinod Duggal – Chief Engineer Alternative Fuels
Gary Farrell – Marketing Manager

Fuel Suppliers

Chevron Research: Geal Eberhard – Sr. Research Engineer
Sun Oil Company: Brian Davis – Fuels Product Manager
Celenese Corp: Raymond Colledge – Mkt. Program Manager
Methanol Producers Assoc.: Ray Lewis – Executive Director
Socal Gas: Henry Mack – NG Vehicle Marketing
SCE: Bill West – Sr. Environment Specialist
SCE: Arthur Canning – Sr. Planning Engineering
LADWP: Ben Wong – R&D Engineering – Systems Development
LADWP: Fred Herrera – Account Executive

SEVERAL OTHER AGENCIES SUPPLIED SUPPORTING DATA AND INFORMATION

Overhead Wire Equipment Suppliers

- Ohio Brass
- K&M
- Unitrac Systems
- Electrack

Regulatory Agencies; City Public Works Depts; others

- L.A. DOT: Traffic Signal Equipment and Maintenance Dept.
- L.A. DPW: Bureau of Street Lighting
- L.A. Fire Dept: Battalion Chief and other
- Southwest Research Institute
- South Coast Air Quality Management District
- California Air Resources Board
- California Energy Commission
- Environmental Protection Agency
- U.S. Dept. of Energy
- Pacific Gas & Electric
- UMTA: Steve Barsony, Vince Demarca
- APTA: Frank Cihok, Mike Melache

SUMMARY CONCLUSIONS

TROLLEY BUSES ARE A REASONABLE AND PROVEN TECHNOLOGY FOR REDUCING EMISSIONS WELL BELOW EMERGING CLEAN FUEL TECHNOLOGIES (METHANOL, NATURAL GAS, DIESEL PARTICULATE TRAPS)

- Trolley coaches will reduce in-basin emissions by 98% compared to diesel operation - - - methanol coaches will reduce emissions by about 65% compared to diesel.
- Operating costs for a trolley system are estimated to be equal to or below new clean fuel technologies.
- Capital costs for establishing the overhead wire and power distribution system are estimated between $1.5 and $2.0 million per mile of a 2-way track including engineering, construction, and contingencies.
- Trolley buses can be operated out of existing divisions (alongside motor coaches) but at increased costs and reduced efficiency compared with dedicated trolley and/or motor coach divisions.
- Articulated coaches offer the potential for dramatic reductions in operating costs on selected routes - - - but will require substantial commitment and effort to integrate into the existing fleet (facility modifications, bus stops, maintenance, scheduling, training).
- Integration of trolley coaches into the fleet will reduce the interchangeability of vehicles to service a variety of routes - - - interlining bus savings will be reduced on some routes - - - and total fleet spares ratio will increase (if/when the trolley system is expanded, a portion of the interlining savings could be regained).
- An eleven route system has been identified for a Phase I trolley bus program. The routes selected are among the most heavily used in RTD's system and cover a wide geographic region. Implementation of a Phase I system will require a staggered approach due to the practical limitations of engineering, design, and construction resources. Three sets or "packages" of routes (each containing 2 to 4 routes) can be implemented over an 8 year timeframe. The first "package" of routes could begin service within 48 months on a very aggressive basis. Two to three lines are recommended for initial conversion - - - permitting RTD to gain a solid technology, operations, and implementation experience base.

- **The partial conversion of an existing "downtown" diesel bus division to a "mixed-use" division for maintaining and operating trolleys is recommended for the first two to three line conversion package. As additional routes are converted, this division could then be reconfigured exclusively to trolley bus operation.**
- **Because of anticipated fleet growth (for the motor and trolley coach), and because of the cost and efficiency advantages of operating single technology bus divisions, an additional CBD operating division should be considered for maintaining and housing either new alternative fuel or trolley coaches. Such a decision will hinge on projected fleet growth, relative environmental difficulties of establishing a motor bus vs. electric bus divisions, and the specific routes to be converted to trolley coach.**
- **Benefits of Articulated coaches decline with reductions in service frequency and patronage. For the final "package" of lines in the 11 route system to be converted, use of 40 ft. coaches should be considered.**
- **A review of operations in other cities indicates that trolley's economic and operational success and/or failure will be critically linked to proper implementation and planning. Lessons learned from other cities include:**
  - **Establish an economically sized system: small systems tend to be technology "orphans" and thus incur high operating costs (i.e., Dayton, Toronto, Boston); system that are too small to support operations out of a single dedicated trolley division are discouraged.**
  - **Proper design of overhead wire systems and use of latest components is critically important for reducing roadcalls due to de-wirements. San Francisco's newest trolley routes report considerably lower roadcalls than older routes. Implementation of gradual turning radii, radio controlled switching devices, proper pole placement and support hardware to maintain wire tension, use of long (10 inch) contact shoes, and new fiberglass pole designs can all help reduce de-wirements well below levels traditionally reported by trolley operators. Minimization of "special work" and the number of turns at intersections through careful route design will also help reduce de-wirements.**

- Proper maintenance of the overhead contact system is also important in reducing de-wirements as well as excessive contact shoe wear. Proper tensioning of wires and replacement/repair of special work and switches at intersections will help increase vehicle availability and reduce roadcalls. Los Angeles' favorable climatic conditions (little rain, mild temperature, and lack of freezing) will help reduce maintenance requirements.

- Driver training is considerably more important than for motor coaches. MUNI officials and managers at other properties estimate that at least one-half of the de-wirements are in large part due to driver errors. Turns that are made too wide, excessive speed, and/or trying to maneuver around stopped vehicles (instead of waiting) are among some of the causes of de-wirements. Also, because the vehicle turning signal initiates the switching devices at intersections forgetting to use the turn signal can also cause de-wirements.

- The use of a battery powered auxiliary propulsion unit (APU) will reduce the negative consequences (costs, schedule delay, roadcalls) of de-wirements. Vancouver is currently operating trolleys equipped with a moderately sized APU. When a de-wirement does occur, the driver can activate the APU to position the bus to get back "on-line" without the need for a maintenance truck to be dispatched to push the trolley back onto the wire. The APU can also be used to maneuver around obstacles.

• Conversion of the proposed Phase I system (11 routes) would reduce emissions in the South Coast Basin by approximately 750 tons annually.

• Commercialization of other non-polluting technologies (such as battery, fuel cell, or roadway powered buses) is highly speculative and would require major technological breakthroughs.

- **The electric power requirements for trolley operations can be easily met by SCE and DWP—new power generating facilities are not required.**

- **New propulsion technologies being offered by vehicle manufacturers (such as AC drive motors and reliable on-board auxiliary power units) promise to make an already reliable technology even more cost effective and versatile than ever before.**

- **Bus riders prefer trolley coaches over motor coaches—RTD's public awareness program as well as experience in other cities indicates that ridership and customer satisfaction will improve with the introduction of trolley coaches.**

- **The initial Phase I system will cost approximately $600 million to implement, cover 150 route-miles, require the construction and/or conversion of two to three operating divisions, and carry about 260,000 people daily.**

RTD'S EXTREMELY HIGH SYSTEM PATRONAGE, FAVORABLE CLIMATIC CONDITIONS ALONG WITH NEW VEHICLE AND OVERHEAD WIRE TECHNOLOGY, ALL COMBINE TO MAKE TROLLEYS A VIABLE OPTION FOR MEETING FUTURE PUBLIC TRANSPORTATION NEEDS IN THE SOUTH COAST BASIN.

OVERVIEW OF TROLLEY BUS SYSTEMS

A TROLLEY BUS IS AN ELECTRICALLY PROPELLED VEHICLE THAT RECEIVES POWER FROM A PAIR OF OVERHEAD WIRES STRUNG ALONG THE BUS ROUTE

- **Unlike light rail vehicles which require only one power wire overhead (and can be "grounded" through the steel wheel/rail interface), a rubber-tire trolley bus requires a pair of overhead wires - - - one for power and one for ground. The wires are located between 19 ft. and 20 ft. above the road with a 2 ft. separation between the (+) and (-) wires.**

- **A pair of contact poles on the roof of the bus transmit power from the overhead wires to the bus propulsion system. The ends of the poles are fitted with grooved carbon shoes on swivel mounts to provide a highly conductive, low friction contact surface. A spring at the base of the pole presses the shoe to the wire so that it remains in contact with the underside of the wire as the bus moves forward.**

- **Although it must follow the wire, the trolley bus can deviate about 15 ft. from the centerline of the wire for curbside passenger stops or to bypass parked vehicles or other obstacles.**

TROLLEY BUS OVERVIEW - - - CONTINUED

- **Trolley buses operate at essentially the same voltage as light rail vehicles - - - 600 to 750 volts direct current (DC)**

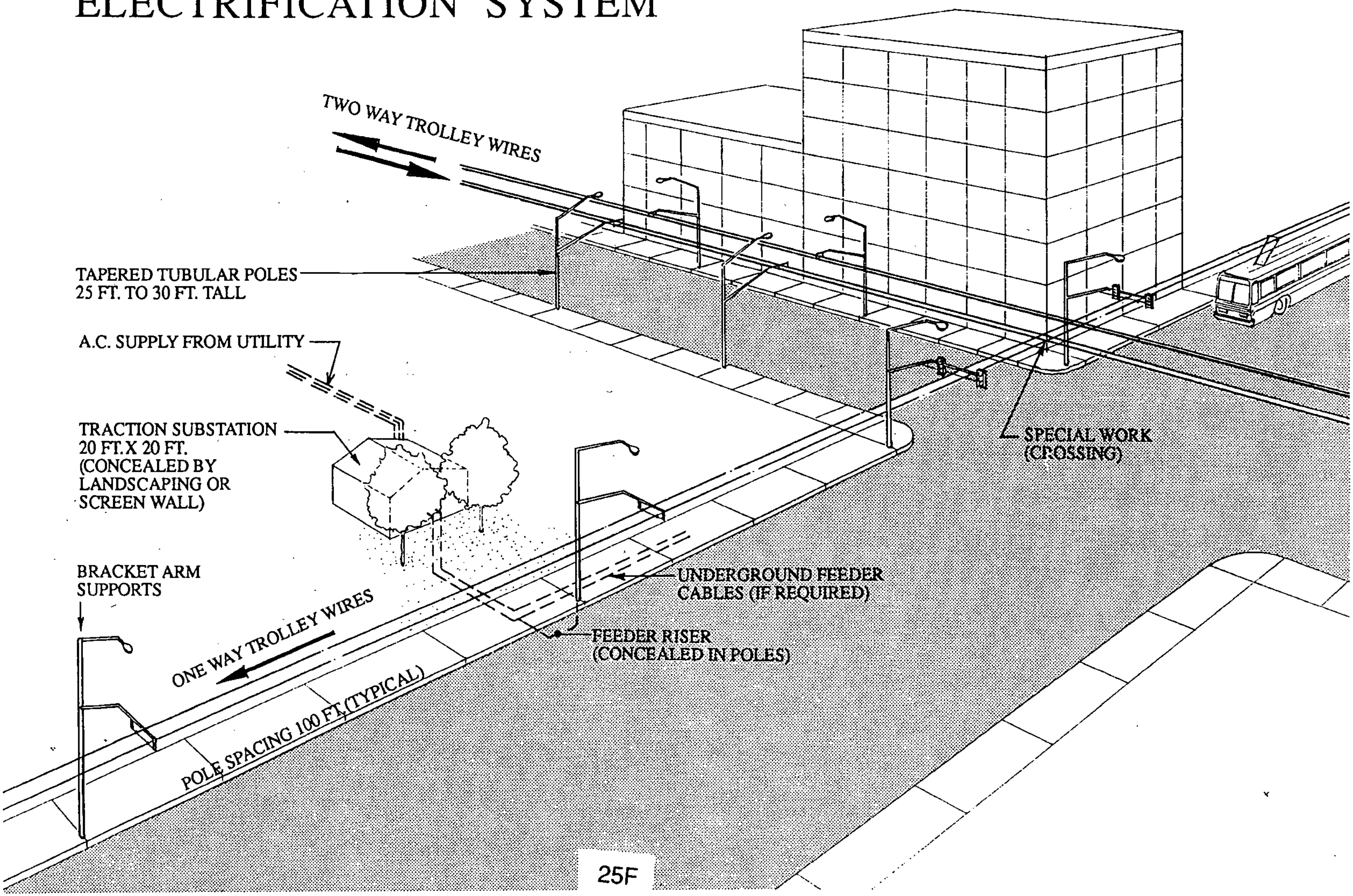
- **Trolley buses have traditionally been equipped with a single DC motor affixed to the rear drive axle.**

- **Trolley buses can be configured as either standard 40 ft. or 60 ft. articulated coaches.**

- **Trolley buses can be equipped with auxiliary power units (APUs) which permit limited off-wire maneuvering of the coach. They are used to propel the coach around temporary street blockages (accidents, etc.) as well as in the operating division (to avoid construction of complex overhead wiring of the maintenance facility) and they can be used at the end of a route to facilitate turnarounds without added street wiring.**

- **Because trolley buses have no engine, transmission, cooling system, or exhaust system to maintain, required maintenance on a trolley coach is considerably less than for a motor coach - - - and reliability is improved.**

ELEMENTS OF TROLLEY BUS ELECTRIFICATION SYSTEM



TROLLEY BUS OVERVIEW - - - CONTINUED

- **Power is supplied to the overhead wires via substations located at intervals of approximately one mile. The substations convert the high voltage AC power supplied by the utility companies to relatively low voltage (750) VDC power required by the trolley coach propulsion system. This is similar to light rail power system designs.**

- **Substations measure about 25 ft x 35 ft x 8 ft and can be located in a corner of parking lots, inside buildings, or at other convenient locations along the bus route. They are generally concealed by landscaping or by a screened fence.**

- **Trolley wire is supported above the roadway by strengthened utility poles that can also be used for streetlighting and/or traffic signal support. Such joint-use poles minimize the number of additional street poles needed along the route and thus enhance the visual integration of the system into the streetscape. However, as is the case with the Blue Line, dedicated single use poles can also be used to support the overhead wire.**

- **Electricity is fed from the substations to the overhead wire by power cables that are routed up through the center of support poles located near the substations. If service levels on the route are high enough, then "feeder" cables are needed to deliver power to points on the line in between substations. These feeder cables are somewhat larger/higher power cables than the trolley overhead wire. The feeder cables can either be routed above ground in parallel with the trolley wires or can be undergrounded to improve the visual appearance of the system.**

TROLLEY BUSES CURRENTLY OPERATE IN SEVERAL NORTH AMERICAN CITIES

	San Francisco		Seattle			Philadelphia	Vancouver	Dayton	Boston	Toronto	Hamilton
	STD	Artic	STD	Artic	Dual mode Artic	STD	STD	STD	STD	STD	STD
Manufacturer	Flyer	Flyer	AMG	MAN	Breda	AMG	Flyer	Flyer	Flyer	Flyer	Flyer
Year Built	1976	1992	1979	1987	1990	1979	1982/83	1977	1976	68/72	1972
Quantity	346	60	109	47	236	110	244	48	41	118	45
Propulsion Mfg.	G.E.	G.E.	Rand-tronics	Siemens	Westing-house	Rand-tronics	Westing-house	G.E.	G.E.	G.E.	G.E.
Propulsion Type	CAM Control	AC Invertor	DC Chopper	DC Chopper	AC Invertor	DC Chopper	DC Chopper	CAM Control	CAM Control	CAM Control	CAM Control
Auxiliary Power	NONE	Battery (2500 lbs)	NONE	NONE	6V-92 Diesel	NONE	Battery (1000 lbs)	NONE	NONE	NONE	50 HP I.C. Engine
Air Conditioning	NO	NO	NO	NO	NO	YES	NO	YES	NO	NO	NO
Total Weight	22,580	44,000	23,600	40,400	47,000	25,600	25,900	22,580	23,000	19,840	20,000

Source: 1990 APTA Fleet Statistics Directory; Interviews with maintenance managers at Transit properties; BAH analysis

TROLLEY BUSES CURRENTLY OPERATE IN SEVERAL NORTH AMERICAN CITIES

- Trolley buses were operated in many other cities from the late 1920s into the 1950s - - including Los Angeles. Trolleys were preferred over the less reliable and higher cost gasoline powered vehicles of the day

- The advent of larger, more powerful diesel engines - - - and low diesel fuel prices in the 1950s saw a dramatic decline of trolley bus operation. By the early 60s trolleys were replaced by diesel in most North American cities

- Currently, only 10 cities in North America operate trolley coaches and include San Francisco, Seattle, Vancouver, Philadelphia, Boston, Toronto, Hamilton, Edmonton, Mexico City, and Dayton. These cities have retained trolley buses for a variety of reasons including inexpensive electricity, hilly terrain, high density routes, and/or public demand that such systems be retained

- Because of concerns over pollution, fuel prices, vehicle reliability, and the increased costs associated with the emerging alternative fuels, several other cities have expressed both formal and informal interest in re-evaluating the appropriateness of trolley bus technology - - - such cities include Dayton, Sacramento, Dallas, Orange County and several others - - -

LOS ANGELES IS LEADING THE WAY IN THIS RENEWED INTEREST IN TROLLEY BUSES.

TROLLEY BUS COACHES IN EUROPEAN CITIES...

Location	Number of Artics	Manufacturer[a]	Date Purchased	Fleet Size: Trolleys/ Other Coaches
Western Europe and North America				
Basle (Switzerland)	20	FBW		28/56
Bergen (Norway)	3	M.A.N.	1985	17/152
Berne (Switzerland)	41	FBW/Hess		41/96
Essen (Germany)	18	Mercedes	1985	
Esslingen (Germany)	1	M.A.N.[b]		
Geneva (Switzerland)	63	Saurer/Hess (24)	1982-1983	74/178
Ghent (Belgium)		Van Hool	1984	
Grenoble (France)	6	Renault PER 180	1983	56/229
Linz (Austria)	21	M.A.N.	1984 (12)	31/72
Milan (Italy)	103	Viberto/Fiat (94)	1964 (54), 1983	174/1,604
Nancy (France)	48	Renault PER 180	1982-1983	48/136
Oporto (Portugal)	10	Caetano	1983	126/484
Saint Etienne (France)	6	Renault PER 180	1983	58/126
Salzburg (Austria)	52	Graf & Stift (12)	1981	58/48
Seattle (U.S.A.)	46	M.A.N.	1985	155/995
Solingen (Germany)	21	M.A.N.	1984	71/
Winterthur (Switzerland)	31	FBW/Hess	1982-1983 (10)	c
Zurich (Switzerland)	63	FBW	1974-1975 (31)	73/176
Eastern Europe and Asia				
Beiijing (PRC)	358	Chinese-built		528/3,183
Bucharest (Romania)	220	DAC		260/1,015
Budapest (Hungary)	78	Ikarus IK280T	d	247/1,769
Moscow (USSR)	135	Vritsky TS1		2,200/6,760
Shanghai (PRC)	850	SK561 & SK663 Chinese-built		850/3,750

a Number of vehicles in latest purchase indicated in parenthesis
b Prototype
c Trolley coaches are 70% of fleet
d Average age of vehicles - 3.5 years in 1984

GRAPHIC 34

Source: BAH Research

TROLLEY BUSES ARE ALSO OPERATED EXTENSIVELY IN MANY EUROPEAN CITIES

- **High diesel fuel prices in Europe economically favor the use of trolley coaches**
- **Trolley bus technology is generally considered more advanced in European cities**
  - **AC propulsion systems**
  - **Extensive use of Kummiler and Mottor (K&M) overhead wire technology (facilitates high speed operation; improved switching equipment; reduced wear and maintenance costs, and other improvements over existing designs used on many of the older routes in North American systems)**
  - **Automatic raising and lowering of trolley poles**
  - **Extensive use of auxiliary power units**
- **Trolley bus operations is particularly extensive in Germany, France, and Switzerland - - - Russia has by far the largest fleet of trolley buses in the world at over 2,500 units.**

BECAUSE LOS ANGELES IS STARTING WITH A "CLEAN SHEET" MANY OF THESE ADVANCES IN BOTH VEHICLE AND OVERHEAD WIRE DESIGNS CAN BE INCORPORATED INTO A NEW TROLLEY BUS SYSTEM.

TROLLEY BUS BENEFITS

FOOTNOTES

1) Analysis of Operating Alternatives for Market Street Trolley Coach Lines, Transit Planning Section, San Francisco Municipal Railway, June 1975, Appendix B

2) Seattle Transit Noise Study, Robert M. Towne & Associates, March 1974

3) Personal Communication, Dhrien Chakrobartz, SEPTA

TROLLEY BUSES ARE CONSIDERABLY LESS NOISY THAN MOTOR BUSES

- **San Francisco MUNI Study(1)**

	Diesel	Trolley	Difference
– Peak sound pressure level at curbside	85dB to 92dB	75dB to 82dB	≈ 10dB

- **Seattle Metro Study(2)**

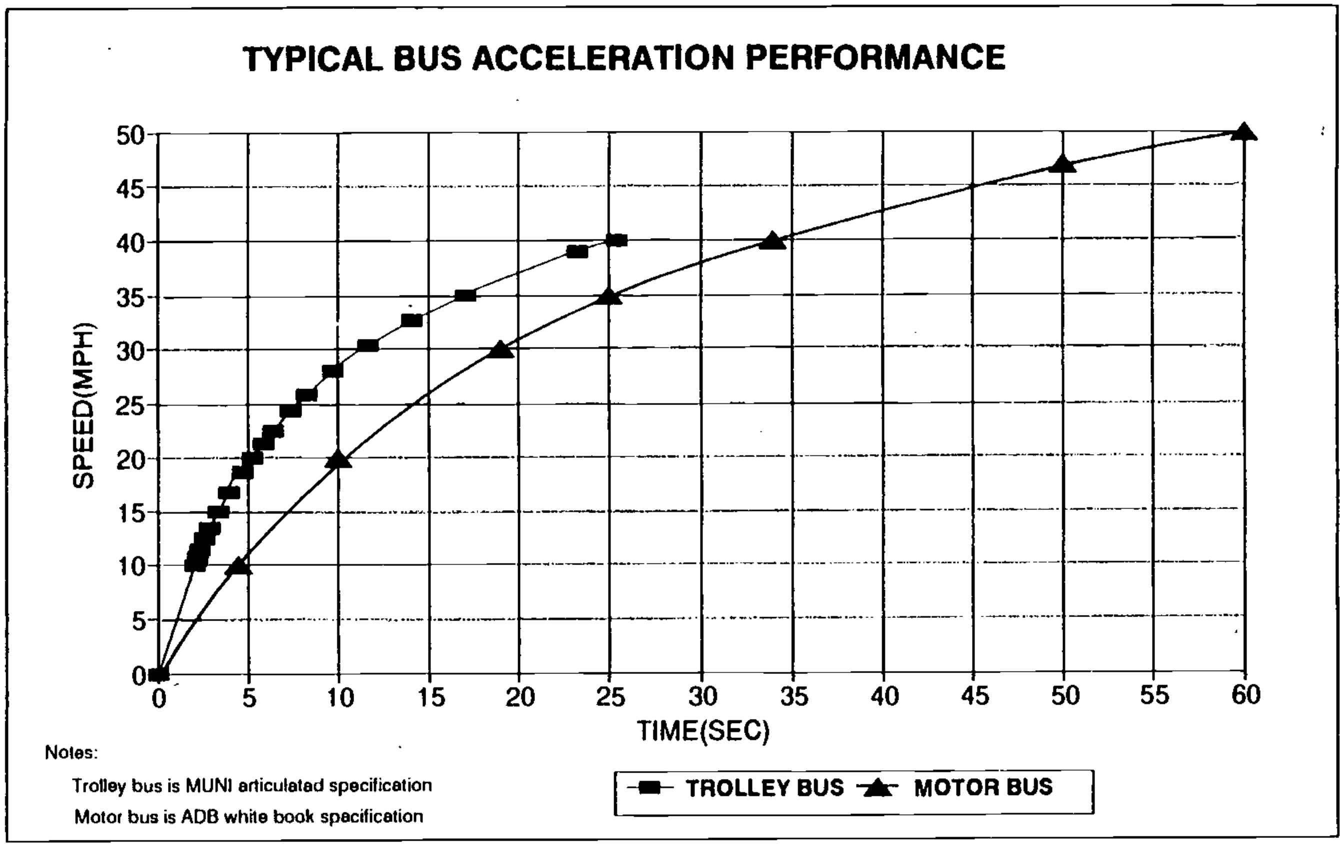
	Diesel	Trolley	
– "Average Operation"	94	74	≈ 20dB

- **Philadelphia SEPTA Study(3)**
  - **Tests showed that the sound made by trolley coaches was not discernibly louder than the ambient street noise level.**

NOTE: A TEN DECIBEL INCREASE IN SOUND PRESSURE LEVEL IS PERCEIVED BY HUMANS AS BEING TWICE AS LOUD.

Benefits of superior trolley performance will vary considerably by route. Minimum benefit will occur on routes that are heavily congested. The benefits however can be enjoyed on downtown routes. Operators in San Francisco, Seattle, Vancouver, and Philadelphia have all confirmed a slight reduction in the required number of vehicles to meet service schedules and a slight reduction in total trip time. Such benefits are reported on both hilly and non-hilly routes. Articulated trolley coaches will particularly benefit from the improved performance offered by electric propulsion systems.

SUPERIOR TROLLEY BUS PERFORMANCE MAY HELP REDUCE FLEET SIZE (AND COMMUTER TRAVEL TIME) COMPARED TO CONVENTIONAL MOTOR COACHES



SAN FRANCISCO MUNI REPORTS FLEET REDUCTIONS OF APPROXIMATELY 5 PERCENT WHEN CONVERTING A LINE FROM A DIESEL TO TROLLEY OPERATION DUE TO AN INCREASE IN AVERAGE ROUTE SPEED.

muni survey form:

TO TRANSIT PATRONS: We need to learn about your travel habits to plan improved transit service. Will you kindly give a minute or two to answer the following questions. Thank you for your help.

---

1. **Please rate the following modes of transportation. If you LIKE a particular mode of transportation, circle a HIGH number. If you DISLIKE a particular mode of transportation, circle a LOW number.**

   A. An Electric Streetcar:

   DISLIKE 1 2 3 4 5 LIKE

   B. A Diesel Motor Bus:

   DISLIKE 1 2 3 4 5 LIKE

   C. An Electric Trolley Bus:

   DISLIKE 1 2 3 4 5 LIKE

2. **Rate the following problems according to how serious you think they are. If you think a particular problem is SERIOUS, circle a LOW number. If you think a particular problem is NOT SERIOUS, circle a HIGH number.**

   A. Overhead Trolley Wire:

   SERIOUS 1 2 3 4 5 NOT SERIOUS

   B. Smoke and Fumes from Diesel Motor Buses:

   SERIOUS 1 2 3 4 5 NOT SERIOUS

3. **Would you prefer to have the ____________ line operated by:**

   A. An Electric Street Car ________

   B. A Diesel Motor Bus ________

   C. An Electric Trolley Bus ________ **(check one)**

4. **If you have any comments, please feel free to use the space below.**

Thank you, Northern California Transit Associates

PRES/RCC - 03

THERE IS STRONG EVIDENCE THAT TROLLEY BUSES ATTRACT INCREASED RIDERSHIP COMPARED TO MOTOR BUSES

- **MUNI performed a ridership survey to gauge the relative acceptance ratings of its diesel motor buses versus electric streetcars versus trolley buses. The survey form is shown on the facing page. Results of the study are shown below:**

Question #1:

Percentage of Responses by Ranking

	DISLIKE VEHICLE →			→ LIKE VEHICLE		
Vehicle	1	2	3	4	5	Average Rating
Streetcar	5.9	1.6	8.5	12.7	71.2	4.4
Diesel Bus	56.5	9.6	9.6	4.3	20.0	2.2
Trolley Bus	17.4	6.6	14.9	10.7	50.4	3.7

GRAPHIC 3.1

Question #2:

Percentage of Responses by Ranking

	SERIOUS PROBLEMS →			→ NOT A SERIOUS PROBLEM		
	1	2	3	4	5	Average Rating
Overhead Trolley Wires	24	8.3	13.2	12.4	42.1	3.4
Diesel Smoke & Fumes	76.1	3.4	6.8	3.4	10.3	1.62

GRAPHIC 3.2

Question #3: Preferred vehicle for the route:

Electric Streetcar	23%
Diesel Bus	22%
Trolley Bus	55%

***Source:* "The Environmental and Economic Feasibilities of Trolley Coach Expansions"; Carl Natvig, MUNI, July 1979, 2nd Edition, p. 18**

OTHER CITIES OPERATING TROLLEY COACHES REPORT RIDERSHIP INCREASES IN THE 10% TO 15% RANGE

- **SF MUNI**
  - #1 line converted to trolley in 1981: 18% increase between 1979 and 1982
  - #4, #3, and #55 lines also converted to trolley in 1982 with increases in patronage of approximately 10% to 15%
  - California and Jackson lines temporarily converted from trolley to diesel in 1970 with a 10% to 15% decrease in ridership

Source: "The Environmental and Economic Feasibilities of Trolley Coach Expansions"; Carl Natvig, MUNI, July 1979

- **Seattle Metro**
  - Approximate 10% increase in ridership when a line is converted from diesel to trolley coach operation

Source: Personal Communication: Mike Bergman; Seattle Metro, and Brian Kelly, BC Transit

HOWEVER, DIRECT COMPARISON OF ROUTES BEFORE AND AFTER TROLLEY BUS CONVERSION IS DIFFICULT DUE TO COINCIDENT CHANGES IN SERVICE LEVELS, ROUTE STRUCTURES, ETC.

ASSUMPTIONS/NOTES

1) Diesel

- Heat of combustion = 136,000 btu/gal (higher heating value)
- Fuel consumption is based on DDC 6V92 equipped diesel buses operating over the same routes as the SCRTD methanol test fleet (i.e., fuel economy of the diesel powered "sister fleet")

2) Methanol

- Heat of combustion = 62,400 btu/gal (higher heating value)
- Fuel consumption is based on DDC 6V92 methanol engine buses operating primarily on Downtown CBD routes. Fuel economy on higher speed routes is comparitively better for methanol coaches.

3) CNG

- 100,000 BTU's/Therm (higher heating value)
- Energy consumption is based on the in service performance of the Cummins CNG L-10 engine being demonstrated at Toronto Transit, Columbus, and SCRTD. Miles-per-therm economy has been adjusted to reflect the differences in Baseline diesel bus fuel economy between SCRTD and the fleets at Toronto and Columbus (See Alternatives Technology Analyses section for details).

4) Trolley

For electric vehicles, the "engine" is effectively the power generating plant and is physically separated from the vehicle. A trolley bus's energy consumption of 3 kWh/mi (equal to 10,023 btu/mi) represents vehicular power absorption. The total energy consumption calculated for trolley buses is based on amount of fossil fuel burned by the utility per mile of trolley operation including energy lost during electrical generation and transmission. Energy supplied by hydroelectric, other renewable, and nuclear sources is assumed to have a heat rate of zero.

Note: See Task Report #3, "Low Emission Transit Alternatives" for additional fuel economy and performance information

TROLLEY BUSES WILL ALSO HELP CONSERVE NATURAL RESOURCES BY CONSUMING LESS FOSSIL FUEL PER MILE OF OPERATION

SCRTD FUEL ECONOMY RESULTS: Alternative Fuels Demonstration			
	Miles per Unit Fuel Consumption	BTU's/Mile (Energy Consumption)	Notes (Facing Page)
Average Diesel	3.2 MPG	42,500	1
Methanol Coach	1.1 MPG	56,727	2
CNG Coach	1.74 Miles/Therm	57,471	3
Trolley Buses	.333 miles/kWh	24,288	4

MOREOVER, NATURAL GAS (AND TO A LESSER EXTENT, COAL) PROVIDE MOST OF THE FUEL USED TO GENERATE ELECTRICAL POWER - - - FUEL SOURCES THAT ARE 100% DOMESTICALLY PRODUCED.

ASSUMPTIONS/CALCULATIONS

For Combustion Engine Technologies

- Mean engine load factor = 27%
  - Mean load factor represents the time weighted average percentage of maximum output power at which the engine operates during revenue service. Estimate of 27% is based on RTD fuel consumption data and dynamometer fuel consumption data supplied by DDA. Load factor (x) Rated HP = average output horsepower.
- Average rated engine HP = 260
- Average vehicle speed = 12.4 mph (average speed for all routes in RTD's system with headways less than 15 minutes. Route data supplied by RTD operations department)
- Required HP-HRs per mile of operation = .27 (x) 260 HR (x) $\frac{1\ \text{HR}}{12.4\ \text{miles}}$ = <u>5.66 HP-HRs/Mile</u>

↕

For Trolley Buses

- Average power consumption = 3 KwH/mile (x) $\frac{1.34\ \text{HP-HRs}}{\text{KwH}}$ = <u>4.0 HP-HRs/Mile</u>

TROLLEY BUSES ARE MORE "ENERGY EFFICIENT" THAN MOTOR COACHES

- **No fuel is consumed at idle as is the case with motor coaches.**

- **Because trolley buses are equipped with regenerative braking system, approximately 20% of required propulsion power can be recovered - - - with motor buses, this power is lost during braking in the form of heat and noise.**[1]

- **Power losses through the mechanical transmission and torque converter of motor coaches are higher than losses through an electric drive system.**

THE NET RESULT IS THAT MOTIVE POWER REQUIRED FOR THE TROLLEY BUS IS LIKELY TO BE BETWEEN 20 AND 30 PERCENT LESS THAN FOR A MOTOR COACH (SEE CALCULATIONS ON FACING PAGE).

(1) Source: "Trolleybus Propulsion Evaluation", Final Report, Booz·Allen & Hamilton, MUNI, June 1975

VEHICLE MAINTENANCE ON THE TROLLEY COACHES WILL BE LOWER THAN FOR CONVENTIONAL MOTOR COACHES

- **Maintenance on engine, transmissions, cooling system, exhaust system and fuel system is eliminated on trolley coaches - - - these systems account for 30 to 40 percent of the total vehicle maintenance requirements for motor coaches.(1)**

- **Brake system maintenance will be reduced by 50 to 75 percent.(2)**

- **All costs associated with refueling and oil changes will be eliminated.**

- **Electric driveline maintenance is required but will consists primarily of periodic motor replacement (See next section for additional details).**

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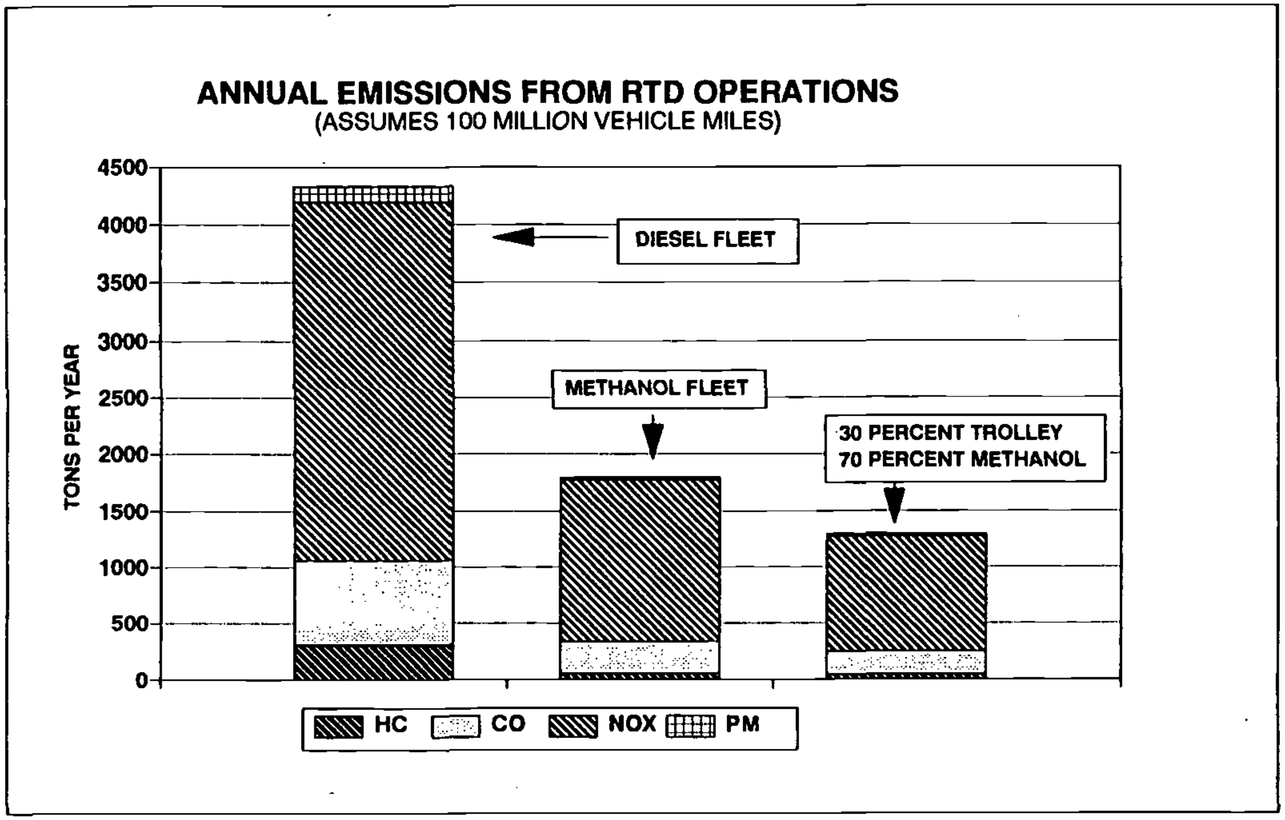
(1) ***UMTA Report PB81-120172, "The Trolley Coach: Potential Market, Capital, and Operating Costs". Percentages match RTD's in-house VMS estimate. See "Review of Maintenance Operations at SCRTD", Final Report, Booz·Allen & Hamilton, June 1988***

(2) ***Based on interviews with maintenance staff at S.F. Muni, Metro, and BC Transit***

PERHAPS MOST IMPORTANTLY, TROLLEY COACHES CAN HELP REDUCE SYSTEMWIDE EMISSION LEVELS BELOW THAT ACHIEVABLE BY ALTERNATIVE FUEL COACHES ALONE



BASED ON THE SUGGESTED AQMP TROLLEY CONVERSION OF 30 PERCENT OF TOTAL SYSTEM MILEAGE, EMISSIONS WOULD BE REDUCED BY ABOUT 600 TONS ANNUALLY VS. AN ALL METHANOL FLEET.

OPERATION AND MAINTENANCE CONSIDERATIONS

WHILE TROLLEY BUSES OFFER SEVERAL BENEFITS, TROLLEY SYSTEMS PRESENT SIGNIFICANT IMPLEMENTATION , OPERATIONS AND MANAGEMENT CHALLENGES

- **Overhead wire Maintenance**
- **Vehicle Scheduling and Operations**
- **Vehicle Maintenance**
- **Facility Modifications**

SEVERAL OPERATIONAL AND MAINTENANCE CONCERNS ARE UNIQUE TO TROLLEY SYSTEMS AND WILL REQUIRE SPECIAL EFFORTS BY RTD TO IMPLEMENT

Overhead Wire Maintenance

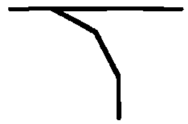
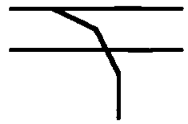
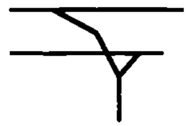
Proper maintenance of overhead wires is necessary to maintain acceptable levels of system reliability, mitigate power transmission losses and reduce de-wirements.

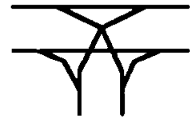
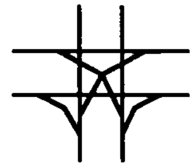
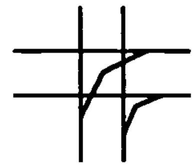
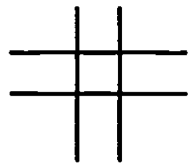
Typical maintenance requirements include:

- **Replacement of overhead wire due to accidents; wear; extreme environmental conditions, etc.**
- **Periodic adjustments of wire tension**
- **Replacement and inspection of "special work" at intersection and crossings**
- **Replacement and inspection of switches**
- **Periodic adjustments to curve segments and cross-span tension wires.**

Overhead wire maintenance in a trolley system is a function of both the vehicle miles travelled and the number of intersections, switches, crossings and other special work per unit mile. The basic trolley wire itself requires very little maintenance and in fact much of the overhead wire in systems throughout North America is over 25 years old. If wire wear becomes excessive transmission efficiency decreases (due to wire heating and reduced contact surface area; de-wirements also increase. Wire is periodically replaced if excessive wear has occurred. Heavily used routes in San Francisco will undergo wire replacements approximately every 5 to 7 years while moderate density routes can last 10 to 20 years.

EXAMPLES OF "SPECIAL WORK" TROLLEY OVERHEAD HARDWARE

TYPE OF SPECIAL WORK	CONFIGURATION
SINGLE 90°	
DOUBLE 90° CURVE	
SINGLE SWITCH	
DOUBLE SWITCH	
SINGLE SWITCH WITH CROSSOVER	
WYE	

TYPE OF SPECIAL WORK	CONFIGURATION
"T" INTERSECTION	
1/2 GRAND UNION	
1/4 GRAND UNION	
DOUBLE CROSSOVER	
SINGLE 90° CURVE WITH CROSSOVER	

OVERHEAD WIRE MAINTENANCE - - - CONT'D

- Trolley wires stretch due to extreme changes in temperature (below freezing) as well as from heavy lateral pull on the wires from the trolley bus itself. (In cities such as Toronto, Edmonton and Hamilton heavy ice often forms on the wires in the winter months and must be removed by a "de-icing" truck each morning before the trolleys begin operations.) As a result of these conditions trolley wires tend to sag in the summer and become overly tight in the winter. In cities such as Los Angeles where temperature variations are much less extreme, this type of maintenance should be reduced considerably.

- The primary maintenance items in trolley overhead system are associated with intersections. Switches, crossings, turn segments, and other "special work" associated with facilitating multiple turns and cross-thru capability at intersections have historically been the items of most concern for trolley systems maintenance managers. While reliability of such devices have improved substantially over the last 10 to 15 years (see overhead wire system design section) the best way to avoid such costs is through careful selection and planning of routes to minimize the number of complex turns and intersections in the system.

TROLLEY OPERATIONS WILL REQUIRE CAREFUL ROUTE PLANNING AND SCHEDULING

- Trolley coaches present a more complex route scheduling and fleet management challenge versus an all motor coach fleet. Compared to many other large U.S. transit systems, the RTD makes extensive use of "interlining". This scheduling technique uses vehicles normally assigned to one route to also cover operations on an ancillary route during peak periods. This technique is used selectively on RTD's more heavily travelled routes to reduce total vehicle requirements and reduce operating costs. Interlining is possible since any vehicle on any route can "cover" operations on any other route. Use of trolley buses on selected routes will limit the available interlining savings since trolleys are effectively tied to the overhead wire and cannot be used on other routes. While motor buses can be intermixed with trolleys this would effectively prevent the complete conversion of the route to trolley operation - - - a characteristics deemed desirable to fully evaluate ridership and other cost impacts of trolley operations. Total fleet vehicle requirements (trolley + diesel) will therefore be greater than for an all diesel (or all trolley) fleet.

- The trolley coach reduces flexibility of operations in several ways that may be significant on some of RTD's routes. A branch or deviation cannot be added to a trolley bus route to serve a specific demand unless the demand is sufficient to justify wire installation. Express service is precluded unless demand is sufficient to justify additional express wire and the headway and running times permit scheduling of non-interferring service. Appropriate service design will help to minimize the effect of these constraints on system operation and service quality.

TROLLEY OPERATIONS WILL REQUIRE CAREFUL PLANNING - - - CONT'D

- **Re-routing and cutback opportunities are generally severely restricted for trolley coach as compared to motor coach operation. Temporary changes in routing due to special events, construction, and other disruptions are therefore more difficult to manage (The use of APU's may mitigate some of these traditional trolley bus disadvantages).**

- **The use of wheelchair lifts or routes with high service frequencies can be much more disruptive to a trolley coach system than to a motor bus system. This is a result of the inability of trolley coaches to pass one another unless the poles on the stopped vehicle are lowered. Vehicle bunching can result.**

- **Deadhead mileage may increase if the installed overhead wire routing does not represent the shortest path back to the maintenance division.**

WHILE TROLLEY COACHES PROMISE OVERALL REDUCED VEHICLE MAINTENANCE, THE ELECTRIC PROPULSION SYSTEM WILL REQUIRE RTD TO ACQUIRE NEW MAINTENANCE SKILLS AND PERFORM NEW MAINTENANCE TASKS

- **Advanced control system diagnostics and maintenance**
  - **Voltage/Speed regulator equipment (chopper controls)**
  - **APU system controls: battery replacement, inspection, and servicing**

- **Motor inspection/maintenance**
  - **DC motors: Insection of commutators and brushers**
    : Periodic motor replacement (300,000 to 400,000 miles)
  - **AC motors: No maintenance on commutators and burshes required**
    : Motor replacement (approximately 500,000 to 750,000 miles)

- **Inspection and maintenance of current collection equipment**
  - **Daily inspection of contact shoes**
  - **Replacement of contact shoes every 4 to 6 days during dry weather; every 1 to 2 days during wet weather conditions**
  - **Periodic replacement of trolley bus poles due to breakage/bending**

RTD'S MAINTENANCE AND OPERATING FACILITIES WILL REQUIRE MODIFICATION TO ACCOMMODATE TROLLEYS

- Ideally, trolley and motor buses should be maintained and operated out of separate facilities. The labor skills, diagnostic equipment, component repair shops, and parts inventory for electric vs. internal combustion propulsion systems are completely unique. The situation would be aggravated if the trolley buses were purchased from a manufacturer not currently represented in RTD's fleet.

- Many of the transit properties in North America currently operating trolley systems do however operate mixed divisions of trolley and diesel buses. Modifications/additions to the facility include:
  - An electronics repair shop for diagnosing and repairing motor control equipment
  - A motor/armature repair room for changing brushes (this would not be needed with AC drive - - - motors are removed and replaced if/when failures occur)
  - A portion of the repair bays must be "wired" to provide voltage for performing system testing and maintenance.

- Traditionally, an extensive overhead wiring matrix must be provided throughout the maintenance yard to permit maneuvering through the daily servicing lanes in and out of repair bays and in the bus storage area.

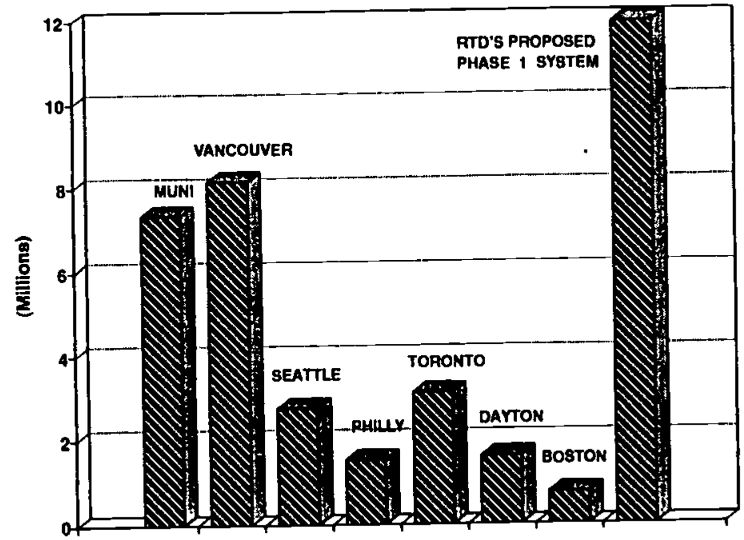
FACILITIES WILL REQUIRE MODIFICATIONS

- The inclusion of a battery driven auxiliary power unit (APU) in the vehicle specification should significantly reduce overhead wire requirements in existing (and new) bus divisions. The bus could operate off-wire while moving through the service lanes as well as in and out of service bays. The bays themselves would still require limited overhead wire for system diagnostic purposes.

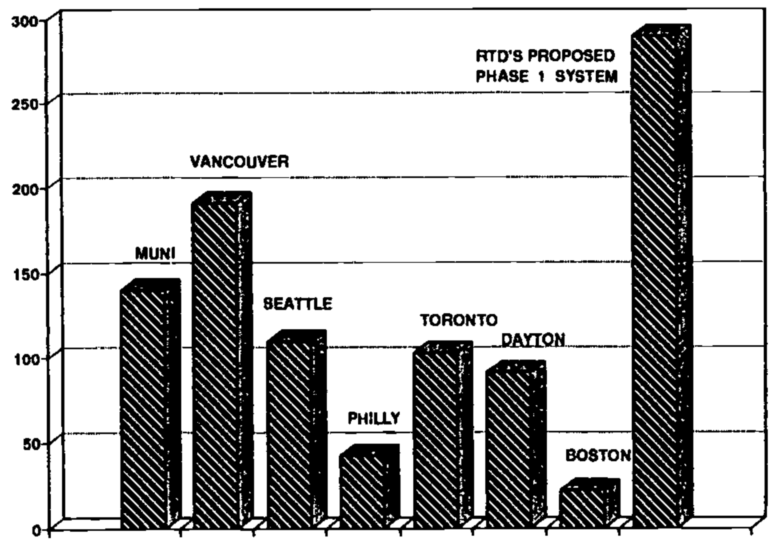
- The vehicle storage area may also require the installation of overhead wire. Vancouver is the only North American city operating trolleys equipped with a battery powered APU. Maintenance managers at Vancouver have indicated that because of miscellaneous parasitic electrical loads (such as the electronic destination signs, communication, and other low level computer related needs) and even more importantly, because the batteries would be required to power the air compressor during the morning start-up, extended off-wire parking will drain the batteries. It is unclear whether a sufficiently sized APU would eliminate the need for overhead wiring in the bus storage area. Our preliminary assessment is that installation of limited overhead wire in the bus parking area will mitigate problems associated with low/dead APU battery systems (RTD will be the first transit property to modify a maintenance division for an all APU equipped trolley fleet).

COMPARISON OF TROLLEY SYSTEM IN NORTH AMERICA

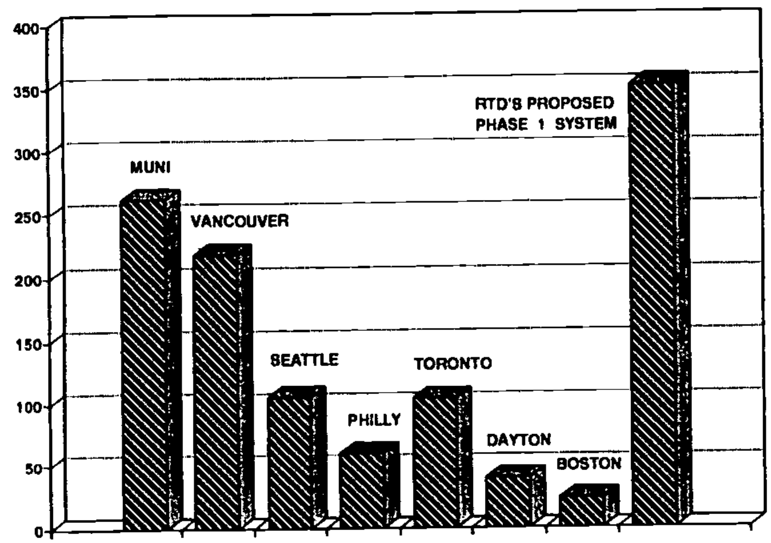
VEHICLE MILES



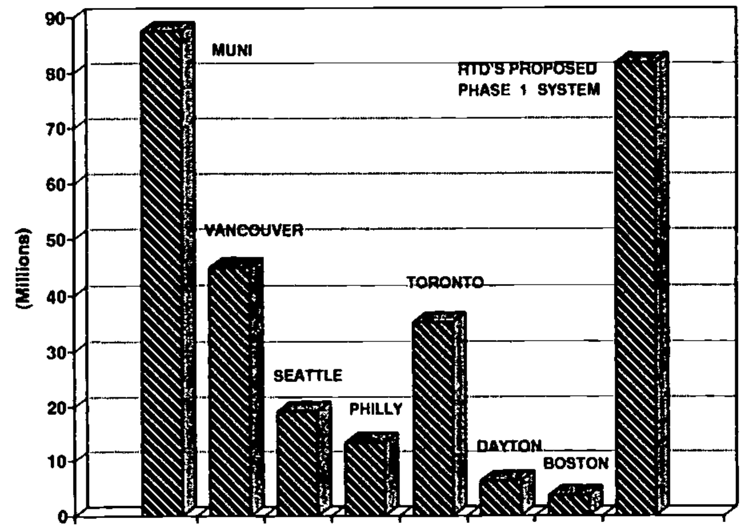
ONEWAY ROUTE MILES



PEAK BUSES



ANNUAL BOARDINGS



TROLLEY SYSTEMS IN NORTH AMERICA VARY CONSIDERABLY BY SIZE

Operating Data	SYSTEM SIZE AND OPERATING STATISTICS (UMTA Section 15 Date)							
	Muni	Vancouver	Seattle	Philadelphia	Toronto	Dayton	Boston	RTD's Proposed Phase 1 System(1)
Total Trolley Fleet	345	244	155	110	139	65	40	438
Peak Buses	262	218	106	60	104	40	23	351
Base Buses	184	128	71	32	48	27	12	202
Peak/Base Ratio	1.421	1.70	1.49	1.88	2.17	1.48	1.92	1.76
Oneway Miles of Overhead Wire	140	191	110	43	103	91	22	290
Annual Boardings	87,407,602	45,000,000	19,158,122	13,355,479	35,267,000	6,186,280	3,512,000	81,713,424
Passenger Miles	118,500,159	—	36,609,515	21,132,178	—	14,493,568	8,454,214	—
Revenue Vehicle Miles	7,319,721	8,143,000	2,744,779	1,526,824	3,096,177	1,609,501	742,081	11,933,607*
Revenue Vehicle Hours	991,053	860,000	320,290	176,449	351,505	126,894	57,016	982,828*
Annual Power Usage (KW)	32,823,400	33,793,450	14,902,889	12,434,175	—	6,732,609	1,389,866	51,600,000

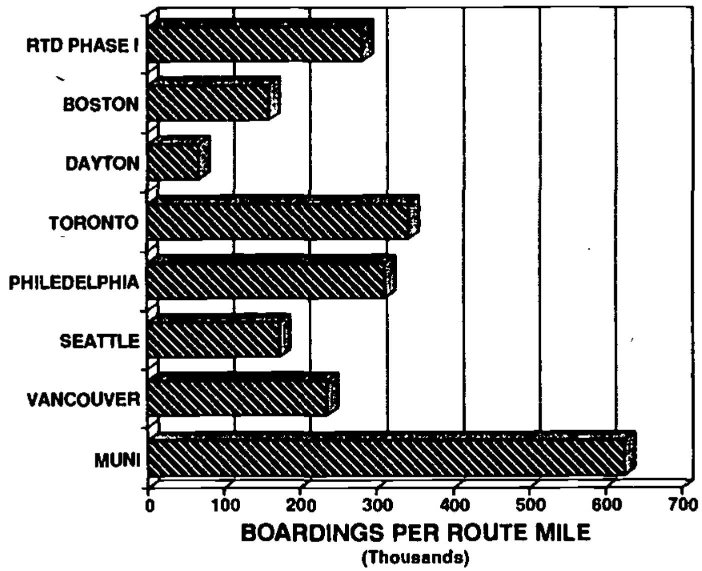
(1) See Route Selection chapter for details on proposed system

*** For the proposed trolley system revenue miles and hours are assumed to be 90% of total miles and hours**

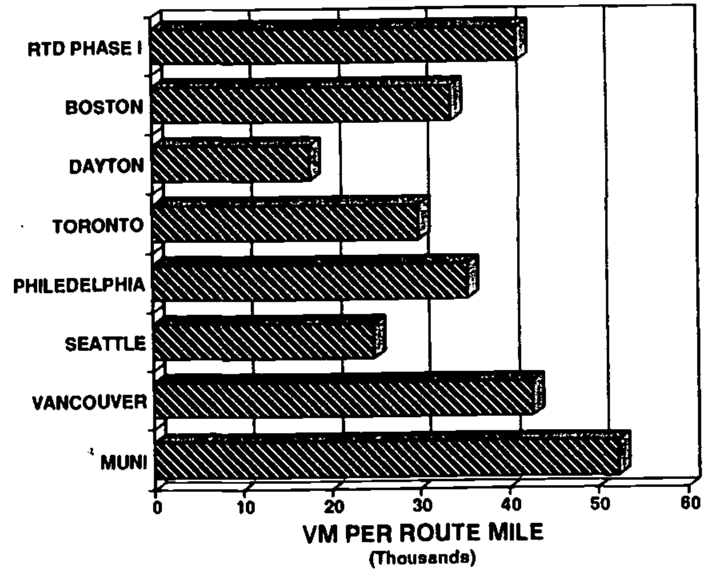
- **San Francisco has the largest fleet of trolleys in the U.S. and Canada**
- **Dayton and Boston operate extremely small trolley fleets with less than 25 buses operating at peak**

RTD'S PROPOSED PHASE I SYSTEM WOULD BE THE LARGEST IN NORTH AMERICA.

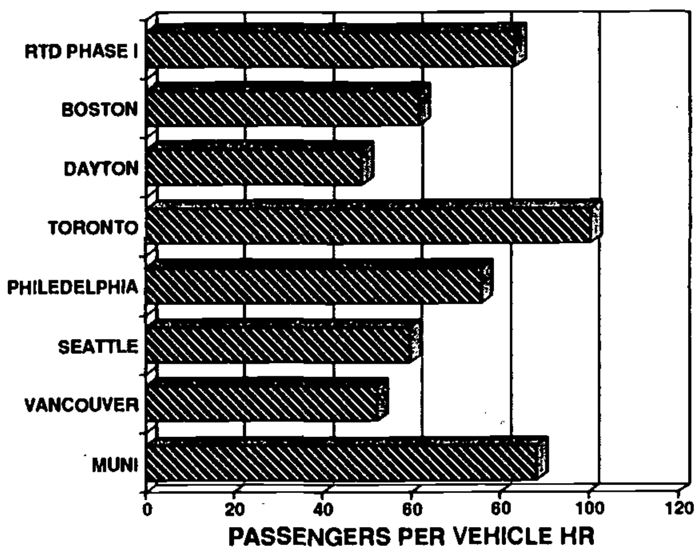
ANNUAL BOARDINGS PER ROUTE MILE



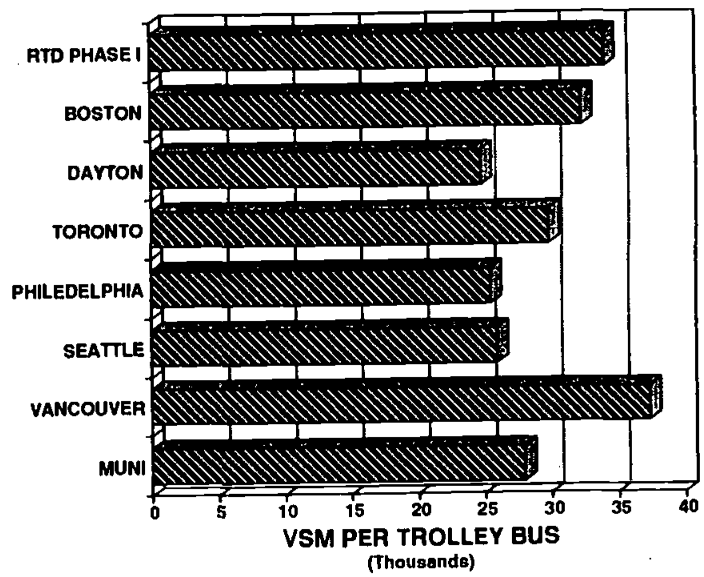
VEHICLE SERVICE MILES PER ROUTE MILE



PASSENGERS PER VEHICLE HOUR



VEHICLE SERVICE MILES PER BUS



TROLLEY SYSTEM UTILIZATION CHARACTERISTICS ALSO VARY DRAMATICALLY

	TROLLEY SYSTEM OPERATING RATIOS							
	Muni	Vancouver	Seattle	Philadelphia	Toronto	Dayton	Boston	RTD's Proposed Phase 1 System
Overhead Wire Utilization								
Service Miles Per Route Mile	52,284	42,634	24,953	35,508	30,060	17,687	33,731	41,150
Service Hours Per Route Mile	7,079	4,503	2,912	4,103	3,413	1,394	2,592	3,389
Annual Boardings Per Route Mile	624,340	235,602	174,165	310,593	342,398	67,981	159,636	281,770
Trolley Bus Utilization								
Annual Passengers Per Bus	333,617	206,422	180,737	222,591	339,106	154,657	152,696	232,802
Annual Revenue Miles Per Bus	27,938	37,353	25,894	25,447	29,771	40,238	32,264	33,999
Annual Revenue Hours Per Bus	3,783	3,945	3,022	2,941	3,380	3,172	2,479	2,800
Overall System Utilization								
Passengers Per Vehicle Hour	88	52	60	76	100	49	62	83
Passengers Per Vehicle Mile	12	6	7	9	11	4	5	7

- **San Francisco arguably operates the most efficient system in terms of catenary utilization with 52,284 annual vehicle service miles per mile of installed overhead wire. The proposed RTD Phase I system would rank third among trolley systems by this measurement criteria and be nearly identical to the Vancouver system.**
- **San Francisco also carries nearly twice the passengers per mile of installed overhead than any other system. The proposed RTD system would be slightly higher than Vancouver by this measurement criteria.**
- **RTD's proposed system would rank second in terms of revenue miles per bus and again be nearly identical to the Vancouver system. Vehicle utilization would thus be very high for the proposed system.**

Comparison of Trolley Systems...

TROLLEY SERVICE REPRESENTS A SUBSTANTIAL PORTION OF TOTAL OPERATIONS IN MANY OF THE CITIES PROVIDING TROLLEY BUS SERVICE

	TROLLEY FLEET STATISTICS AS A PERCENT OF TOTAL BUS OPERATIONS							
	Muni	Vancouver	Seattle	Philadelphia	Toronto	Dayton	Boston	RTD's Proposed Phase 1 System
Total Peak Buses (% Trolley)	42.0%	28.0%	14.0%	7.0%	8.0%	13.0%	3.7%	16.0%
Boardings (% Trolley)	47.0%	31.0%	26.0%	7.0%	9.0%	20.0%	3.4%	19.0%
Vehicle Miles (% Trolley)	36.0%	24.0%	10.5%	4.0%	5.0%	18.0%	3.1%	14.0%
Vehicle Hours (% Trolley)	42.0%	33.0%	19.0%	5.0%	7.0%	20.0%	2.8%	16.0%

Source: 1990 APTA Transit Operating and Financial Statistics

TROLLEYS PLAY A PARTICULARLY IMPORTANT ROLE IN SAN FRANCISCO MUNI'S OPERATIONS.

SAN FRANCISCO IS EXPANDING THEIR TROLLEY BUS SYSTEM

Quote from MUNI's 1988-1993 Short Range Transit Plan:

> **"MUNI has found that the conversion of motor coach routes to trolley coach operation can result in operating cost savings, improved reliability and reduced noise and air pollution impacts. In recent years, the 1-CALIFORNIA and 24-DIVISADERO routes have been converted, and the 33-ASHBURY trolley route has been extended one and one-half miles.**
>
> **By 1991, MUNI proposes to covert the 31-BALBOA route to electric operation. This route was selected for trolley conversion because it has an established, high level of ridership (17,000 daily passengers), twenty percent of the route is already under wire, and the project has widespread neighborhood support. It is estimated that the 31-BALBOA electrification could result in up to $300,000 in annual budgetary savings.**
>
> **Also in the early 1990s, MUNI proposes to extend the 14-MISSION trolley coach line approximately 2/3 mile to the Daly City BART station.**
>
> **Beyond the five-year time frame, several trolley coach route extensions and modifications are proposed in order to serve the demand anticipated from development in Mission Bay - - - it is also possible that more diesel coach route electrification may take place as service demands increase"**

SAN FRANCISCO IS ALSO CURRENTLY IN THE PROCESS OF ACQUIRING 60 NEW ARTICULATED TROLLEY COACHES.

TROLLEY SYSTEMS IN SEATTLE AND VANCOUVER ALSO APPEAR TO BE IN GROWTH MODE

Seattle

Seattle has also recently completed a significant expansion of their overhead wire system. They are in the process of taking delivery on 236 dual mode articulated vehicles purchased from Breda. These dual mode buses are equipped with full internal combustion engine propulsion drivetrains and have complete off-wire capability. They operate on electric inside a tunnel and on diesel fuel outside the tunnel. Metro will also likely begin replacement of their 40 foot trolleys in the late 1990s (Seattle completed a total rehabilitation and expansion of their overhead wire network in 1980 bringing the total one way route miles to 110).

Vancouver

Vancouver has also completed major "express" and limited stop extensions of their trolley system in the last few years and now outranks San Francisco in total installed catenary. Vancouver is in the process of taking delivery on 25 articulated trolleys and will order 25 more in the 1994/95 timeframe. They are also investigating purchase of additional 40 foot trolleys.

TORONTO IS IN THE PROCESS OF DISMANTLING ITS TROLLEY SYSTEM - - - AND DAYTON IS AT A CROSSROADS

Toronto

Toronto Transit generally sees their trolley system as a high cost operation and at one point was in the process of dismantling their trolley bus system. Primary reasons cited are high overhead maintenance costs, an aging trolley bus fleet (purchased in 1972), and unfavorable fuel economics compared to natural gas. Toronto has effectively elected to aggressively pursue complete replacement of their diesel fleet with natural gas powered buses. Toronto has the disadvantage of operating trolleys in comparatively harsh weather conditions. Overhead wire maintenance is high due to large temperature swings between summer and winter, freezing conditions, and generally wet weather. Additionally, their trolley fleet utilizes "first generation" CAM control speed regulation technology thus reducing trolley bus efficiency and increasing maintenance. Finally, Canada generally has extremely favorable natural gas fuel prices compared to many areas in the U.S. and an abundance of supply. Transit properties in Canada, as a matter of national energy policy, have been strongly encouraged to pursue natural gas vehicles. Strong community support however has prevented the abandonment of the trolley system.

Dayton

Dayton is currently engaged in a major study to decide the fate of it's trolley system. The Miami Valley Regional Transit Authority (MVRTA) has concluded that maintenance and operations costs are well above diesel coach and benefits of trolley (reduced noise and pollution) do not justify the continued maintenance of the overhead wire and aging vehicle fleet. However, a variety of community groups, business leaders, and political action committees have formed a "Save-the-Trolleys" organization with a goal of retaining, rehabilitating and possibly expanding trolley service in Dayton. The Dayton trolley system is generally under-utilized compared to other systems in North America but has strong community and ridership loyalty. The primary point of controversy surrounds costs estimates for rehabilitating the overhead power distribution system as well as the trolley bus fleet.

TROLLEY BUSES ARE ENJOYING RENEWED INTEREST AROUND THE COUNTRY

- **Emission regulations will likely force the use of alternative fuels thus significantly increasing the costs of operating a transit system. Capital investments in fuel and maintenance facilities will also be required.**

- **Only known technology that can provide zero emission vehicles and reliable operation.**

- **Transit ridership is up at many properties - - - particularly on CBD routes.**

- **Air quality continues to grow worse in many cities due to population growth.**

- **Trolleys offer the potential for lower operating costs but require a major capital investment in vehicles and overhead wire system.**

- **Sacramento, Orange County, Dallas, Hamilton Ontario, and Dayton are all re-visiting the trolley bus option in recognition of these changing environmental and cost factors.**

TROLLEY SYSTEM OPERATIONS AND MAINTENANCE COSTS CAN BE COMPARED WITH DIESEL COSTS AT TRANSIT PROPERTIES SUBMITTING DATA TO UMTA

- **Transit properties are required by UMTA to report maintenance and operating expenses by mode. Such data however is widely recognized by the industry as not totally accurate and often times misleading. The exact cost-centers and accounts included in each reporting category often differ somewhat from property to property. The apportioning of shared overhead resources among different modes also varies among properties making cost comparisons between modes jaded. Occasionally what one property considers an operating expense is considered a capital expense by another property.**

- **It is appropriate to use Section 15 data to compare general operating statistics such as fleet size, vehicle service miles, vehicle service hours, etc. since there is little room for interpretation when reporting such data. Comparisons of cost related data however can be misleading.**

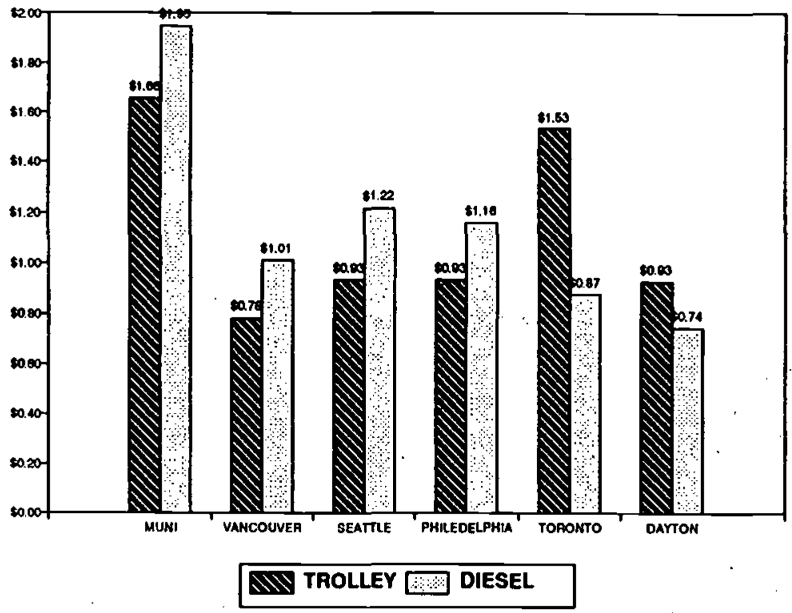
- **Complicating the diesel versus trolley cost comparisons using UMTA formatted data (Section 15 reports) is the large difference in the size of trolley systems among different properties as well as the relationship of the size of the trolley fleet to the diesel fleet at any one property. Properties with small trolley systems will naturally show comparatively high costs since trolley specific equipment and labor will be applied over only a few buses. Other overhead accounts also tend to be inequitably applied to modes that represent only a small portion of the total transit system operations. To compare costs between modes we have therefore excluded "administration" and "non-vehicle maintenance" expense categories listed in the section 15 reports. We have focused on "vehicle maintenance cost" and "vehicle operations cost" categories to obtain a more direct and accurate comparison between modes.**

TROLLEY VS. DIESEL FLEET COST COMPARISONS

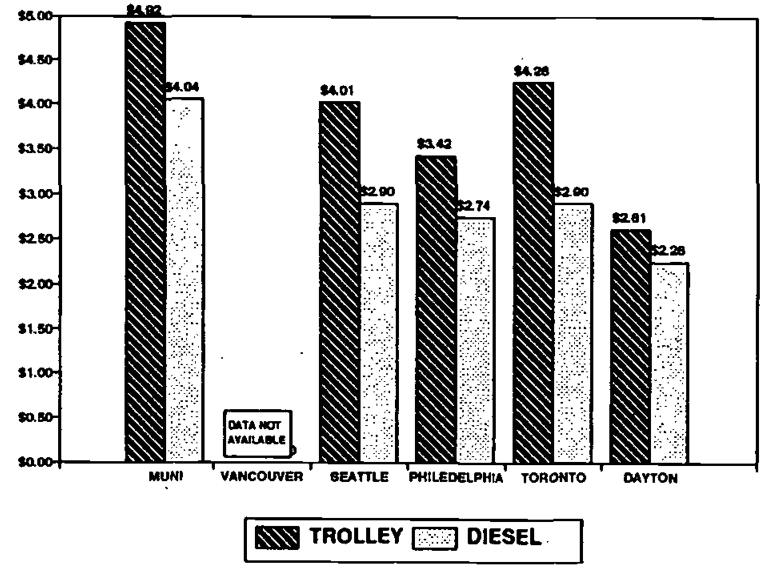
- **It is important to recognize the different types of service that trolley versus diesel buses are assigned to in the various cities operating trolley coaches. Trolley coaches are generally assigned to high patronage routes with low average trip speeds and a high ratio of start/stops per vehicle mile. Total trip length is generally low so that the average annual mileage accumulation on trolley buses is comparatively low. Diesel buses normally accumulate more miles but carry fewer passengers than trolley buses. This reality however is of course an inherent characteristic of the route rather than the vehicle technology itself. As a consequence trolley buses are disadvantaged in cost-per-mile comparisons with diesel buses but are at an advantage in cost-per-hour or cost-per-passenger calculations.**

- **The maintenance costs associated with a diesel fleet is very much a function of the age of fleet. Older coaches require considerably higher levels of maintenance on driveline and other subsystems such as exhaust, cooling and fuel systems. Trolley coaches in contrast have comparatively even maintenance requirements throughout their useful life due to the simplified driveline and elimination of support subsystems. In reviewing the current maintenance and operating costs of trolley systems it should be recognized that the trolley fleets are generally older than the comparative diesel fleets with the weighted <u>average</u> age of trolley coaches in North American systems being about 13 years.**

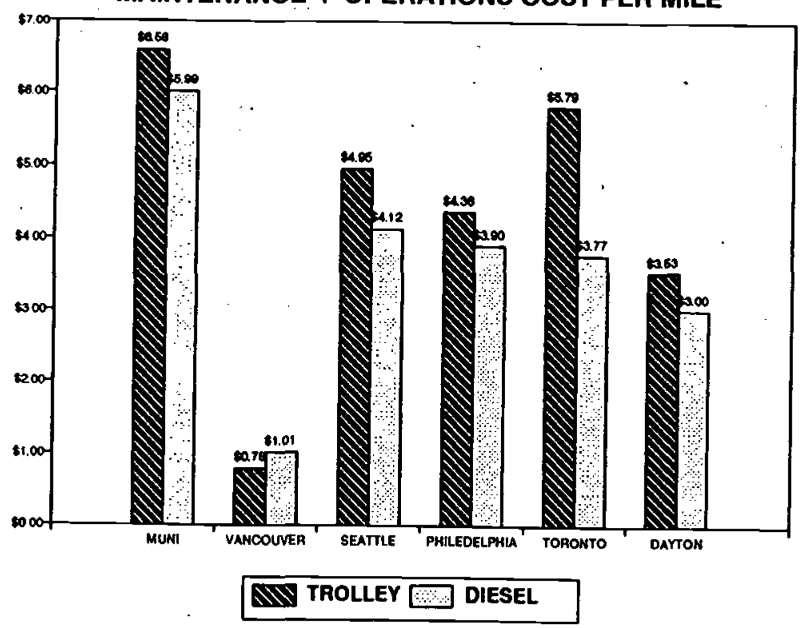
MAINTENANCE COST PER MILE



VEHICLE OPERATIONS COST PER MILE



MAINTENANCE + OPERATIONS COST PER MILE



DIESEL VS. TROLLEY - - - COST PER MILE

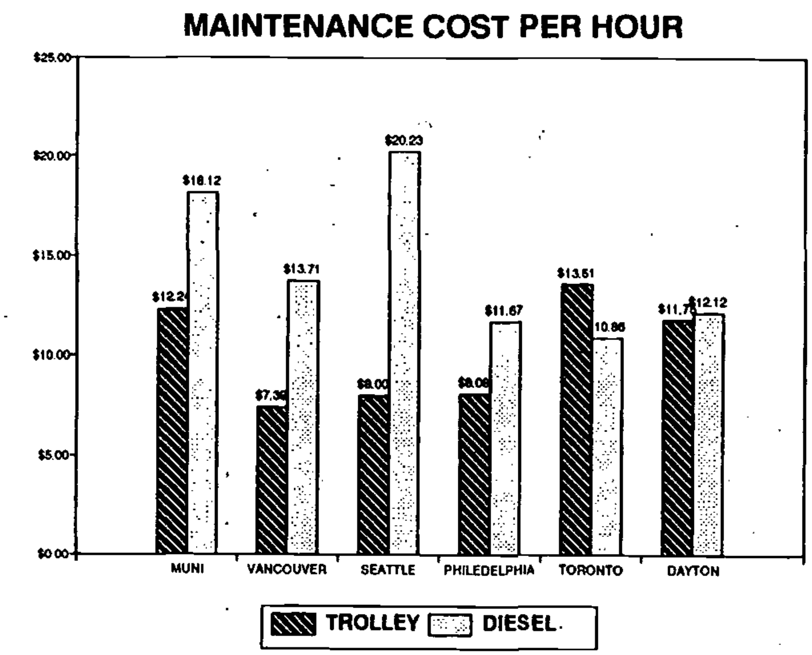
- Even on a per-mile basis vehicle maintenance costs are lower for trolley coaches at 4 of the 6 properties examined. Toronto's trolley fleet was purchased between 1968 and 1972 which partially explains their high maintenance costs. Both Dayton and Toronto are officially in the process of phasing out their trolley operations.

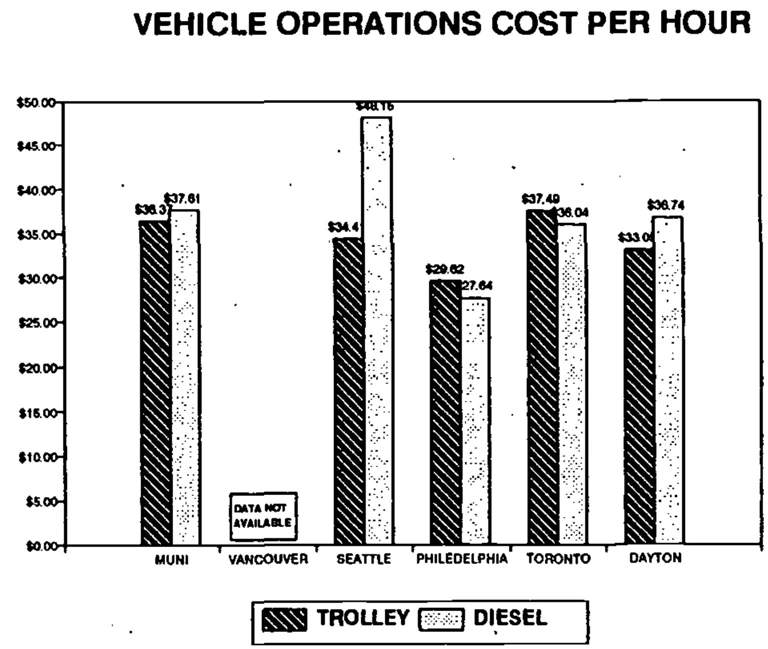
- For Seattle, Vancouver and Muni (the three properties with substantial trolley operations), maintenance cost per-mile averaged 21% lower for trolleys compared to diesel coaches.

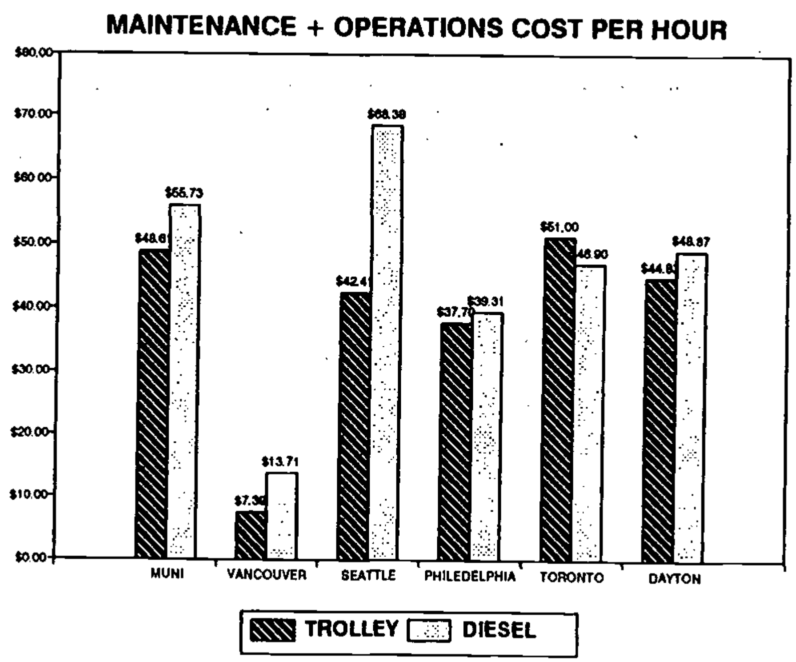
	COST PER MILE					
	Muni	Vancouver	Seattle	Philadelphia	Toronto	Dayton
Maintenance						
Trolley	$1.66	$0.78	$0.93	$0.93	$1.53	$0.93
Diesel	$1.95	$1.01	$1.22	$1.16	$0.87	$0.74
Operations						
Trolley	$4.92	N/A	$4.01	$3.42	$4.26	$2.61
Diesel	$4.04	N/A	$2.90	$2.74	$2.90	$2.26
Total Trolley	$6.58	$0.78	$4.95	$4.36	$5.79	$3.53
Total Diesel	$5.99	$1.01	$4.12	$3.90	$3.77	$3.00

Source: 1990 Transit Operating and Financial Statistics

- Vehicle operations costs (which include drivers salaries) on a per-mile basis are higher for trolleys than for diesels at all properties. This in-part reflects the increased scheduling and management complexity of operating the trolley system. Cost differences are aggravated by the low vehicle miles accumulated per bus operator.


MAINTENANCE COST PER HOUR
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
$12.2
$18.12
$7.39
$13.71
$8.00
$20.23
$8.06
$11.67
$13.51
10.86
$11.7
$12.12
MUNI
VANCOUVER
SEATTLE
PHILEDELPHIA
TORONTO
DAYTON
TROLLEY
DIESEL


VEHICLE OPERATIONS COST PER HOUR
$50.00
$45.00
$40.00
$35.00
$30.00
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
$36.3
$37.61
DATA NOT AVAILABLE
$34.4
$29.62
27.64
$37.49
36.04
$33.0
$36.74
MUNI
VANCOUVER
SEATTLE
PHILEDELPHIA
TORONTO
DAYTON
TROLLEY
DIESEL


MAINTENANCE + OPERATIONS COST PER HOUR
$80.00
$70.00
$60.00
$50.00
$40.00
$30.00
$20.00
$10.00
$0.00
$48.61
$55.73
$7.39
$13.71
$42.4
$68.39
$37.70
$39.31
$51.00
46.90
$44.8
$48.87
MUNI
VANCOUVER
SEATTLE
PHILEDELPHIA
TORONTO
DAYTON
TROLLEY
DIESEL

DIESEL VS. TROLLEY - - - COST PER HOUR

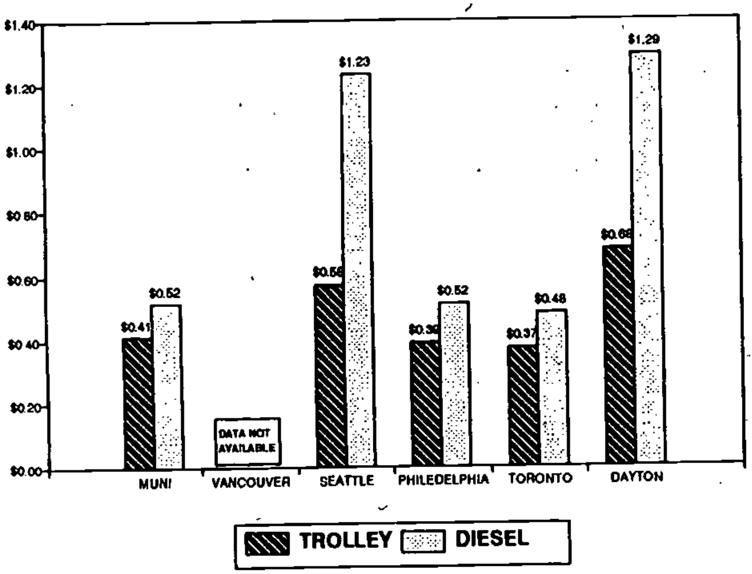
- **With the exception of Toronto, maintenance cost <u>per hour</u> are lower for trolley buses at all transit properties. For Seattle, MUNI, and Vancouver, the maintenance cost per hour averaged 46% lower for trolleys compared to diesel coaches.**

- **Vehicle Operations cost per hour are about the same for diesel and trolley coaches at most properties.**

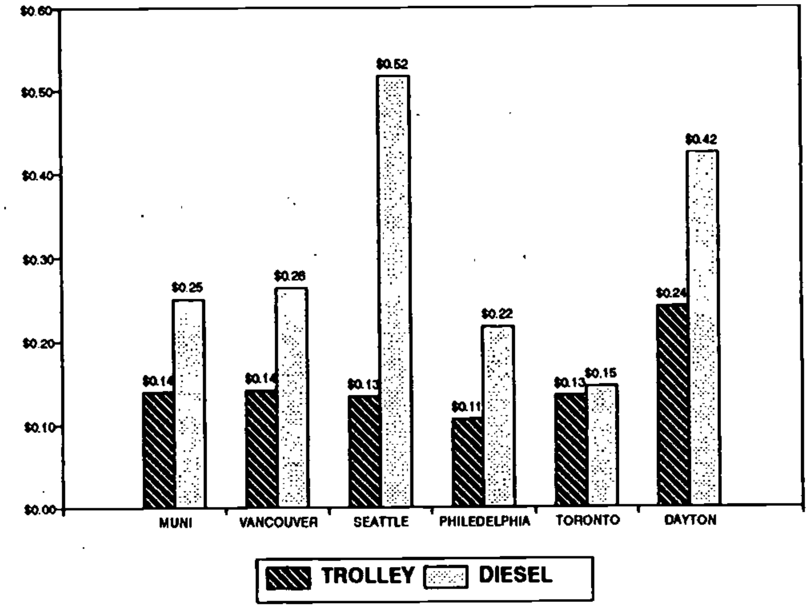
- **Total maintenance plus vehicle operations costs on a per-hour basis are lower at 4 of the 6 transit properties (with Dayton and Toronto again being the exception).**

	COST PER HOUR					
	Muni	**Vancouver**	**Seattle**	**Philadelphia**	**Toronto**	**Dayton**
Maintenance						
Trolley	$12.24	$7.39	$8.00	$8.08	$13.51	$11.75
Diesel	$18.12	$13.71	$20.23	$11.67	$10.86	$12.12
Operations						
Trolley	$36.37	N/A	$34.41	$29.62	$37.49	$33.09
Diesel	$37.61	N/A	$48.15	$27.64	$36.04	$36.74
Total Trolley	$48.61	$7.39	$42.41	$37.70	$51.00	$44.83
Total Diesel	$55.73	$13.71	$68.38	$39.31	$46.90	$48.87

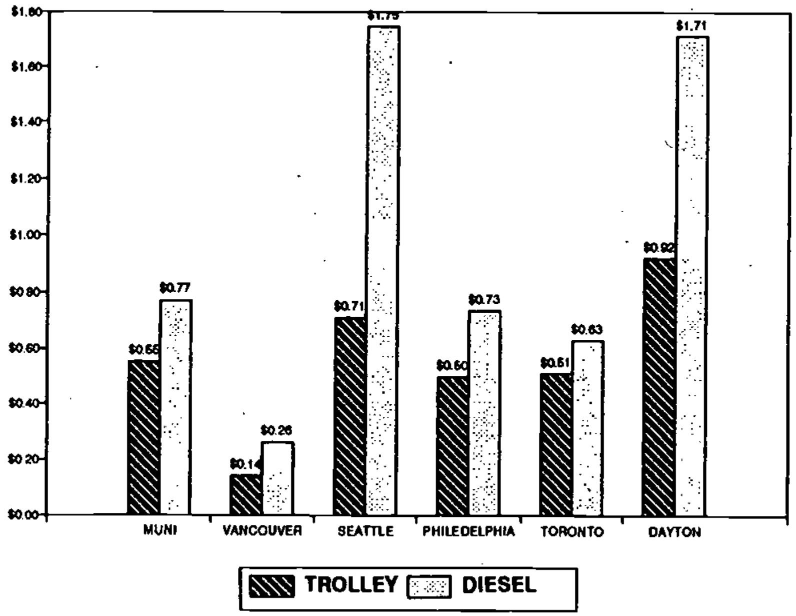
VEHICLE OPERATIONS COST PER PASSENGER



MAINTENANCE COST PER PASSENGER



TOTAL COST PER PASSENGER



DIESEL VS. TROLLEY - - - COST PER PASSENGER

- **On a per-passenger basis, trolley buses are a clear cost winner**

	COST PER BOARDING					
	Muni	**Vancouver**	**Seattle**	**Philadelphia**	**Toronto**	**Dayton**
Maintenance						
Trolley	$0.14	$0.14	$0.13	$0.11	$0.13	$0.24
Diesel	$0.25	$0.26	$0.52	$0.22	$0.15	$0.42
Operations						
Trolley	$0.41	N/A	$0.58	$0.39	$0.37	$0.68
Diesel	$0.52	N/A	$1.23	$0.52	$0.48	$1.29
Total Trolley	$0.55	$0.14	$0.71	$0.50	$0.51	$0.92
Total Diesel	$0.77	$0.26	$1.75	$0.73	$0.63	$1.71

ELECTRIC POWER SOURCE PROFILE FOR SOUTHERN CALIFORNIA

TO PROPERLY MEASURE THE EQUIVALENT EMISSIONS FROM TROLLEY BUS OPERATIONS, THE FOLLOWING KEY DATA ARE NEEDED:

- **Average energy consumption of trolley buses (in kilowatt hours/mile)**
- **Emission factors* for each power generation process used to provide electricity for Southern California**
  - **Coal Fired Steam Turbine**
  - **Gas Fired Steam Turbine**
  - **Oil and Gas Turbine Engines**
  - **Fossil Fuel Cogeneration (combined cycle)**
  - **Nuclear, Hydroelectric, Solar, Wind, and Geothermal**
- **Total power generated (kilowatt hours per year) by each process**
- **Transmission losses**
  - **Utility Power Distribution System**
  - **Trolley Coach Power Distribution System**

EMISSION FACTORS FOR A PARTICULAR PROCESS (SUCH AS COAL FIRED STEAM TURBINES) MAY VARY DEPENDING ON THE LEVEL OF TECHNOLOGY AND EMISSION CONTROLS APPLIED TO A GIVEN PLANT.

* **'EMISSION FACTOR' IS DEFINED AS THE MASS OF EMISSIONS PRODUCED PER KILOWATT HOUR GENERATED**

OTHER CONSIDERATIONS IN EVALUATING EMISSIONS FROM TROLLEY BUSES INCLUDE:

- **Unique power source profiles and associated technology levels of DWP versus SCE supplied electricity**

- **The types of power plants and percent of total power supplied by facilities located in the South Coast Air Basin, versus those outside the Air Basin but in California, versus power generation outside California**

- **Capacity of existing power supply infrastructure and potential additional sources of power if needed**

- **Planned improvements to power generating facilities that will change emission factors**

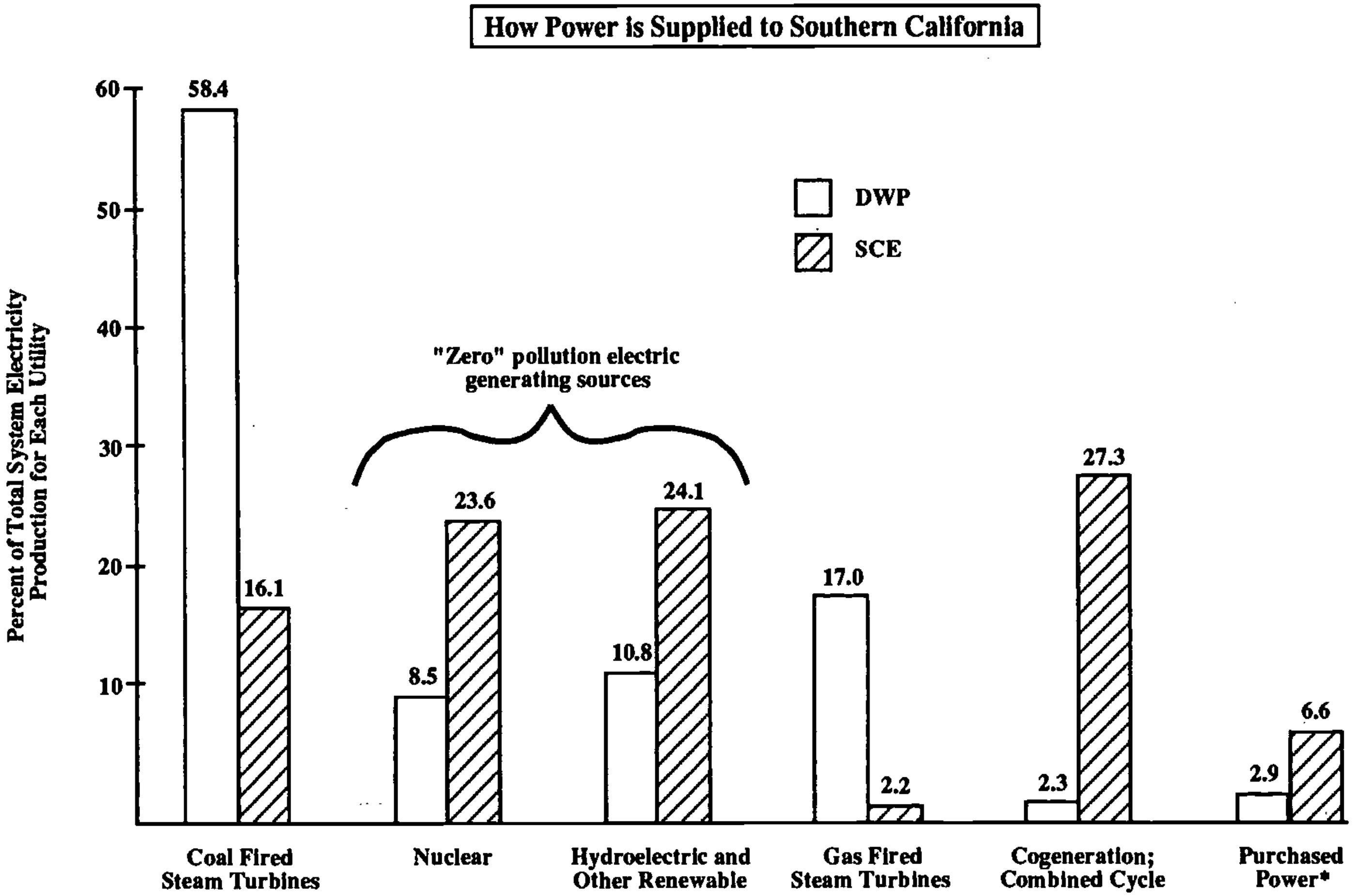
CAPACITY, UTILIZATION, AND POWER GENERATION BY SOURCE FOR SCE AND DWP

SCE Systemwide Totals	Capacity (KW)	Average Annual Utilization	Power Generation (MWH)
Steam Turbine – Oil and Gas	8,435,000	19.59%	14,475,000
Combined Cycle – Oil and Gas	1,072,000	22.65%	2,127,000
Gas Turbine – Oil and Gas	659,000	0.38%	22,000
Diesel Engine	7,600	35.20%	23,000
Steam Turbine – Coal	1,638,400	70.02%	10,050,000
Nuclear	2,541,129	68.93%	15,343,000
Hydroelectric	2,472,320	51.86%	11,232,000
Purchased Power – Fossil Cogeneration	1,932,000	83.63%	14,153,000
Purchased Power – Biomass	266,000	61.37%	1,430,000
Purchased Power – Geothermal	532,000	67.55%	3,148,000
Purchased Power – Wind	126,000	67.32%	743,000
Purchased Power – Solar	266,000	23.69%	552,000
Purchased Power – As Available	63,000	341.74%	1,886,000
Imported Power – Coal	190,000	24.45%	407,000
Imported Power – Hydroelectric	623,000	103.84%	5,667,000
Imported Power – Other	346,000	78.49%	2,379,000
Total	21,169,449		83,637,000
DWP Systemwide Totals	**Capacity (KW)**	**Average Annual Utilization**	**Power Generation (MWH)**
Steam Turbine – Oil and Gas	3,037,000	16.02%	4,262,194
Steam Turbine – Coal	1,785,000	85.76%	13,409,379
Nuclear (Purchased + DWP)	396,602	61.51%	2,136,984
Hydroelectric	1,935,200	7.41%	1,256,620
Purchased Power – Fossil Cogen	222,000	30.26%	588,409
Imported Power – Coal	137,000	108.82%	1,306,000
Imported Power – Hydroelectric	1,240,000	13.36%	1,451,111
Imported Power – Other	—	—	725,555
Total	8,752,802		25,136,252

Source: LADWP and SCE supplied data; BAH analyses

Electric Power Source Profile for Southern California...

NON-POLLUTING ELECTRIC GENERATING SOURCES PROVIDE A SIGNIFICANT PORTION OF SOUTHERN CALIFORNIA'S POWER NEEDS



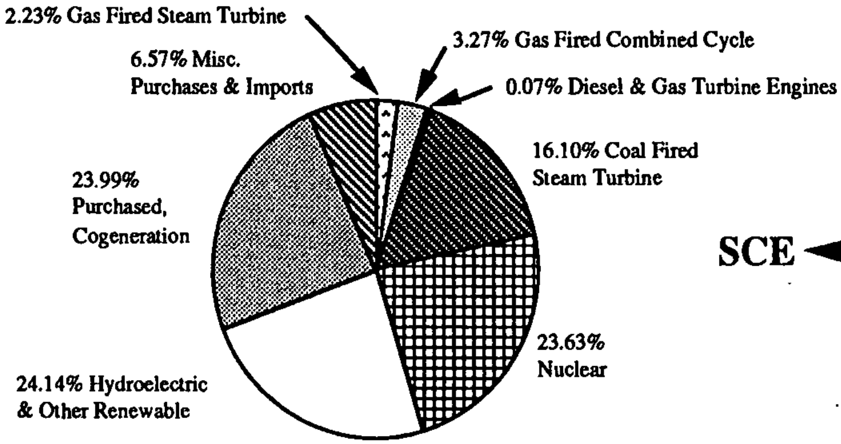
* Assumed to have average emission factors for power produced in U.S.

GRAPHIC 4

Source: LADWP and SCE power plant generation data; BAH analyses

Electric Power Source Profile for Southern California...

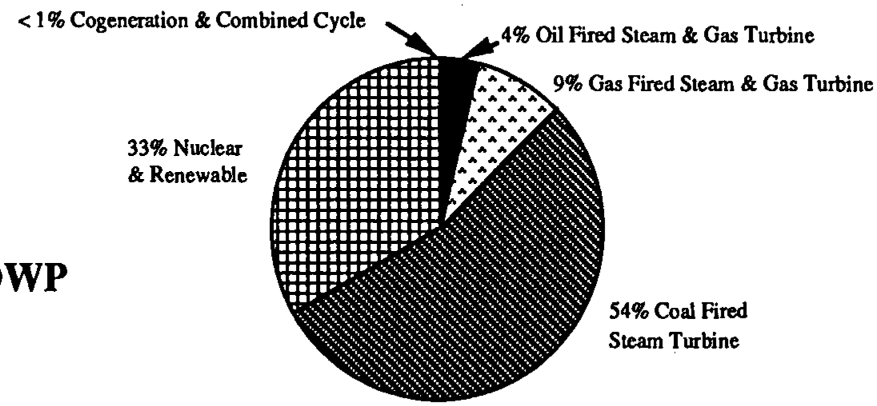
DWP'S POWER GENERATION PROFILE IS SIMILAR TO THAT OF AN AVERAGE U.S. UTILITY WHILE SCE'S POWER IS CONSIDERABLY CLEANER

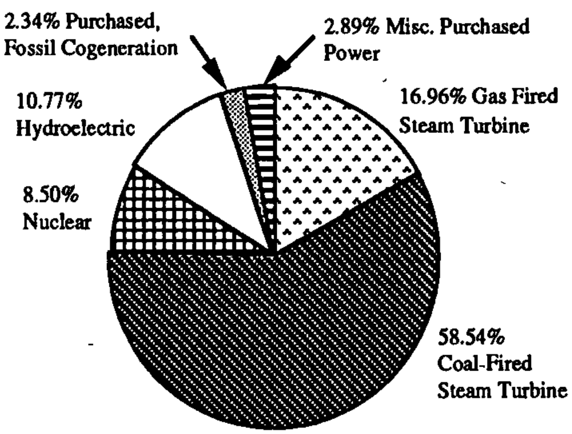


SCE ←

47% OF THE TOTAL POWER SUPPLIED BY ZERO EMISSION SOURCES (NUCLEAR, HYDROELECTRIC, OTHER RENEWABLE) AND ONLY 16% FROM COAL BASED GENERATION.

U. S. Average





LADWP

GRAPHIC 5

***Source:** Electric power generation data supplied by DWP, SCE, and Electric Power Research Institute; BAH analyses (See Task 3, "Environmental and Energy Considerations" for additional data)*

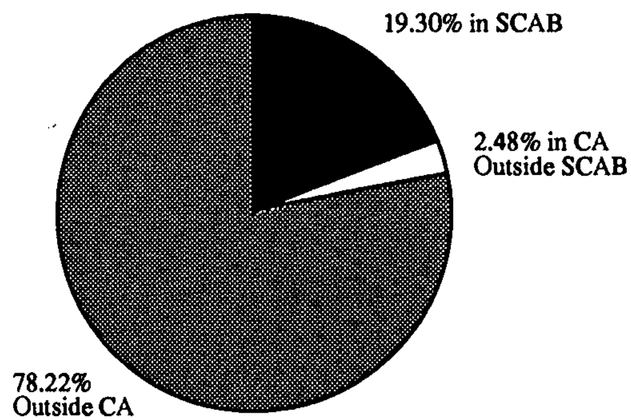
POWER PRODUCTION IN THE SOUTH COAST AIR BASIN VS. TOTAL PRODUCTION

SCE Power Sources	Average Annual System Production (MWH)	Average Produced in SCAB (MWH)	% Produced in SCAB
Steam Turbine – Oil and Gas	14,475,000	10,138,000	70%
Combined Cycle – Oil and Gas	2,127,000	324,000	15%
Gas Turbine – Oil and Gas	22,000	18,000	82%
Diesel Engine	23,000	23,000	100%
Steam Turbine – Coal	10,050,000	—	0%
Nuclear	15,343,000	—	0%
Hydroelectric	11,232,000	—	0%
Purchased Power – Fossil Cogeneration	14,153,000	14,153,000	100%
Purchased Power – Biomass	1,430,000	1,430,000	100%
Other Purchased Power	14,782,000	—	—

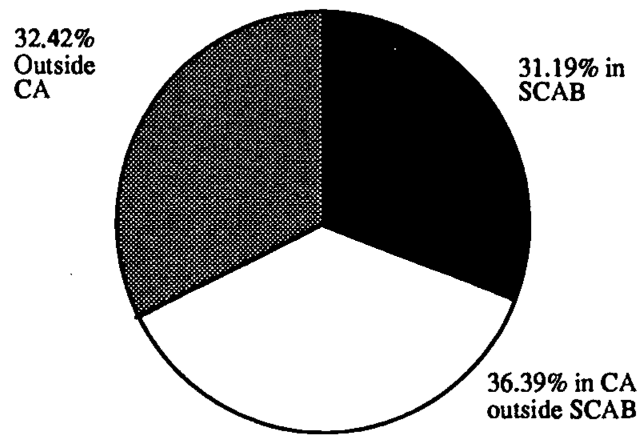
DWP Power Sources	Average Annual System Production (MWH)	Average Produced in SCAB (MWH)	% Produced in SCAB
Steam Turbine – Oil and Gas	4,262,194	4,262,194	100%
Steam Turbine – Coal	13,409,379	—	0%
Nuclear	2,136,984	—	0%
Hydroelectric	1,256,620	—	0%
Purchased Power – Fossil Cogeneration	588,409	588,409	100%
Other Purchased Power	3,484,083	—	—

THE MAJORITY OF POWER SUPPLIED TO SOUTHERN CALIFORNIA IS PRODUCED OUTSIDE THE SOUTH COAST AIR BASIN

LADWP Power Generation and Purchases



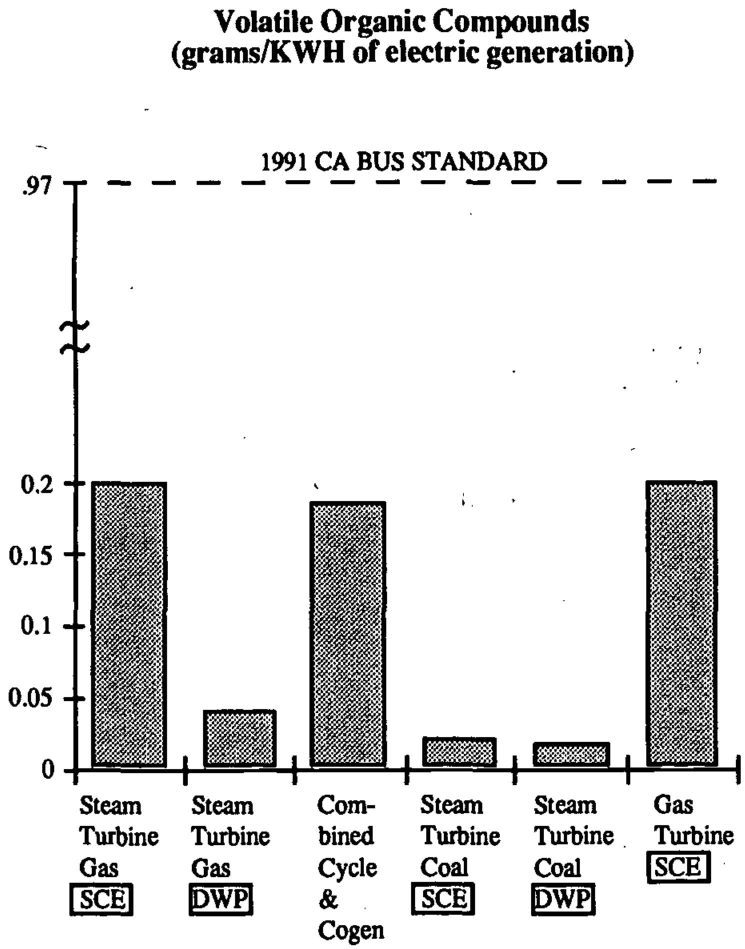
SCE Power Generation and Purchases

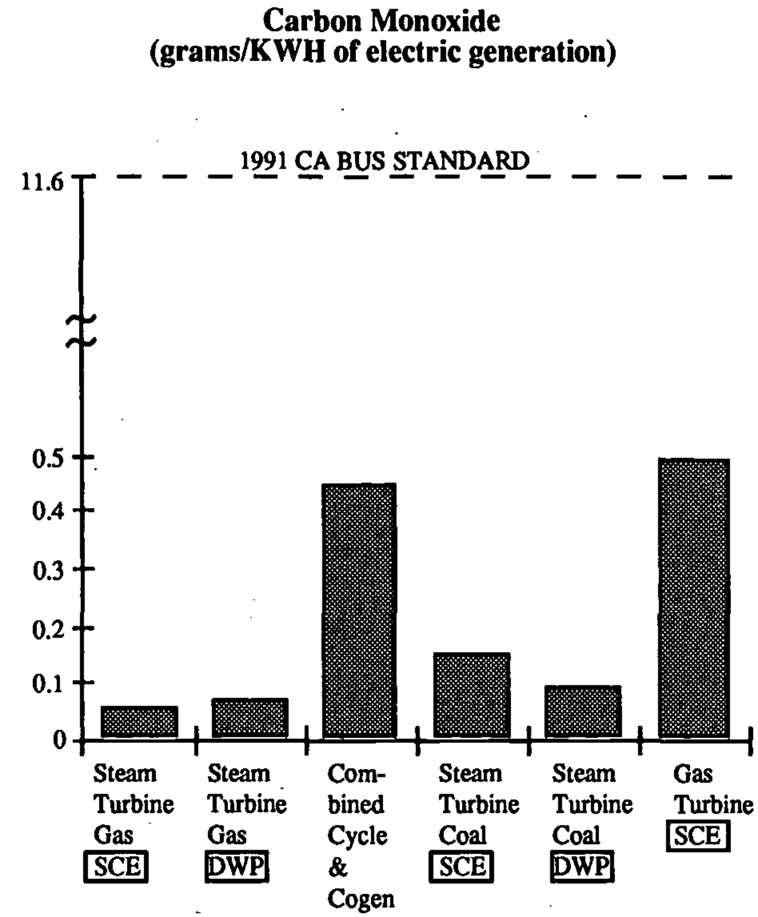


GRAPHIC 6

Source: BAH analyses

VOC AND CO EMISSIONS ALSO VARY BY PROCESS TYPE . . . AND LEVEL OF PLANT TECHNOLOGY



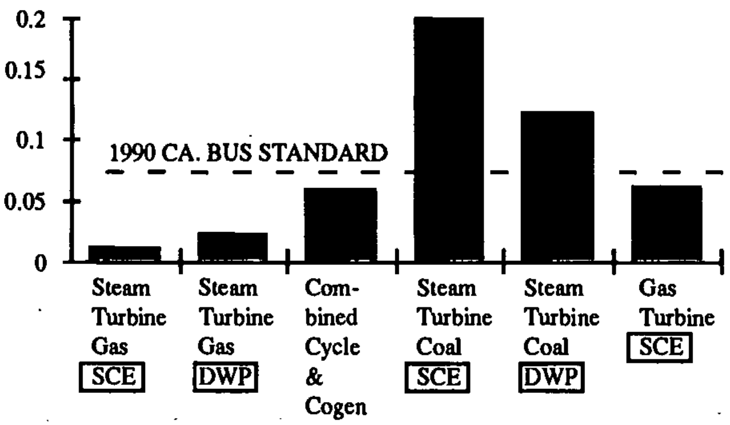


GRAPHIC 35

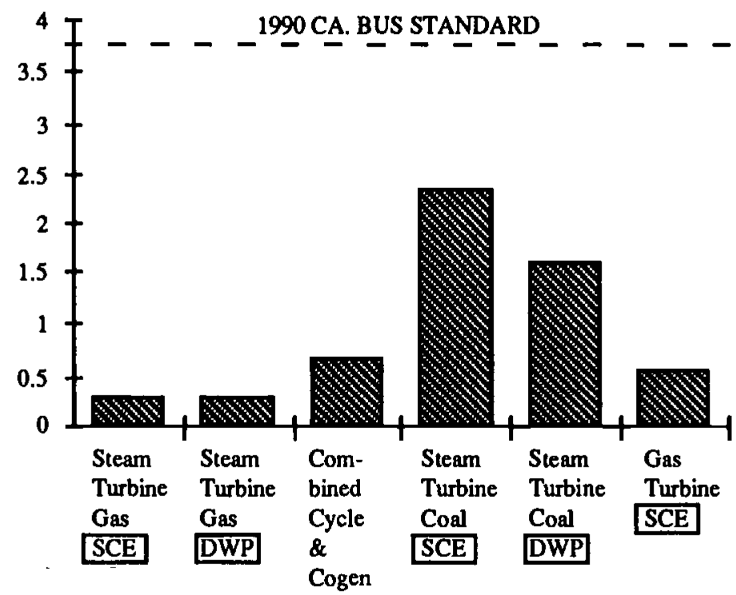
PRES/RCC - 03

THE EMISSION FACTORS ASSOCIATED WITH EACH SOURCE OF POWER VARY CONSIDERABLY - - - NOX AND PARTICULATES ARE THE EFFLUENTS OF MOST CONCERN FROM URBAN BUSES

Particulates
(grams/KWH of electric generation)



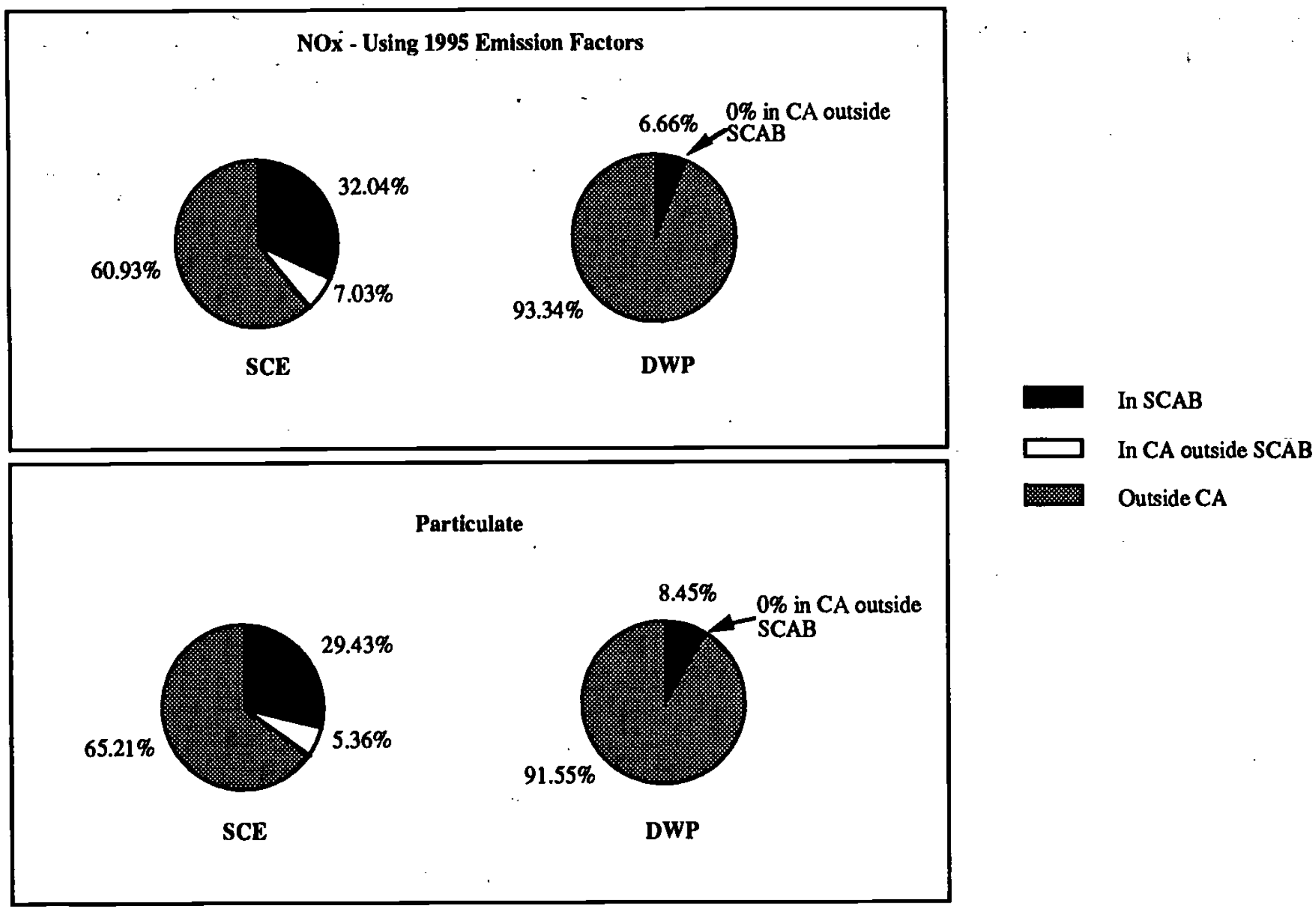
1995 Nitrogen Oxides
(grams/KWH of electric generation)



GRAPHIC 7

Source: BAH analyses; Emission factor data for power plants supplied by SCE and DWP

THE MAJORITY OF PARTICULATE AND NOX EMISSIONS PRODUCED BY ELECTRIC POWER GENERATION WILL BE OUTSIDE THE SOUTH COAST BASIN



GRAPHIC 36

PRES/RCC - 03

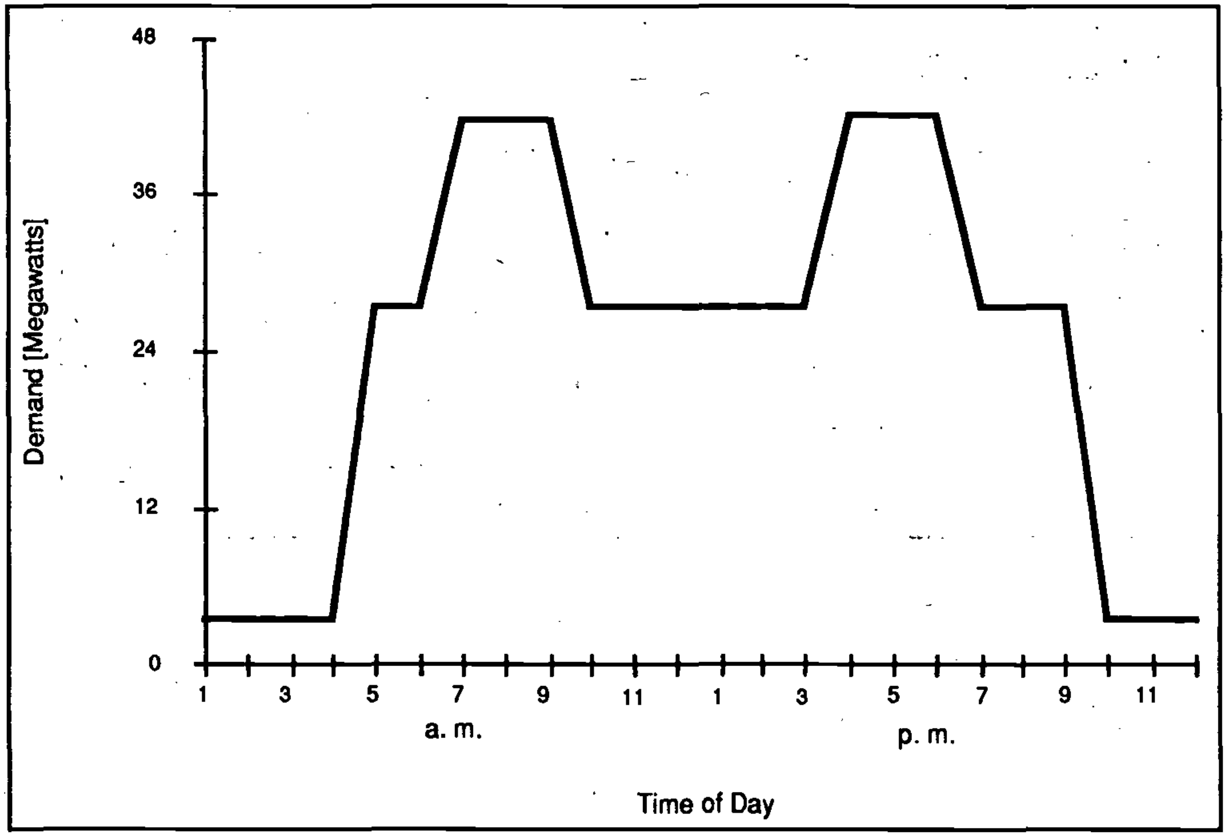
ELECTRIC POWER GENERATED EMISSIONS INSIDE AND OUTSIDE OF THE BASIN CAN BE DETERMINED BY MULTIPLYING PLANT-SPECIFIC EMISSION FACTORS BY THE TOTAL POWER PRODUCED AT EACH PLANT

Electric Power Generated Emissions (Percent by Region)				
	NOx	PM	HC	CO
SCE				
In Basin	32.0	29.4	75.2	71.4
In California/Outside Basin	7.0	5.4	21.3	12.6
Outside California	61.0	65.2	3.5	16.0
Total	100.0%	100.0%	100.0%	100.0%
DWP				
In Basin	6.7	8.5	53.1	28.6
In California/Outside Basin	0.0	0.0	0.0	0.0
Outside California	93.3	91.5	46.9	71.4
Total	100.0%	100.0%	100.0%	100.0%

Source: BAH analyses; See Task Report 4, "Environment and Energy Considerations" for additional details

TROLLEY POWER DEMAND AT MAXIMUM SYSTEM MATURITY (TOP 40 SCRTD ROUTES)

Peak # of Buses on Top 40 Routes	Base # of Buses on Top 40 Routes	No. of Buses on OWL Service	AVG. Speed At Peak (MPH)	AVG. Speed at Base or OWL Service (MPH)	Peak Power (Kw)	Base Power (Kw)	OWL Power (Kw)
1,248	739	80	11.2	13.4	41,933	29,708	3,216



GRAPHIC 49

Note: ***Power Requirements = (AVG. Speed) x (Power Consumption / Bus) x (# of Buses)***
For Peak Bus Power = (11.2 MPG) x (3 Kw HR / Mile) x (1,248 Buses) = 41,933 Kw

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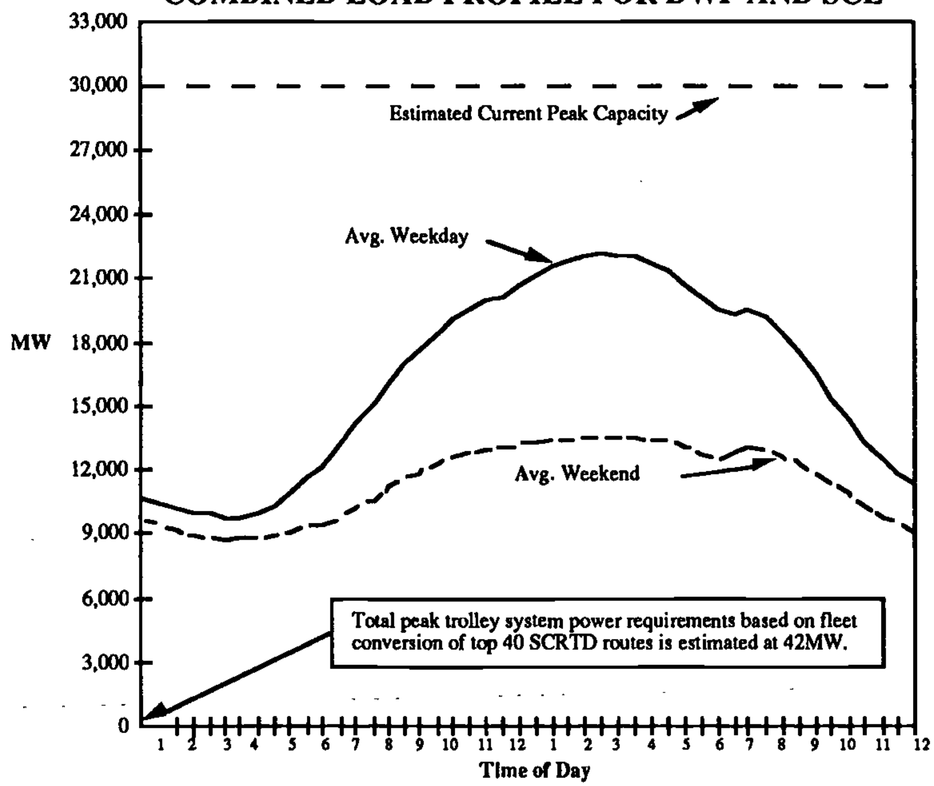
THE TOTAL POWER REQUIRED BY TROLLEY OPERATIONS AT MAXIMUM SYSTEM MATURITY WILL NOT SIGNIFICANTLY AFFECT THE OVERALL LOAD PROFILE FOR SOUTHERN CALIFORNIA - - - OR REQUIRE THAT NEW POWER GENERATION FACILITIES BE CONSTRUCTED

COMBINED LOAD PROFILE FOR DWP AND SCE

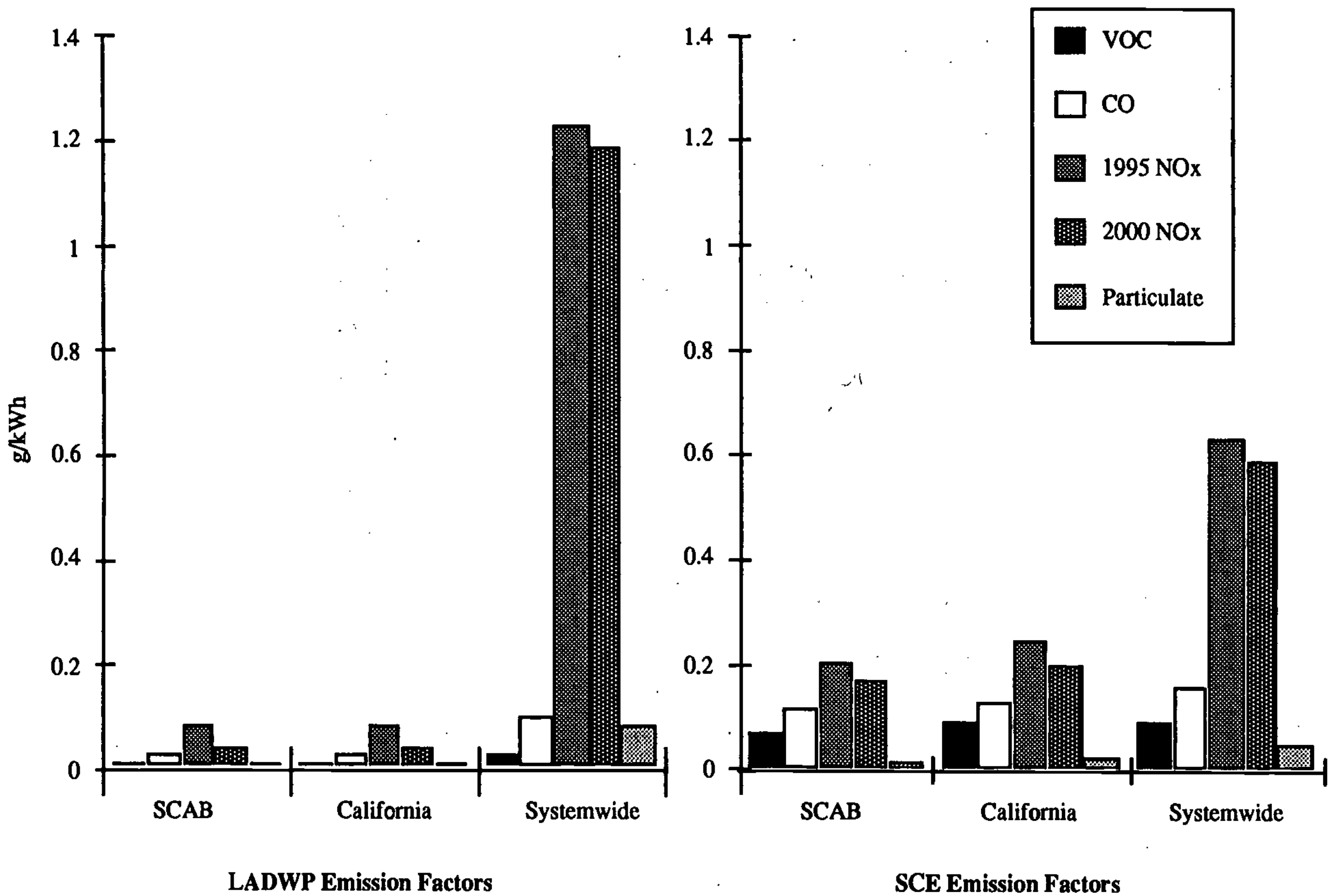


Source: DWP and SCE load profile data/BAH analysis.

GRAPHIC 8

Note: ***40 Routes in SCRTD's system meet the AQMD suggested trolley conversion guidelines of 15 minute or less continuous headways (See Route Selection section for details)***

TROLLEY BUS EMISSION FACTORS FOR LADWP AND SCE



GRAPHIC 37

PRES/RCC - 03

DWP'S SYSTEMWIDE EMISSION FACTORS ARE SOMEWHAT HIGHER THAN SCE'S . . . IN BASIN EMISSIONS ARE ONLY A FRACTION OF THE TOTAL FOR BOTH UTILITIES

SOUTHERN CALIFORNIA EDISON

		VOC	CO	NOx (yr 1995)	NOx (yr 2000)	Particulates
Within SCAB	G/KWHR	0.070	0.110	0.200	0.170	0.010
	G/BHP-HR	0.052	0.082	0.150	0.127	0.007
System Total	G/KWHR	0.094	0.155	0.635	0.589	0.051
	G/BHP-HR	0.070	0.115	0.474	0.439	0.380

* Both SCE and DWP have plans in place to reduce NOx emissions from power plants located in the SCAB during the years 1989-2000.

LOS ANGELES DEPARTMENT OF WATER & POWER

		VOC	CO	NOx (yr 1995)	NOx (yr 2000)	Particulates
Within SCAB	G/KWHR	0.013	0.026	0.086	0.041	0.004
	G/BHP-HR	0.010	0.019	0.064	0.031	0.003
System Total	G/KWHR	0.026	0.096	1.413	1.370	0.072
	G/BHP-HR	0.019	0.069	1.050	1.020	0.054

Source: SCE, DWP emission factor data; BAH analyses

Community Awareness Program

A COMPREHENSIVE COMMUNITY AWARENESS PROGRAM HAS BEEN DEVELOPED AND IS CURRENTLY UNDERWAY

OBJECTIVES INCLUDE:

- **Provide substantive and clear information about the proposed trolleybus system to communities throughout the South Coast basin, as well as to other city and state officials who might be affected by trolley bus implementation**

- **Answer all technical, programmatic, and service related questions that may arise during the program**

- **Solicit reactions, suggestions, and concerns from members of the communities**

- **Identify those communities that appear to have a special interest in seeking a trolley bus route established in their neighborhood - - - and would therefore be good candidates for early trolley bus implementation.**

Note: ***For a more detailed review of the Community Acceptance Program including a complete listing of public meetings at which the Trolley Bus Program was discussed, please see Task Report 6, "Community Acceptance"***

THE PUBLIC OUTREACH EFFORT HAS FOCUSED ON PRESENTATIONS BY THE PROJECT TEAM AT COMMUNITY MEETINGS THROUGHOUT THE SOUTH COAST BASIN

Presentations included the following key elements:

- **A short video was shown depicting electric trolley buses operating in the central business districts and suburban neighborhoods of several North American cities;**

- **A fact sheet, given to each attendee, outlined important background information and relevant project facts. Each fact sheet was customized for that particular community, neighborhood or area;**

- **A bilingual project brochure was also given to everyone. The brochure addressed the importance of electric trolley buses in terms of the regulatory requirements, as well as potential environmental health improvements;**

- **Charts, graphs, maps, renderings, and photo displays were placed around meeting rooms to help attendees visualize various technical and aesthetic aspects of the project.**

DURING THE FIRST PHASE OF THE PROGRAM, APPROXIMATELY 60 SUCH MEETINGS WERE HELD, INCLUDING AT LEAST ONE IN EACH OF THE SIX LACTC GEOGRAPHIC AREAS.

FOR EACH MEETING, A LIST OF ATTENDEES WAS GATHERED AND A BRIEF SUMMARY OF THE COMMUNITIES' INPUT WAS LISTED ON FORMS AS SHOWN BELOW

(Example only):

RECORD OF COMMUNITY INPUT

MEETING DATE: January 19, 1991

COMMUNITY CONTACT: San Fernando Valley Transportation Summit Group

AGENCY CONTACT: Nick Patsaouras, Alan Pegg, Albert Perdon, Gary Spivack,Nadeem Tahir, Bob Kreeb

COMMUNITY INPUT:

Comments from the community were very supportive of electric trolley implementation.

- The study should report on the feasibility of battery power.
- Electric trolleys are okay as an interim step pending technology improvements that eliminate need for overhead wires.
- Electric trolley okay for major streets; on residential streets utilities are being put underground.
- Commit also to research and demonstration projects to improve electric bus technology.

ISSUES:

- The possible danger of electromagnetic fields around the wires.
- The possible additional generating capacity needed.
- The cost of later converting overhead wires to underground wires.

COMMENTS ON LINES:

- Ventura Boulevard would be an excellent choice.
- Victory Boulevard is an excellent candidate.
- Electric buses will make Ventura Boulevard a speedway and ruin it for small businesses.

ACTION ITEMS:

- Analyze Ventura Blvd. and Victory Blvd. for conversion – N. Tahir, B. Kreeb
- Hold additional meetings in San Fernando Valley with focus on community input along Ventura Blvd. & Victory Blvd. – M. Hernandez, K. O'Grady.

***Note:** All records of community input for each meeting are presented in an Appendix to Task Report 6, "Community Acceptance"*

PARTICIPANTS AT THE COMMUNITY MEETINGS WERE ASKED TO FILL OUT COMMENT SHEETS - - - THE PROJECT TEAM HAS RECEIVED ABOUT 300 OF THESE SHEETS TO DATE

COMMENT SHEET

- RTD and LACTC are jointly performing a study to determine the implementation requirements of bus electrification in LA County.
- The study will compare Electric Trolley buses to other cleaner fuels technologies.
- Part A, to be completed in February, will identify a small number of existing bus lines for early conversion to electric trolley bus service.
- Part B, to be completed in June, will result in a countywide electric trolleybus implementation plan.
- You are a part of this study; your opinion is needed.

Yes, I support Electric Trolleybuses in Los Angeles.

Yes, I support installing Electric Trolley buses on the following Streets: ____________________

____

____

Yes, I support Electric Trolley buses under the following conditions: ____________________

____

____

I have the following concerns about Electric Trolley buses and do not support them at this time: _____

____

____

Name: ____________________

Organization: ____________________

Address: ____________________

____

Telephone: ____________________

***Note:** All comment sheets have been provided to RTD as part of the Task 6 Report*

ELECTRIC TROLLEY BUS

ROUTE SPECIFIC MEETINGS

City	Bus Routes	MEETING ATTENDEES				Letters of Support to Date
		Elected Officials	City Staff	Chamber Meetings	Special Interest	
Alhambra	76	X			X	X
Beverly Hills	16					
Burbank	92/93		X		X	
Carson	45		X			
Commerce	18		X			
Compton	45		X			
Culver City	33				X	
El Monte	76	X	X	X		X
Glendale	92/93, 180/181	X	X	X		X
Hawthorne	40	X	X			
Inglewood	40		X			
Lawndale	40	X	X			
Los Angeles City	16, 18, 30, 33, 40, 45, 76, 92/93, 180/181, 420/424	X	X	X	X	
Monterey Park	18, 30					
Pasadena	180/181	X	X		X	X
Rosemead	76	X				X
San Fernando	92/93				X	
San Gabriel	76	X				
Torrance	40		X			

PUBLIC REACTION AND ACCEPTANCE THUS FAR HAS BEEN EXTREMELY POSITIVE:

- **Reduction of air pollution perceived as a major benefit - - - particularly in areas with heavy bus traffic**

- **Reduced noise and vibration also seen as major benefits**

- **Virtually all communities expressed an interest in trolley bus service with no communities indicating that they were firmly opposed to their implementation.**

SEVERAL POTENTIAL CONCERNS WITH TROLLEY OPERATION WERE EXPRESSED AT COMMUNITY MEETINGS AND ARE BEING ADDRESSED AS THE PROGRAM PROCEEDS

CONCERNS	RESPONSE
Health effects of electromagnetic fields due to use of overhead wires	Trolleys will operate on the same voltage as Metro Light and Heavy Rail. Health effect issues have been linked to high voltage AC transmission – not 750 volt DC. Industry is conducting studies we will watch closely
Maneuverability/flexibility of the trolley system	Trolleys can operate on any street that a normal bus can. APUs increase flexibility of off-wire operation. Routes change infrequently – overhead wires can be moved if necessary
Hazards associated with high voltage wires such as accidents, fire-fighting efforts, and repair and maintenance	Experience in other cities shows these issues are manageable and do not present any serious impediment to safe operation and maintenance of the system. Proper programs and training must be put in place.

POTENTIAL CONCERNS WITH TROLLEY OPERATION - - - CONTINUED

CONCERNS	RESPONSE
Aesthetic acceptability of the overhead wires	**Measures to mitigate visibility of wires and improve streetscape have been included in the basic design and costing of the system:** • **Joint use of traffic signal and streetlight poles to support overhead** • **Use of a "feederless" power distribution system** • **Planting of trees along route where appropriate** • **Minor route modifications to minimize clustering of wires/equipment at intersections**
Useful life of trolley bus technology–will it become obsolete with advancements in battery, fuel cell, or roadway powered vehicles	**All non-polluting, self-contained technologies must overcome major design and cost obstacles before commercialization is practical or even feasible. Such developments cannot be counted on or planned for. Trolleys can yield near zero level pollution today.**

VEHICLE TECHNOLOGY

SEVERAL FUNDAMENTAL DECISIONS REGARDING VEHICLE TECHNOLOGY MUST BE MADE

Vehicle Size and Configuration

- **Standard 40 Foot**
- **Articulated 60 Foot**

Traction System

- **AC**
- **DC**

Secondary Power

- **APU/Dual Mode**
- **Type**

MODERN TROLLEY BUS PROPULSION SYSTEMS INCORPORATE SEVERAL ADVANCES OVER OLDER TROLLEY BUS DESIGNS

- **Use of solid state speed control vs. switched resistor CAM controllers**
  - **Better power regulation efficiency**
  - **Smoother ride: no jerk when changing speed**
  - **Improved maintenance diagnostics: use of plug-in modules for complex control equipment**
  - **Improved regenerative braking**
- **The most recent trolley bus designs also incorporate**
  - **AC drive (versus DC propulsion drive)**
  - **Battery powered APUs (versus diesel or gasoline powered APUs)**

IMPROVEMENTS IN SOLID STATE CONTROLLER TECHNOLOGY AND REGENERATIVE BRAKING WILL REDUCE POWER CONSUMPTION OF NEW TROLLEY COACHES BY 25 TO 35 PERCENT OVER OLDER TROLLEY DESIGNS

	POWER CONSUMPTION (KWh/MILE)					
	EXISTING DESIGN	ADVANCED SYSTEMS				
LOAD	GENERAL ELECTRIC	GARRETT-STROMBERG	WESTING-HOUSE	ALSTHOM ATLANTIC	AVERAGE ADVANCED	AVERAGE REDUCTION FROM EXISTING TROLLEYS
EMPTY	4.18	2.50	2.35	2.42	2.42	58%
SEATED	5.12	3.23	2.92	2.69	2.94	57%
CRUSH	5.01	3.61	3.35	2.96	3.30	66%
AVERAGE	4.77	3.11	2.87	2.69	2.89	61%

GRAPHIC 48

TESTING BY BAH IN 1985 AT SAN FRANCISCO MUNI SHOWED ADVANCED SYSTEMS TO IMPROVE FUEL ECONOMY FROM 4.77 KWH/MILE TO 2.9 KWH/MILE ON STANDARD 40 FOOT COACHES.

AC PROPULSION SYSTEM IS PREFERRED OVER DC

- **Approximately same efficiency as DC drive**
- **Better regenerative braking performance - - - especially at low speed**
- **Less traction motor maintenance**
  - **No commutator and brush system**
  - **Impervious to dirt and water ingestion**
- **Less prone to major traction motor failure**
  - **Flash over**
  - **Commutator burning**
  - **High current over heating**
- **Both GE and Westinghouse have proven competitive systems**

OFF-WIRE CAPABILITY CAN BE ACHIEVED WITH A DUAL MODE BUS OR AN AUXILIARY POWER UNIT (APU)

- Dual mode buses have a separate diesel engine and drivetrain to supplement the electric traction system
  - Full performance can be attained both on and off wire
  - Disadvantages of both systems tend to come along with the advantages
  - Very complex vehicle – two complete power systems
    - Extremely heavy - - - increasing operating costs (fuel consumption; brake wear, etc.)
    - Very expensive
    - Difficult to service - - - reliability is an issue
- A small scale variant of dual power is a small internal combustion engine APU driving an alternator
  - Approximately 100 horsepower – 20 mph top speed
  - Range limited only by fuel tank size
  - Can be diesel or gasoline fueled
    - Alternative fuel capability could be developed
  - Complex system
    - Approximately 1000 pound weight penalty
    - Separate driver controls for engine starting, monitoring, etc.
    - Supplemental traction motor controller required
  - Small engine APU systems relatively popular in Europe
- Battery APU can provide limited off-wire capability
  - Performance and range is a direct function of the battery system weight
  - Simple drive controls - switch or automatic activation with loss of overhead line power
  - Low maintenance requirements

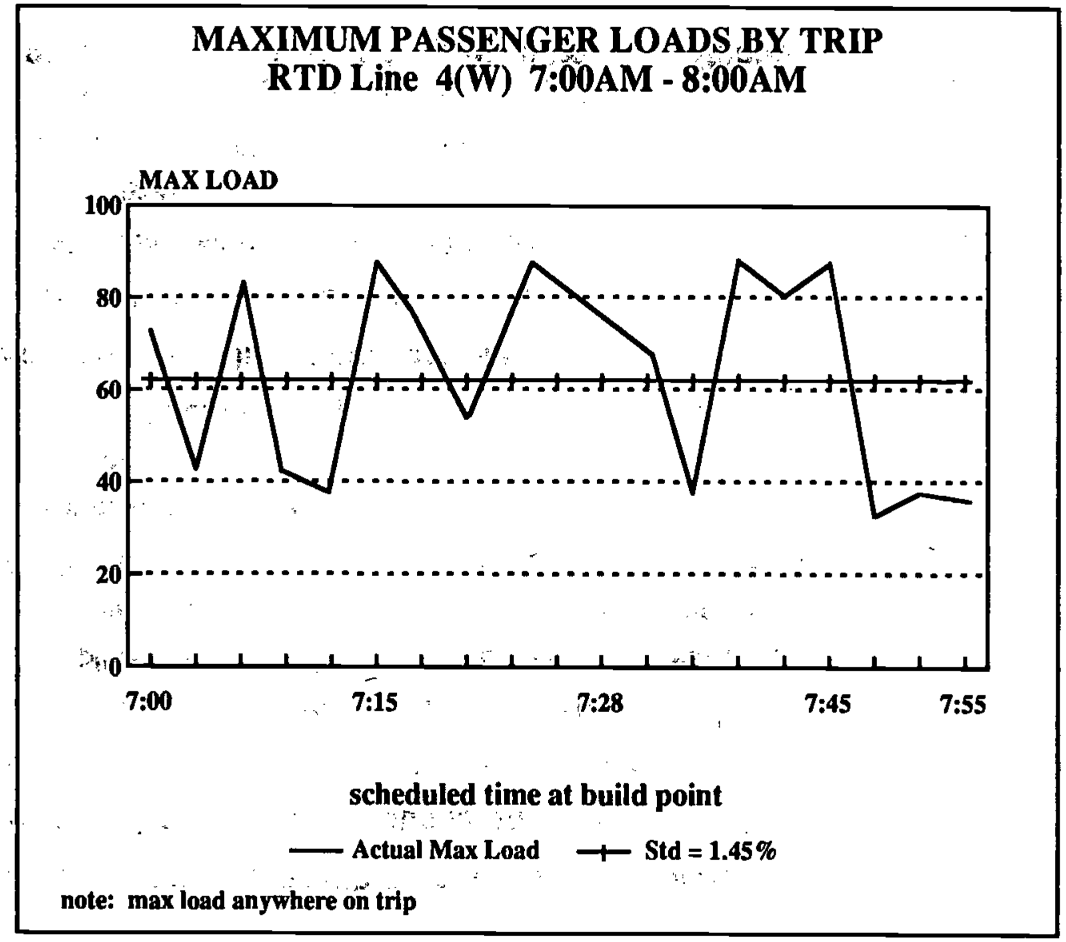
BATTERY TYPE AUXILIARY POWER UNIT (APU) IS RECOMMENDED

- **Saves wiring in division yards ($2M+)**
- **Provides in-service operational flexibility**
  - **Maneuver around accidents**
  - **Short turn-back runs**
  - **Power through insulated sections**
- **800-1000 pound battery system will be adequate**
  - **2 to 3 mile range**
  - **Most cost/weight effective**
  - **Requires little maintenance**
- **Standard Lead/acid golf cart or tubular cell type battery**

APU TESTING DONE BY BOOZ, ALLEN FOR SAN FRANCISCO MUNI IN 1988 CONCLUDED THAT BATTERY POWERED APUS OFFER ADVANTAGES IN TERMS OF RELIABILITY, MAINTENANCE AND COST OVER GASOLINE POWERED APUS - - - DUAL MODE BUSES ARE TOO COMPLEX, EXPENSIVE AND HEAVY FOR PHASE I IMPLEMENTATION - - - AND EMISSIONS REDUCTIONS ARE COMPROMISED.

BATTERY POWERED APU DESIGN RECOMMENDATIONS

- Battery would be protected with a Smart (Micro-Processor) System
  - Charges battery whenever bus is on-wire
  - Smart System would control battery charger
    - Charging current determined by state-of-charge
    - Applies equalizing charge at proper rate and frequency
    - Can also control periodic automatic battery watering
  - Smart System can identify maintenance needs and defects
    - Weak batteries needing replacement
    - Bad battery connections
- A tubular cell lead/acid battery system is recommended
  - Lowest cost on a life cycle cost basis
  - Highly developed for electric vehicles
    - Withstand repeated deep discharges
    - High cycle life
  - Replacement batteries are readily available
  - Battery tray and Micro-Processor would be compatible/adaptable to most of the new technology batteries when they become cost effective
    - Nickel/Iron
    - Nickel/Cadmium


MAXIMUM PASSENGER LOADS BY TRIP
RTD Line 4(W) 7:00AM - 8:00AM
MAX LOAD
100
80
60
40
20
0
7:00
7:15
7:28
7:45
7:55
scheduled time at build point
Actual Max Load
Std = 1.45%
note: max load anywhere on trip

GRAPHIC 57

ARTICULATED TROLLEY COACHES CAN OFFER ADVANTAGES FOR RTD

- Reduce fleet size requirements: A 2 for 3 replacement of standard 40 ft coach is possible based on capacity as shown below:

	40 - FT (1)	ARTIC (2)
Total Seated	43	65
Total Standee Rating	60	90

A 3 for 4 replacement ratio is more common practice in other cities and allows for a reduction in fleet size while mitigating the associated increase in headways. A one for one replacement would result in an increase of route capacity by 50%.

- Reduce vehicle bunching and improve vehicle/passenger load distribution. Many of RTD's routes are at or over capacity. Such lines often experience a vehicle load distribution phenomena as illustrated on the facing page. Peak passenger loading appears to occur on every other bus at a particular stop with alternate arriving buses well below capacity. Increasing headways (slightly) but providing for greater capacity on each bus would tend to smooth the supply of buses versus passenger demand. Careful scheduling and monitoring on a route-by-route basis would be required to take full advantage of the articulated concept. Nevertheless, articulated buses can offer RTD transportation planners a useful means of reducing vehicle bunching and better distributing vehicle availability on selected routes in RTD's system.

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(1) *SCRTD Standard Bus Specification*

(2) *Typical Articulated Bus Specification*

CALCULATIONS/ASSUMPTIONS: STD VS. ARTICULATED COACH OPERATING COSTS

FUEL

40-FOOT TROLLEY	41 BUSES x $\frac{42,000\ \text{MILES}}{\text{BUS}}$ x $\frac{3.0\text{kWh}}{\text{MILE}}$ x $\frac{\$.09}{\text{kWh}}$	= \$464,940
ARTICULATED TROLLEY:	27 BUSES x $\frac{42,000\ \text{MILES}}{\text{BUS}}$ x $\frac{4.5\ \text{kWh}}{\text{MILE}}$ x $\frac{\$.09}{\text{kWh}}$	= \$459,270

DIRECT MAINTENANCE

40-FOOT TROLLEY	41 BUSES x $\frac{42,000\ \text{MILES}}{\text{BUS}}$ x $\left[\frac{\$.53}{\text{MILE}}\ \text{(vehicle)} + \frac{\$.25}{\text{MILE}}\ \text{(catenary)}\right]$	= \$1,343,160
ARTICULATED TROLLEY:	27 BUSES x $\frac{42,000\ \text{MILES}}{\text{BUS}}$ x $\left[\frac{.92}{\text{MILE}}\ \text{(vehicle)} + \frac{\$.25}{\text{MILE}}\ \text{(catenary)}\right]$	= \$1,326,780

OPERATIONS COSTS

40-FOOT TROLLEY	41 BUSES x $\frac{42,000\ \text{MILES}}{\text{BUS}}$ x $\frac{\$2.10}{\text{MILE}}$	= \$3,616,200
ARTICULATED TROLLEY:	27 BUSES x $\frac{42,000\ \text{MILES}}{\text{BUS}}$ x $\frac{\$2.10}{\text{MILE}}$	= \$2,381,400

GRAPHIC 47

Note: Articulated trolley maintenance costs are assumed to be 75 percent higher than for a 40 foot trolley on a per mile basis. For details on fuel and maintenance costs of 40 ft. and articulated trolleys, see the Alternative Technology Analyses section of this report and/or Task Report 3, "Low Emission Transit Alternatives".

ARTICULATED COACHES CAN OFFER SUBSTANTIAL SAVINGS IN OPERATING COSTS

EXAMPLE LINE 30			
	40-FOOT TROLLEY COACH	ARTICULATED TROLLEY COACH (2 for 3 REPLACEMENT)	ARTICULATED TROLLEY COACH (3 FOR 4 REPLACEMENT)
PEAK PM BUSES	41	27	31
PEAK HEADWAYS	4 MINUTES	6 MINUTES	5.3 MINUTES
OPERATING COSTS			
• FUEL (Power)	$464,940	$459,270	$527,310
• MAINTENANCE	$1,343,160	$1,326,780	$1,523,340
• OPERATIONS	$3,616,200	$2,381,400	$2,734,200
TOTAL	$5,424,300	$4,167,450	$4,784,850
SAVINGS FOR ARTICULATED COACHES (PER YEAR PER ROUTE):			
• DOLLARS		$1,256,850	$639,450
• %		23%	12%

GRAPHIC 10

THE SAVINGS RESULT ALMOST ENTIRELY FROM A REDUCTION IN OPERATOR COSTS DUE TO A REDUCED NUMBER OF VEHICLES ON THE ROAD.

ELECTRIC POWERED ARTICULATED BUSES DIRECTLY ADDRESS TRADITIONAL SHORTCOMINGS OF ARTICULATED MOTOR BUS DESIGNS - - THUS FACILITATING THE SUCCESSFUL IMPLEMENTATION OF THE ARTICULATED CONCEPT

	DIESEL ARTICULATED	ELECTRIC ARTICULATED
Performance	Diesel articulated coaches are traditionally underpowered,resulting in poor acceleration and driveability.	Electric Artics receive as much power as required from the overhead wire. Acceleratrion is better than even 40 ft diesel coaches (see trolley advantages).
Reliability	Generally very poor due to high load factors imposed on engine, transmission, final drive, and cooling systems. Other subsystems, including air conditioning and generators, are also "stretched".	Anticipated reliability is very good due to AC drive systems, solid state controllers and simplicity of final drive system (no transmission, cooling system, or engine to maintain).
Durability	Generally poor since major drive components are strained. Braking systems also show poor durability due to heavy loading.	Anticipated durability is good since electric drive systems are designed for high load factor applications (steep grades such as in San Francisco and/or crush passenger loads). Regenerative braking will reduce high brake wear.

GRAPHIC 11

RISKS ASSOCIATED WITH ARTICULATED TROLLEY BUSES MUST BE MITIGATED TO CAPTURE COSTS SAVINGS POTENTIAL

- Previous SCRTD experience with articulated diesel buses was not good
  - High maintenance costs
  - Protracted and occasional unsuccessful negotiations with Municipalities for lengthened bus stops
  - High body damage costs - especially the trailer
- SCRTD must simultaneously learn to manage electric trolley and articulated bus operations
- No proven articulated trolley bus product in North America
  - Seattle METRO's M.A.N.'s still have problems
    - Center axle adhesion - tirewear - traction
    - M.A.N. abandoned N.A. market
  - MUNI's New Flyers are not yet in service
    - Prototype scheduled for delivery Summer '92
    - Production trolley delivery Fall '93
- Procurement may be difficult
  - New Flyer is only remaining North American manufacturer with any trolley experience
  - Neoplan has built diesel articulated – Bid MUNI with Japanese propulsion system
  - Breda (Italy) sold METRO dual mode Artic coaches - - - and bid MUNI Artic trolley at $800k

USE OF ARTICULATED COACHES IS CRITICALLY LINKED WITH PROPER ROUTE ASSIGNMENTS

- **Short headways; high patronage**
- **Heavy use during base as well as peak**
- **Minimum required R.O.W. and bus stop modifications**
- **Operating division must be able to accommodate Artics with minimum facility modification**
- **Other routes specific traffic issues that might be aggravated by an articulated coach (articulated coaches will have a slower average route speed due to longer dwell times and increased difficulty in moving thru traffic)**

CAREFUL TROLLEY BUS IMPLEMENTATION PLANNING CAN ASSURE SUCCESS

- **Personnel at new division selected for dedication to program and commitment to success**
- **Focus training on positive aspects and team concept**
  - **Part of a premium service operation - - - "this is no ordinary bus"**
- **Support Program Team**
  - **Tools and diagnostic equipment**
  - **Adequate space and other facilities**
- **For the long term operation, the establishment of a new articulated trolley bus division should be considered**

OVERHEAD WIRE AND POWER DISTRIBUTION SYSTEM DESIGN

RTD is in the unique situation of having the opportunity to establish the first all new trolley bus system in North America in the last 30 years. Component specifications and system design can be developed without the hindrance of having to conform to any existing overhead wire infrastructure and equipment inventory. The very latest and most maintenance free equipment (being used most frequently in Europe) can be specified for the system. Our discussions with trolley operators in North America also suggest that there are several things they might do differently if they could "start from scratch" - - - as such, L.A. can benefit from the lessons learned in other cities. Some of these design considerations are somewhat obscure, but nevertheless important for easing implementation problems and improving operating efficiencies. RTD/LACTC should consider sponsoring a "trolley bus technology symposium" inviting trolley system operators from around the would as well as vehicle and overhead catenary equipment suppliers.

Booz·Allen and MKE have already incorporated in the recommendations in our task reports many of the major design elements needed to establish the foundation for a premier trolley system.

Note: For a more detailed discussion of overhead wire and power distribution design, please see Task Report 1, "Technology Assessment"

ALTHOUGH THE GENERAL DESIGN AND DIMENSIONING OF TROLLEY OVERHEAD WIRE SYSTEMS ARE SIMILAR WORLDWIDE, EQUIPMENT SPECIFICATIONS ARE SELECTED BASED UPON OPERATIONS AND MAINTENANCE, AESTHETICS, COSTS, CLIENT PREFERENCES, AND OTHER CONSIDERATIONS

EQUIPMENT OPTIONS

Traction Power Supply: "Feederless" system vs. parallel feeder wires

Parallel Feeders (if used): Underground vs. overhead routing

Substations: Size, spacing , and location considerations

Trolley Wire Support: Cross-span wires vs. cantilever poles

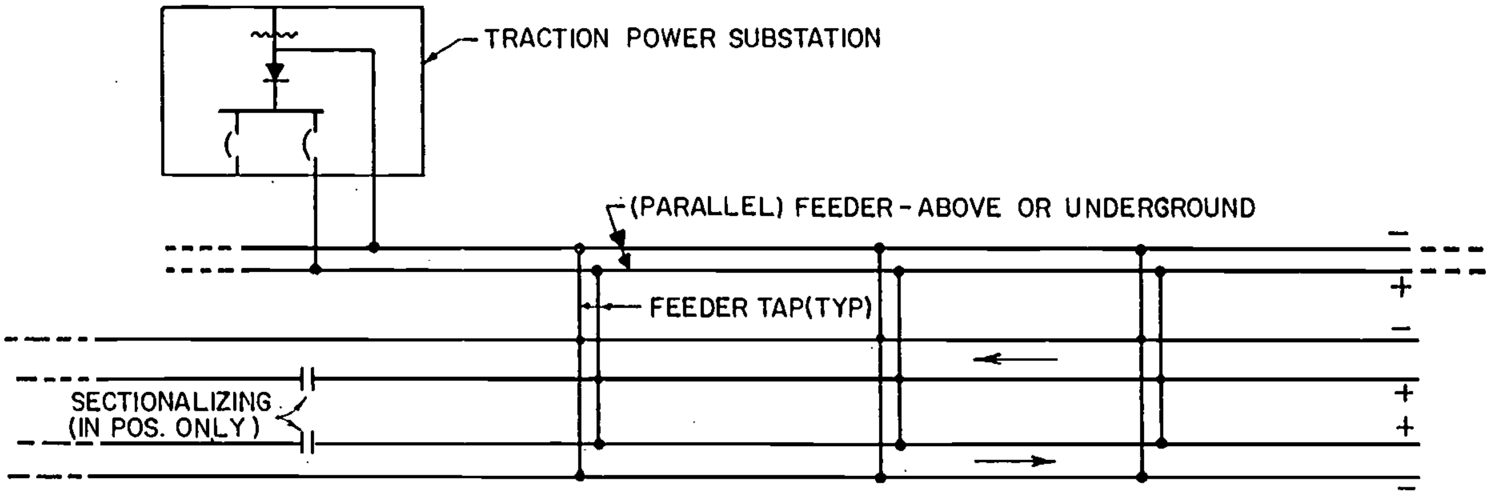
Cantilever Poles: Separate trolley support poles vs. joint-use of trolley poles with streetlight and traffic signal equipment

POWER SUPPLY EQUIPMENT SIZING IS BASED ON ELECTRICAL NEEDS OF THE SYSTEM. SEVERAL FACTORS WILL INFLUENCE THE POWER REQUIREMENTS ALONG A PARTICULAR ROUTE

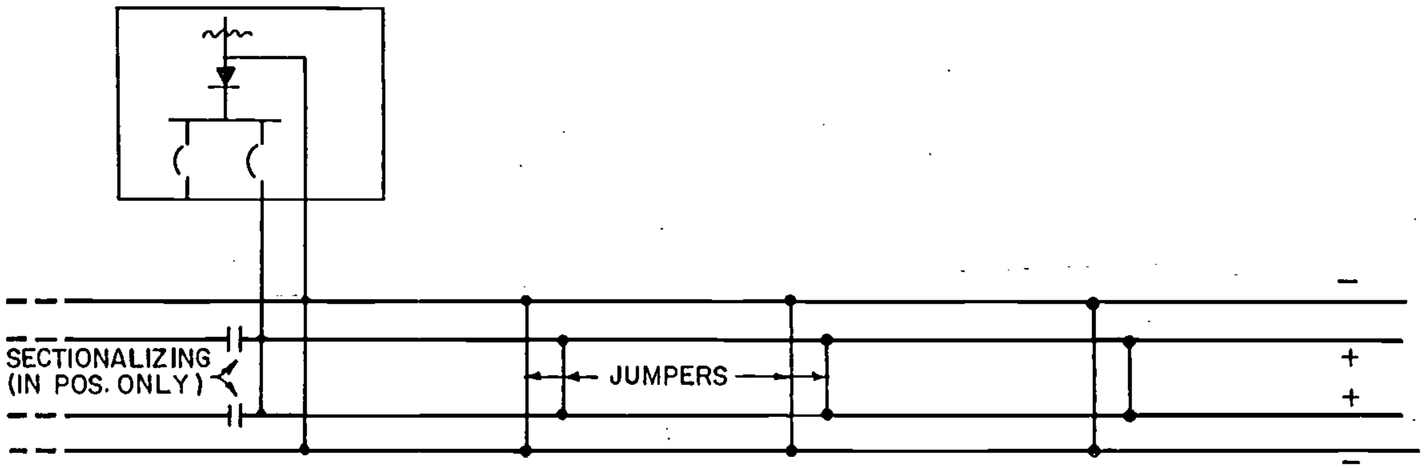
- **Bus headways**
- **Scheduled speeds; number of intersections; number of accelerations/decelerations**
- **Vehicle load factors**
- **Street profile (grades)**
- **Traffic growth**
- **Electrical losses in the system**
- **Degree of system redundancy desired (in the event a single substation fails and adjacent stations must "take up the load")**

WHEN SEVERAL TROLLEY LINES OPERATE ON A SHARED ROUTE, EQUIPMENT MUST BE SIZED ACCORDINGLY.

FEEDER VS. FEEDERLESS SYSTEM



FEEDER SYSTEM



FEEDERLESS SYSTEM

A "FEEDERLESS" SYSTEM IS PREFERRED FOR THE LOS ANGELES APPLICATION

Description

Traditional overhead wire systems often require a 3rd wire to be strung in parallel with the traction power wires. This wire is larger in diameter than the trolley wires and is used to "feed" power to points in between substations thus minimizing power losses in the trolley wire itself. An alternative approach is to locate substations more frequently along the route and utilize high conductivity copper overhead wire. Route density influences the viability of such "feederless" systems. Preliminary analyses indicates that feederless systems are implementable along most of RTD's routes.

Advantages

- **Reduces street construction work**
- **Reduces overall capital costs**
- **Improves aesthetic acceptability of system**
- **Eliminates need for undergrounding of feeder cables**

Disadvantages

- **If route density increases, additional and/or larger substations will be required - locating substations may become an issue**
- **Soft copper wire wears more quickly than harder bronze/brass wire, thus increasing maintenance and replacement costs**

UNIT COSTS FOR TRACTION POWER SUPPLY SYSTEMS - - - INCLUDING SUBSTATIONS AND FEEDER CABLES - - - ARE SHOWN BELOW:

	TROLLEY WIRE OPTIONS ($1,000 per route mile)			
	SINGLE TRACK		DOUBLE TRACK	
FEEDER TYPE/BUS FREQUENCY	ONE WAY	TWO WAY	ONE WAY	TWO WAY
UNDERGROUND FEEDER SYSTEMS				
HIGH FEQUENCY	$805	$817	$812	$826
LOW FREQUENCY	$730	$742	$737	$751
OVERHEAD FEEDER SYSTEM				
HIGH FREQUENCY	$421	$433	$428	$442
LOW FREQUENCY	$400	$411	$407	$420
FEEDERLESS SYSTEM				
HIGH FREQUENCY	$330	$342	$337	$351
LOW FREQUENCY	$330	$342	$337	$351

GRAPHIC 48

UNDERGROUNDING OF FEEDER CABLES WILL COST APPROXIMATELY $400,000 PER ROUTE MILE

LOCATING SUBSTATIONS WILL BE A SIGNIFICANT IMPLEMENTATION TASK

- **Pre-assembled substations measure approximately 20 feet x 20 feet but require additional clearance on all sides - - - substations are anticipated to be sized from about 500 KW for single bus routes to 1000 KW for downtown lines with multipie routes operating on the same street.**

- **Minimum substation sites should be 25 feet x 35 feet**

- **Substation should be located as close to the trolley line as possible - - - no more than 200 feet away.**

- **Possible locations include corners of parking lots, nearby buildings, and other locations**

- **Utility companies (DWP and SCE) have expressed an interest in assisting RTD in locating and maintaining the substations.**

Overhead Wire and Support Hardware Costs
(per Route Mile)
$Thousands

	Trolley Wire Options			
	Single Track		Double Track	
	One-Way	Two-Way	One-Way	Two-Way
<u>Basic Trolley Overhead</u>				
Cross Span Supports	$590	$710	$690	$890
Bracket Arms	$390	$780	$520	$1,040
Additional Costs for Incorporating Street <u>Lights and Traffic Signals and Shared Poles</u>				
Cross Span Supports	$200	$200	$200	$200
Bracket Arms	$100	$200	$200	$200
<u>Special Work Items per Intersection</u>				
Turn Movement (Note: all of these	$25	$50	$25	$50
Crossing items are not needed	$10	$40	$40	$80
Switch (Pair) at every intersection)	$15	$30	$30	$30
<u>Representative Total</u>				
Cross Span Supports	$830	$990	$950	$1,190
Bracket Arms	$530	$1,060	$680	$1,340

CANTILEVER BRACKET ARMS ON CURBSIDE SUPPORT POLES ARE PREFERRED OVER CROSS SPAN WIRES TO SUPPORT TROLLEY OVERHEAD

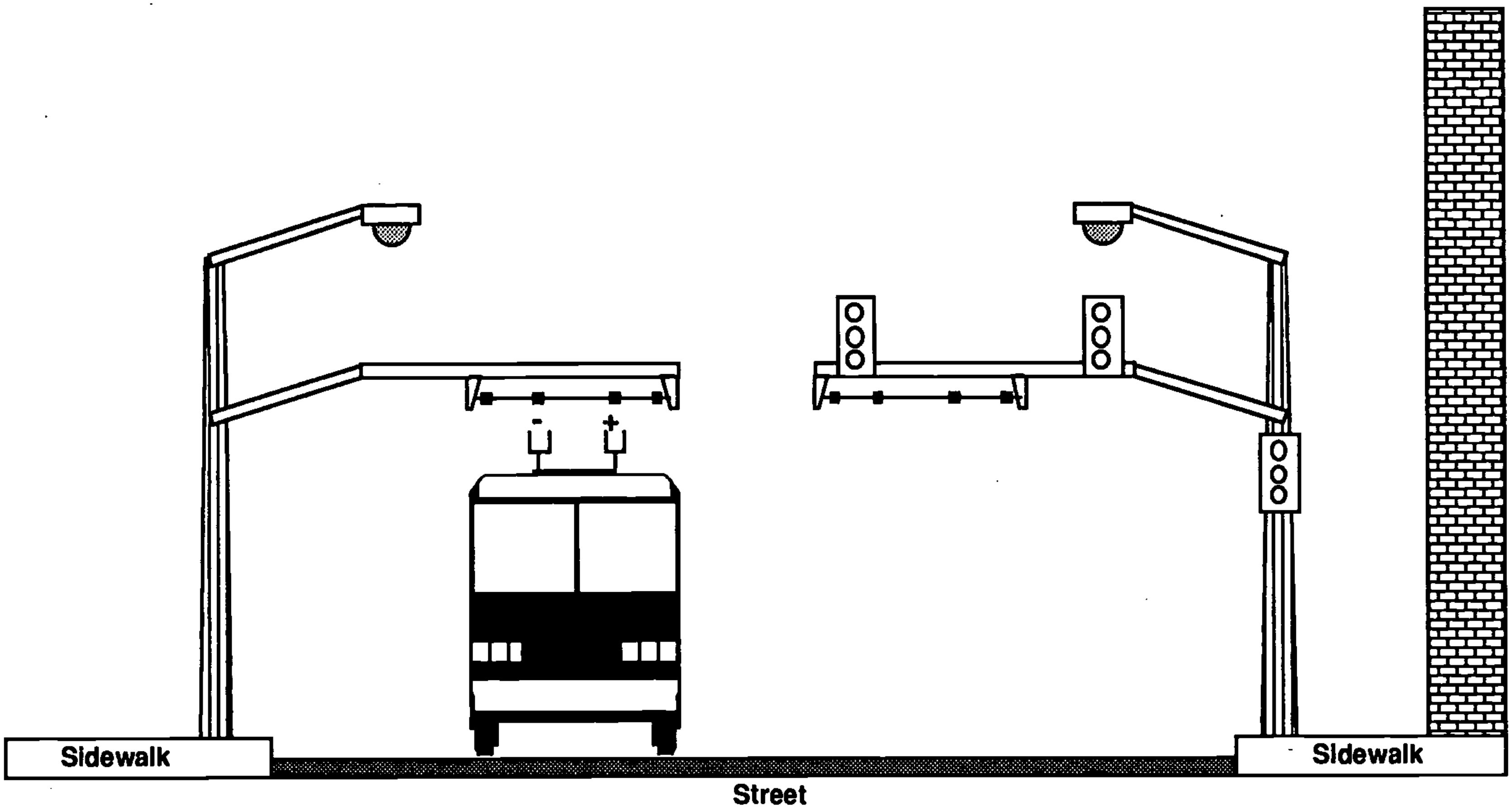
Definition

Cross span wires can be fastened between poles located on opposite sides of the street, or attached to eye bolts located on buildings along the street. Trolley wires are then suspended from the cross span wire as shown on the following page. This was the method of support used in Los Angeles many years ago. Trolley wire can also be suspended from cantilever bracket arms affixed to support poles that line the street on both sides. The support poles can be either installed expressly for trolley wire support or joint-use poles can be installed that function both as traffic signal and/or street light support as well as for trolley wire support.

Advantages

The primary advantage of cantilever bracket arms is visual mitigation of the cross span wire that is visible from all points on the streetscape. Joint-use poles further reduce visual intrusion of the system by minimizing the number of additional curbside poles needed for overhead support.

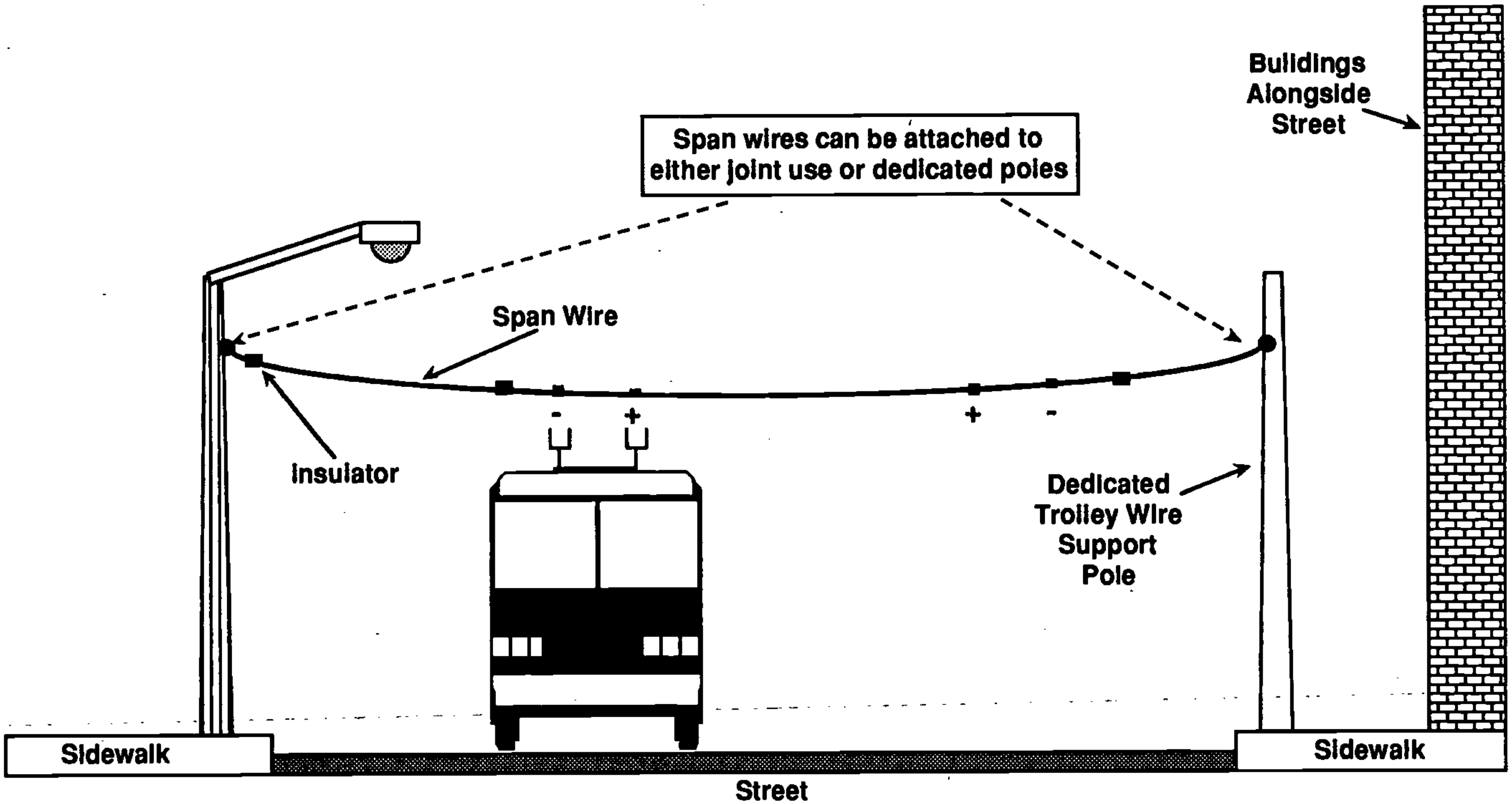
BRACKET ARM SUPPORT



GRAPHIC 50.2

PRES/RCC - 03

CROSS SPAN WIRE SUPPORT



CROSS SPAN SUPPORT

GRAPHIC 50.1

IMPLEMENTATION OF SHARED USE POLES WILL REQUIRE CONSIDERABLE COORDINATION WITH UTILITIES, VARIOUS PUBLIC WORKS DEPARTMENTS, STREET MAINTENANCE DEPT., AND LOCAL COMMUNITIES

- **Street light designs vary considerably throughout Southern California as a result of local requirements and community preferences**

- **Responsibility for streetlight maintenance and traffic signal equipment also varies from city to city**

	Utility	**Traffic Signalling**	**Street Lighting**
L.A. City	DWP	L.A. DOT	Bureau of Street Lighting
L.A. County	SCE	Dept. of Public Works	Dept. of Public Works

- **Other agencies affected by trolley wire installation such as CALTRANS and local fire departments will also need to be involved during the engineering design phase of the program.**

- **Locating new poles and/or re-design of existing poles will be a major issue with property and business owners along the route - - - an extremely high degree of cooperation between the design team, the community, and RTD will be required to establish a mutually acceptable system.**

PRELIMINARY DISCUSSIONS WITH THESE AGENCIES INDICATE THAT SEVERAL ISSUES MUST BE RESOLVED FOR IMPLEMENTATION TO PROCEED SMOOTHLY

Issue	Concern	Resolution
Safety	• Implementation of shared use poles will pose a safety hazard for equipment maintenance personnel. High voltage wires should not be routed inside lower voltage streetlight and traffic signal poles.	• Proper training and maintenance procedures must be implemented. Shared-use poles are commonly used in other cities operating trolley fleets. Less than 5% of the support poles will require high voltage feed wires inside the poles.
	• Trolley wires could pose a hazard for fire fighters. Emergency situation and fire fighting operating procedures must be developed.	• Again, proper disconnect and auto-shut-off systems must be developed early in the design phase with the cooperation of the Fire Dept. No fatal flaws exist.
Design Standards	• Unique and historic street poles exist in many parts of the city - - - these poles should be retained.	• Almost any ornate pole can be adapted for trolley support but higher costs may result. Pole design must be based on agreements with local neighborhoods.

ISSUES MUST BE RESOLVED - - - CONTINUED

Issue	Concern	Resolution
Power outages	• Temporary power outages will shut down the entire system.	• Adjacent substations will not be fed from the same primary utility power supply. System design capacity will be such that a single substation can fail and power from adjacent substations can support continued operations.
Street closures and temporary blockages	• Constructions, street closures, accidents, etc. will halt trolley service - - - inconvenience passengers while waiting for a motor bus to continue service.	• Trolley buses will be equipped with battery APUs which will permit buses to continue around most obstructions and back onto the overhead wire.
Maintenance of the System	• Who will maintain the trolley overhead wire and support poles?	• RTD will maintain overhead wire - - - pole maintenance agreements must be established with local authorities.

IMPROVEMENTS IN POWER DISTRIBUTION AND OVERHEAD WIRE EQUIPMENT DESIGN IN RECENT YEARS OFFER THE POTENTIAL FOR REDUCING TROLLEY SYSTEM OPERATING COSTS

- **Evolutionary improvements in overhead wire system designs have taken place over the last 10 years, which appear to improve system reliability, reduce overall maintenance and reduce incidents of de-wirements. Some of these changes include:**
  - **Replacement of old 30-degree angle switches with lower angle (10- or 15- degree) switches. These switches allow for executing a turn at higher speeds with less risk of de-wirement.**
  - **Use of radio controlled track switching devices at intersections instead of old style "selectric" switches. Newer switches are controlled by a low frequency radio signal activated by the driver's turn signal. This new radio controlled switch technology dramatically reduces de-wirements compared to older selectric style switches.**
- **Use of "deep runner crossings" – this overhead wire architecture allows the contact shoe to maintain continuous contact as the trolley moves through crossings at intersections. Older designs tend to lift the wire out of the shoe so that it is riding mostly on the flange of the shoe as the trolley moves through a crossing. "Deep runner" crossings reduce incidents of de-wirements.**
- **Use of fiberglass pick-up and long (10-inch) contact shoes – more flexible poles and longer shoes also help to reduce de-wirements.**
- **"Extra" curve segments – new trolley routes in San Francisco and Seattle use "extra" curve segments at intersections and on sharp turns. The gradual track turning profile more closely follows the actual bus turning radius and reduces wear as well as de-wirements.**
- **San Francisco reports that the newest trolley route extensions (which incorporate these improvements) show a 50% reduction in de-wirements.**

AESTHETIC CONSIDERATIONS FOR CATENARY SYSTEMS

AESTHETIC CONSIDERATIONS

- **The successful operation of electric trolley bus systems for many years in San Francisco, Vancouver, and other cities that are known for high urban density standards attests to the probability of success for similar systems in Los Angeles. Through the proper selection of route corridors, design of system elements, and mitigation of negative impacts, electric buses can provide a cleaner, quieter form of public transport in highly travelled urban corridors.**

- **The key purpose of this task is to evaluate the compatibility of electric buses in the candidate electric bus corridors and to visually present what potential these systems have for enhancing the urban design cohesiveness of the communities through which they pass. Electric bus systems can either enhance or impair the visual setting, depending upon the scale and design of the transit facility, the physical and visual characteristics of the areas along the system's route, and the extent of mitigation measures. What may be an acceptable design in the Los Angeles Central Business District may not be an appropriate design in the South Bay or the San Fernando Valley.**

Note: ***For a more detailed review of aesthetic considerations, see Task Report 5, "Aesthetic Issues"***

TO UNDERSTAND THE IMPACT OF OVERHEAD TROLLEYS ON THE URBAN ENVIRONMENT A PLANNING APPROACH WAS UNDERTAKEN WHICH INCLUDED:

- **Identifying through a windshield survey the general existing urban design characteristics of each candidate route in order to evaluate a corridor's positive and negative aesthetic features. Characteristics included the location and species of existing street trees, existing overhead utility poles, existing types of street lights, generalized existing land uses, building pattern and scale, street characteristics (curb parking, diagonal parking, landscape median) and other unique conditions.**

- **Determine streetscape conditions typical to a variety of corridors in the RTD system to use as prototypes for evaluation purposes.**

- **Identifying possible mitigation measures for the visual impacts of the overhead trolley system.**

THE FOLLOWING ROUTES WERE USED TO EVALUATE THE VISUAL IMPACTS AND MITIGATION MEASURES OF OVERHEAD WIRE SYSTEMS: #92, #204, #40, #45, AND # 30.

THE TROLLEY BUS CATENARY SYSTEM CAN BE UNOBTRUSIVELY INTEGRATED INTO THE URBAN ENVIRONMENT

- **Feederless power supply**
- **Cantilever arms off curbside poles (no cross-span wires in middle of street)**
- **Integrated joint use poles with traffic signals and street lighting**
- **Minimize special work at intersections by limiting route design to one turn per intersection**
- **Plant trees to mitigate the visual impact of trolley wires**

ADDITIONALLY, THE TROLLEY SYSTEM CAN SERVE AS A CATALYST FOR IMPROVING THE STREETSCAPE THROUGH OTHER MEASURES SUCH AS UNDERGROUNDING OF UTILITY LINES AND IMPROVED BUS STOP DESIGNS

PLANTING OF TREES ALONG THE ROUTE OFFERS THE MOST EFFECTIVE MITIGATION MEASURE:

- **Although the residential streets of Los Angeles have excellent specimens of street trees, its major streets have few trees. Urban design studies being developed for the City of Los Angeles Community Plan Revision Program by community groups and the City's consultants identify street trees as ingredients essential to each community's urban design concept. Street trees can provide shade, reduce air pollution, enhance the visual environment, and provide a unifying image for a community.**

- **Depending on the species selected, a 36-inch to 48-inch box tree should be considered in order to obscure views of the overhead wire for the pedestrian on the sidewalk and the motorist on the street. Selection of the species and a tree maintenance program is important to avoid totally blocking commercial signage along the route. The City of Los Angeles usually recommends that several species of trees should be a part of any urban design concept for each street to avoid a monoculture.**

- **The City of Los Angeles Bureau of Street Maintenance, Street Tree Division spacing standards call for desirable distance between trees at 40 feet to 50 feet. Since trolley wire support poles are to be located 100 feet apart, it can be estimated that a maximum of two trees could be placed between each pole for a maximum total of 196 trees per mile including both sides of the street. A street with a considerable number of curb breaks and utilities would permit fewer trees.**

OTHER MITIGATION MEASURES ARE ALSO AVAILABLE TO COMMUNITIES AND RTD TO ENHANCE THE VISUAL IMPACT OF THE SYSTEM

- **Cantilever Poles and Pole Design**

  Trolley wires in urban areas have historically been supported by span wires which are visible across the entire street. Cantilever poles are available, however, which project 15-17 feet from the curb, leaving the center lanes open to the sky. As most candidate streets in the Los Angeles area are quite wide, the use of cantilever poles will substantially reduce visual impact.

- **Combining Trolley Poles with Street Light and Traffic Poles**

  Street light poles are typically 29-30 feet high and 50-75 feet apart, staggered on either side of the street with "cobra" light fixtures, and in certain areas, "historic" poles and fixtures. Combining trolley poles with street lights will avoid an increase of visual clutter on the sidewalk and will provide the opportunity to replace outdated infrastructure efficiently. City departments must to agree to any joint use of poles.

- **Limiting Turns to Avoid Excessive Wires at Intersections**

  The number of overhead wires at an intersection increases with the number of movements at an intersection. Developing routes that are one way or which avoid left turns can reduce the impact on a particular street.

AESTHETIC ENHANCEMENTS - - - CONTINUED

- **Street Furniture/Special Paving**

  Although the introduction of pedestrian amenities (special benches, bus stops, trash receptacles, paving, banners, graphics, etc.) will not block the view of power poles and overhead wires, such furniture tends to lower the viewpoint of the motorist and pedestrian and contribute to an overall enhanced environment in the community. Such furniture is particularly effective at bus stops.

- **Undergrounding of Utilities**

  Many of the streets in the Los Angeles region with key bus routes have overhead utility wires. Some streets have utility poles with five crossbars and over ten wires. Undergrounding of utilities is costly; however, undergrounding of these wires by the local utilities and removal of the poles in concert with the construction of a trolley system can dramatically improve the visual environment.

EXISTING URBAN DESIGN CHARACTERISTICS OF REPRESENTATIVE ROUTES

Routes	Name	1-Way Route Miles	Overhead Utilities One Side (Miles)	Overhead Utilities Both Sides (Miles)	Existing Street Trees (Miles)	Unique Features
# 204	Vermont Avenue	15.2	6.5	.5	3.0	• Wide landscaped median from 120th to Gage with Canary Island Pines. • Frontage road from Manchester to Florence. • Street trees clustered near USC and north of Santa Monica Blvd. • No overhead wires north of Pico Blvd.
# 45	Broadway Mercury Avenue	15.5	3.3	4.0	2.8	• Landscaped median Imperial to 93rd Street. • Unique double globe lights in downtown as well as wide sidewalks.
# 40	Hawthorne-Union St.-L.A. County Jail	14.4	3.0	2.8	3.5	• Attractive streetscape of Jacaranda and coral trees plus diagonal parking on Market Street in Inglewood. • Route passes around historic Leimert Park. • Downtown same as Route 45.
# 30	Pico Blvd. 1st Street	12.3	3.5	4.3	4.7	• Historic lights, double acorn from Mariposa, to Harbor Fwy.; Unique double-globe lights on Broadway. • Streetscape plan with cable suspended over roadway in Boyle Heights. • Atlantic Blvd. in Monterey Park, attractive streetscape.
# 92/93	18th St. to Glen Oaks (Buena Vista in Burbank) Total Route to San Fernando	16.8 26.4	5.8	1.0	5.1	• Historic lights on Main Street between 1st and 9th and on Spring St. between 7th and 9th Streets. • Attractive streetscape on Brand Boulevard with landscaped median, wide sidewalks, special traffic signals and globe lights. • Ficus, Magnolia, Carrotwood, London Plane trees on route.

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PRELIMINARY COST ESTIMATES FOR ENHANCING THE AESTHETIC APPEARANCE OF SELECTED ROUTES IN RTD'S SYSTEM ARE SHOWN BELOW:

ROUTE	MILES of NEW TREES	TOTAL COST
#204	12.2	$4,782,400
#45	12.7	$4,978,400
#40	10.9	$4,272,800
#30	7.6	$2,979,200
#93/93	11.7	$4,586,400

GRAPHIC 12

- **Costs associated with aesthetic improvements of streetscape (as listed above) include:**
  - **48-inch box tree @ $2000 each, (196 trees per mile) = $392,000/mile**
  - **36-inch box tree @ $1000 each, (196 trees per mile) = $196,000/mile**
  - **Special bus shelters: $12,000 each**
  - **Decorative brick paving: $10/sq. ft.**
  - **Tree gates: $2000 each**
  - **Handicap ramps per corner: $2800**

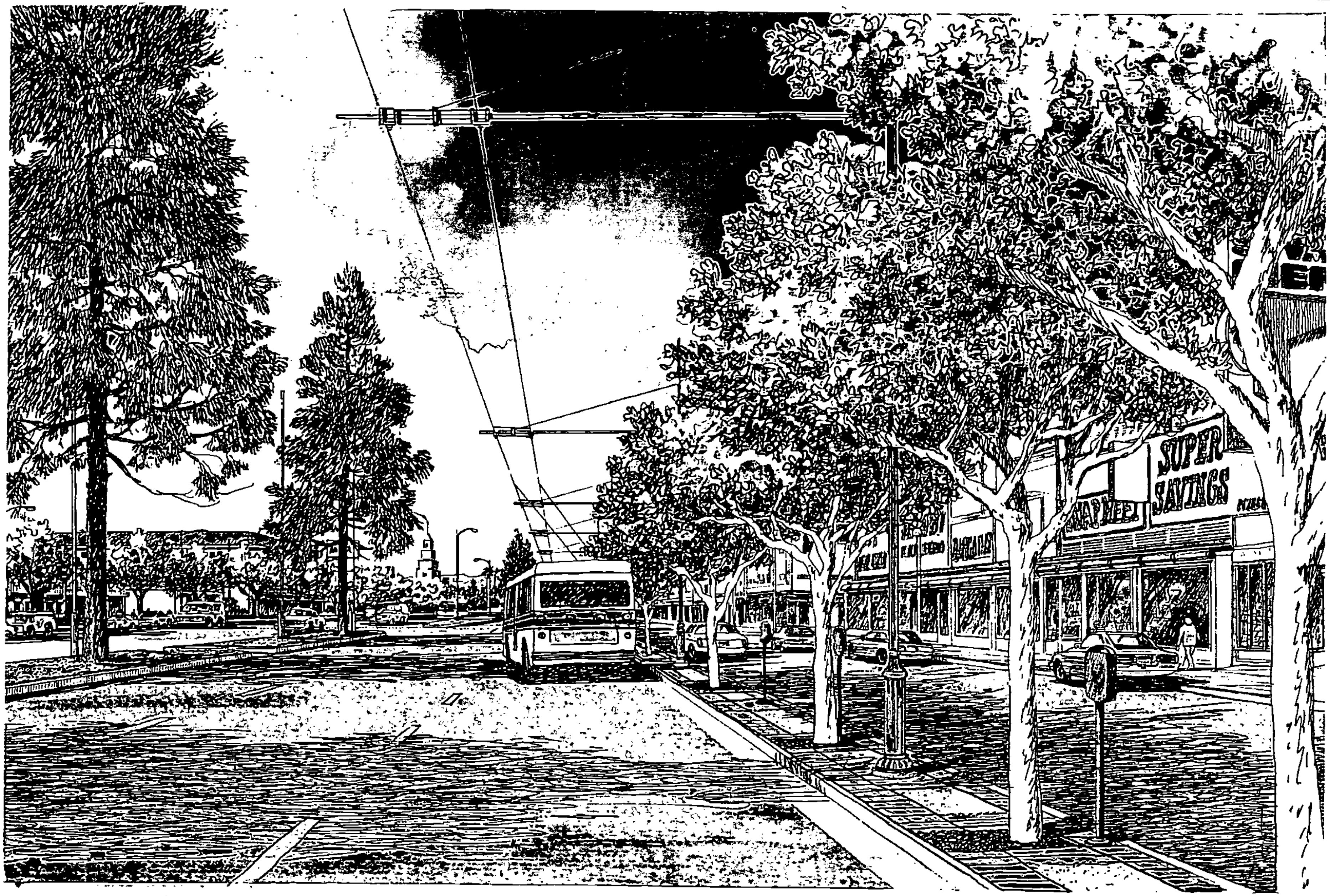
ELECTRIC TROLLEY URBAN DESIGN

SOUTHERN CALIFORNIA RAPID TRANSIT DISTRICT

GRUEN ASSOCIATES
ARCHITECTURE•PLANNING•ENGINEERING

EXISTING CONDITION - FRONTAGE ROAD
ROUTE #204 - VERMONT AVENUE

111-PIC FACER



ELECTRIC TROLLEY URBAN DESIGN

SOUTHERN CALIFORNIA RAPID TRANSIT DISTRICT

GRUEN ASSOCIATES
ARCHITECTURE•PLANNING•ENGINEERING

AFTER ELECTRIC TROLLEY - FRONTAGE ROAD
ROUTE #204 - VERMONT AVENUE

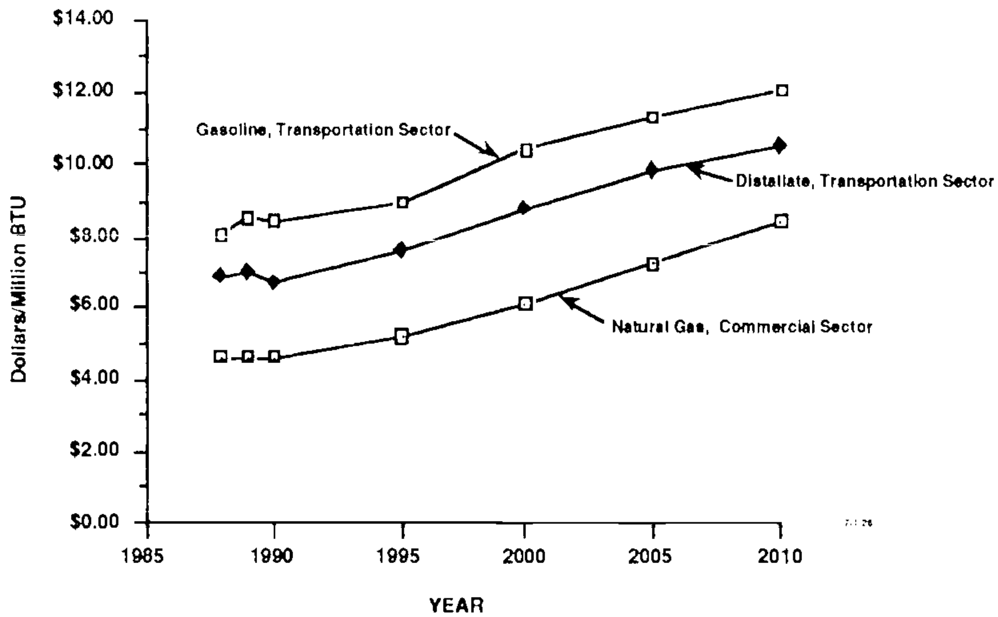
FUEL PRICING ISSUES

FUEL AND ELECTRICITY COSTS WILL HAVE A SUBSTANTIAL IMPACT ON BUS OPERATING COSTS AND THUS PLAY AN IMPORTANT ROLE IN SELECTING PROPULSION TECHNOLOGIES TO MEET SCRTD'S FUTURE FLEET REQUIREMENTS

- **Factors that will effect future fuel prices include:**
  - **Likely changes in California mandated specifications for diesel fuel for on-road vehicles**
  - **Increasing demand for diesel fuel among other user groups**
  - **Reserves and availability of domestically supplied natural gas**
  - **The development of a methanol vehicular fuel market**
  - **Numerous other factors (population growth, conservation practices, processing technology developments, discovery of new sources, worldwide political stability, etc.) that affect the supply and demand of each of the various fuels**

THE FACTORS AFFECTING FUTURE WORLDWIDE ENERGY PRICING ARE COMPLEX AND DYNAMIC— A VERY BRIEF REVIEW OF SELECTED IMPORTANT ISSUES LIKELY TO EFFECT RELATIVE FUEL PRICES IS PRESENTED

NATURAL GAS PRICES TEND TO FOLLOW THOSE OF CRUDE OIL BUT HAVE HISTORICALLY BEEN LESS VOLATILE AND LOWER ON THE BASIS OF COST PER BTU—THIS TREND IS LIKELY TO CONTINUE



GRAPHIC 59

Source: ***U.S. Department of Energy, 1990 Annual Energy Outlook***

- DOE predicts that real crude oil prices will rise through 2010, as a result of the decline in reserves held by non-OPEC producers, especially in Alaska and the North Sea (1990 Annual Energy Outlook)
- If no major discoveries are made, production will become increasingly concentrated in the Middle East, where 50 percent of the world's oil reserves are located.

HOWEVER REGULATION IS LIKELY TO INCREASE DIESEL FUEL PRICES RELATIVE TO OTHER FUELS

- **California to impose stringent formulation specifications on diesel fuel beginning in 1993**
  - **Low sulfur – not to exceed 0.05 percent**
  - **Low aromatics – not to exceed 10 percent**
  - **High cetane – must show equivalent emissions to low aromatic fuel (minimum cetane likely to be 40-50)**
- **Estimated cost increase California diesel fuel spec (due to refining and distribution costs) is estimated at 5 to 15 cents per gallon**
- **Industry experts contend that new formula diesel fuel and jet fuel will compete for the same distillate fraction from crude oil, and the price of diesel will rise faster than other distillates**

THE PRICE OF METHANOL WILL BE HIGHLY DEPENDENT ON THE COST OF NATURAL GAS FEEDSTOCK

- Methanol is made from natural gas
  - Process involves reforming methane molecule
  - Large scale plants are at best 65 percent efficient
- Methanol can be made from coal
  - Approximately 10 times more costly than natural gas process—manufacture of methane is an intermediate step
  - Higher CO_2 production
- Capital, operating and transportation costs add to the methanol cost
  - Plant location is critical
  - Transportation mode is critical
    - Transportation of gas by pipeline is costly
    - Marine vessel transportation of methanol is much less costly than by rail or truck
    - Methanol shipment by pipeline is still in experimental stage

IF A SUBSTANTIAL VEHICLE MARKET IS TO DEVELOP, METHANOL WILL BE SUPPLIED BY FOREIGN SOURCES WHERE THE FEEDSTOCK PRICE IS LOW COMPARED TO DOMESTIC NATURAL GAS

THE PRICE OF LNG WILL ALSO VARY WITH NATURAL GAS FEEDSTOCK PRICES—BUT WILL BE LOWER THAN METHANOL ON A BTU BASIS

	Wholesale Cost of Imported LNG ($ per Gallon)	Wholesale Cost of Imported Methanol ($ per Gallon)
Wellhead Gas ($/MBTU)	$2.00	$2.00
Feedstock Cost ($/Gallon)	$.20 (1)	$.192 (2)
*Capital Charges ($/Gallon)	$.065	$.08
*Plant Operating Costs ($/Gallon) (3)	$.064	$.10
Transportation (4)	$.05	$.05
Total Cost per Gallon	$.379	$.422
Total Cost per Diesel Equivalent Gallon	$.72 (5)	$1.14 (6)

* Methanol cost data taken from California Energy Commission AB234 fuels report
LNG cost data supplied by Cryogenic Fuels Inc., Fairfax VA

(1) Assumes LNG = 84,640 BTU's/Gallon Higher Heating Value, and Processing Efficiency = 85%
(2) Assumes Methanol = 62,400 BTU/Gallon Higher Heating Value, and Processing Efficiency = 65%
(3) Includes Plant Maintenance, Lebor, Overhead and Utilities
(4) Typical Liquid Transport Costs by Ocean Going Vessel From Middle East
(5) Assumes Thermal Efficiency of Natural Gas Engines is 15% Below Diesel Engines, and Diesel Fuel = 136,000 BTU/Gal
(6) Actual In-Service Fuel Consumption Ratio Based on Bus Demonstrations Around the County (2.7:1)

U.S. DEMAND FOR NATURAL GAS WILL BE INCREASINGLY MET BY IMPORTS

- **Total demand for natural gas has increased substantially in recent years**
  - **Primarily because of increasing consumption by utilities for electric generation**
    - **Conversion of coal-fired plants for environmental regulation compliance**
    - **Conversion of oil-fired plants for lower fuel costs**
  - **Normal growth for domestic heating/hot water/cooling**
- **U.S. production will peak around the year 2000**
  - **New domestic sources are deeper and more costly to develop**
  - **Alaskan Natural Gas Transportation System (pipeline) may be completed in approximately 2005—800 billion cubic feet per year to lower 48 states**
- **Worldwide, natural gas will remain abundant for 20 or more years—foreign natural gas will remain less costly**

LIQUIFIED NATURAL GAS WILL BECOME INCREASINGLY IMPORTANT IN THE U.S. FUEL MARKETPLACE

- Canada will become a major supplier of gas
  - Imports will be through existing pipelines
  - Canadian resources will not meet U.S. needs
- Shortfalls will be met by increased imports of liquefied natural gas (LNG)
  - "Liquefaction is the only economically viable non-pipeline mode of transportation for natural gas in large volumes"*
  - Therefore, availability of LNG in the U.S. should substantially increase during the next two decades
- Two LNG terminals are currently in operation in the U.S.
  - Import Algerian LNG in special tankers
  - Boil gas in competition with domestic gas suppliers

TRANSPORTATION USE OF LNG COULD BENEFIT FROM THIS GROWING PRIMARY MARKET

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* *U.S. Department of Energy—1990 Annual Energy Outlook*

ELECTRICITY PRICES IN THE U.S. ARE EXPECTED TO INCREASE AT A LOWER RATE THAN OTHER ENERGY SOURCES . . .

Historical and Predicted Commercial Prices of Energy by Fuel Type (1989 Dollars per Million BTU)

FUEL	1988	1989	1990	1995	2000	2005	2010	Annual Percent Growth Rate
Diesel	4.73	4.85	4.78	5.63	6.82	7.81	8.61	2.8%
Natural Gas	4.69	4.64	4.70	5.17	6.13	7.22	8.45	2.7%
Electricity	21.26	20.81	20.60	20.73	21.29	22.10	22.51	.3%

Historical and Predicted Industrial Prices of Energy by Fuel Type (1989 Dollars per Million BTU)

FUEL	1988	1989	1990	1995	2000	2005	2010	Annual Percent Growth Rate
Diesel	4.36	4.47	4.4	5.27	6.47	7.47	8.28	3.0%
Natural Gas	2.97	2.89	3.0	3.37	4.35	5.44	6.63	3.7%
Electricity	14.38	14.07	13.93	13.76	14.31	15.12	15.53	.4%

Source: U.S. DOE, 1990 Annual Energy Outlook

. . . DUE IN PART TO MULTI-FUEL CAPABILITY OF ELECTRIC PRODUCTION, STABLE DEMAND, AND DECLINING CAPITAL COSTS AS EXISTING PLANTS ARE DEPRECIATED AND USED MORE INTENSIVELY

CONCLUSIONS

- **Of all the motor coach alternative fuels, LNG will likely offer the lowest energy cost in the long run**

- **Both CNG and LNG will offer lower energy costs than methanol on a BTU basis**

- **LNG and methanol will be supplied to the U.S. predominantly by off-shore sources – processing these fuels with domestic natural gas will generally not be economically attractive (a small portion of LNG will be processed using domestic natural gas that is too poor in quality for pipeline feedstock)**

- **Diesel fuel prices will increase relative to other alternative fuels – but will remain the lowest cost fuel at least for the near term**

- **In the longer term, electricity prices will drop relative to other fuels**

ALTERNATIVES TECHNOLOGY ANALYSIS

A KEY ELEMENT OF THIS TROLLEY BUS STUDY IS THE COMPARISON OF ELECTRIC BUS OPERATION WITH OTHER EMERGING ALTERNATIVE FUEL TECHNOLOGIES ALONG A VARIETY OF CRITERIA:

- **Capital Costs**
  - **Vehicles**
  - **Fuel Facilities**
  - **Maintenance Facilities**
- **Operating Costs**
  - **Fuel**
  - **Maintenance**
- **Emission Reductions**
- **Safety**
- **Technology Maturity/Reliability**

THE ALTERNATIVE FUEL TECHNOLOGIES REVIEWED INCLUDE METHANOL, NATURAL GAS (BOTH COMPRESSED AND LIQUEFIED), TROLLEY COACHES, AS WELL AS DIESEL WITH PARTICULATE TRAPS.

SCRTD HAS IMPLEMENTED THE MOST COMPREHENSIVE ALTERNATIVE FUELS TESTING PROGRAM IN NORTH AMERICA

	Units in Service	Planned	Miles to Date
Methanol	30	140	≈ 1,100,000
CNG	9	10	≈ 15,000
Methanol/Avocet	8	12	≈ 70,000
Particulate Trap Diesel	11	21	≈ 95,000

ADDITIONALLY, RTD HAS MODIFIED THREE OPERATING DIVISIONS TO HANDLE METHANOL FUEL (DIVISIONS 1, 2, & 5) AND ONE DIVISION (#15) TO ACCOMMODATE CNG REFUELING. VIRTUALLY ALL OF THE COST DATA USED IN EVALUATING THE ALTERNATIVE FUEL OPTIONS IS BASED ON RTD'S IN-HOUSE EXPERIENCE. TROLLEY BUS CAPITAL AND OPERATING COST DATA HAS BEEN GATHERED FROM EQUIPMENT MANUFACTURERS AND FROM TRANSIT PROPERTIES CURRENTLY OPERATING TROLLEY BUSES.

ALTERNATIVES TECHNOLOGY ANALYSIS

- Capital Costs
- Technology Maturity/Reliability
- Operating Costs
- Emission Reductions
- Safety
- Other Considerations/Advanced Technologies

TROLLEY BUSES LAST LONGER THAN MOTOR COACHES

The useful life of a conventional motor bus is 12 to 20 years. During this period, the coach will undergo 2 or more major engine and transmission rebuilds and perhaps a partial rehabilitation/refurbishment. In practice, most transit properties choose to dispose of or sell buses just prior to the time when a major infusion of capital is required (such as an engine/transmission rebuild, or a body/chassis refurbishment). At this point, the bus has probably reached, or is near, its fully depreciated life of 12 years and the investment required to keep the bus on the road in a safe and reliable condition is high - - - and therefore a decision is made to re-invest in a new bus.

The practical useful life of a trolley bus appears to be longer than for a motor bus. When the last fleet of trolley buses were scrapped in San Francisco, they were 27 years old. Seattle retired a fleet of trolley buses in 1979 that averaged over 30 years of age. In practical terms, the incremental investment required to keep a trolley bus in good working condition is less than for a motor bus at a given age and mileage level - - - operators of trolleys therefore have chosen to re-invest in the older trolley instead of scrapping. It is reasonable to assume that for a given level of re-investment in major repair and rehabilitation work, the useful life of a trolley is conservatively 1-1/2 times that of a motor coach. Additionally, UMTA guidelines for bus replacement require 12 year life for motor buses and 18 year life for trolley buses.

NEW TROLLEY BUSES WILL BE MORE EXPENSIVE THAN OTHER NEW BUS TECHNOLOGIES

Bus Type	Initial Vehicle Capital Cost	Useful Life	Notes
Diesel Baseline	$ 210,000	12 yrs.	Average new 40 ft coach
Diesel with Trap	$ 230,000	12 yrs.	Premium quoted by DDC and Cummins for a trap engine
Methanol	$ 240,000	12 yrs.	Average new methanol bus
CNG	$ 255,000	12 yrs.	Recent price quote from New Jersey Transit
LNG	$ 250,000	12 yrs.	Estimates from Baltimore & Houston project managers of LNG Demo's
Trolley Bus (40 ft)	$ 400,000	18 yrs.	BAH Estimate
Trolley Bus (Artic)	$ 625,000	18 yrs.	BAH estimate based on present MUNI bid

ASSUMPTIONS

Estimates for fuel facility conversions are preliminary engineering estimates to be used for comparative purposes. They are extremely dependent on specific site location and circumstances. RTD has already converted 3 of its divisions to methanol compatible tanks. The fuel tanks at two additional divisions (12 & 13) were replaced within the last two years and are therefore already methanol compatible. They could be converted to full methanol operation with a minimal investment. Division 6 is scheduled for fuel tank replacement within the next 2 to 3 years and a methanol compatible system could be installed for only slightly more than new diesel tanks.

NOTES

(1) Assumes three (3) 300 hp compressors rated at 750 SCF/min capable of refilling buses continuously at 5 minutes/bus with a 1 minute "recovery time" between refills. Also assumes that a 150 psi supply line is available to supply natural gas to the compressor station

(2) 20,000 SCF storage capacity (used as a buffer only)

(3) Assumes (2) 50,000 gallon LNG storage tanks

(4) Assumes (4) 30,000 gallon methanol storage tanks

FUELING FACILITIES WILL REQUIRE MODIFICATIONS TO ACCOMMODATE NEW ALTERNATIVE FUEL VEHICLES - - - CNG WILL HAVE THE HIGHEST FACILITY CONVERSION COST

	CNG	LNG	Methanol
Pumps, compressors, lines, and related safety equipment and controls	$1,600,000(1)	$50,000	$150,000
Fuel storage tanks	$75,000(2)	$670,000(3)	$210,000(4)
Fuel dispensing equipment	$75,000	$75,000	$75,000
Engineering/Construction/Installation	$500,000	$200,000	$300,000
Total	$2,250,000	$995,000	$735,000

(see notes on facing page)

DIESEL FUEL FACILITIES ARE OF COURSE ALREADY IN PLACE. TROLLEY BUSES ARE "FUELED" VIA THE OVERHEAD WIRE. CAPITAL COSTS ASSOCIATED WITH ESTABLISHING THE OVERHEAD WIRE SYSTEM ARE DETAILED IN A PREVIOUS SECTION

ASSUMPTION/NOTES

- Estimates for maintenance facility conversions are preliminary engineering estimates and are extremely dependent on specific site locations and circumstances. They are used for comparative purposes only

- CNG, LNG, and methanol will all require safety related improvements as these fuels are generally considered more volatile and dangerous than diesel fuel. Building ventilation, electrical, and fire protection systems will all require some upgrading

- APU's on buses preclude need to construct extensive overhead wire network in facility yards. Assumes 10 working bays and inspection lines at $50,000/each are converted for trolley maintenance. Special trolley bus diagnostic equipment and the installation of high voltage feed wires to the maintenance facility will also be required. Maintenance facilities will not require their own substations. Also, modifications may be required at some facilities to accommodate special needs of articulated coaches.

MAINTENANCE FACILITIES WILL ALSO REQUIRE MODIFICATION TO ACCOMMODATE NEW TECHNOLOGY BUSES. THESE COSTS WILL BE ROUGHLY THE SAME FOR ALL THREE COMBUSTION ALTERNATIVE FUELS. FOR TROLLEY BUSES, FACILITY MODIFICATIONS WILL BE REQUIRED TO PERMIT ELECTRIC DRIVE SYSTEM DIAGNOSTIC AND REPAIR FUNCTIONS

	CNG/LNG or Methanol	Trolleys
Building Ventilation	$ 100,000	—
Electrical System Improvements (to mitigate ignition sources)	$ 100,000	—
Fire Protection Systems	$ 100,000	—
Overhead wire installation in repair bays and other special equipment required for trolley repair	—	$ 750,000
Total	$ 300,000	$ 750,000

ADDITIONALLY, SOME DIVISIONS WILL REQUIRE MODIFICATION TO ACCOMMODATE ARTICULATED COACHES.

ALTERNATIVES TECHNOLOGY ANALYSIS

- Capital Costs
- Technology Maturity/Reliability
- Operating Costs
- Emission Reductions
- Safety
- Other Considerations/Advanced Technologies

OF THE AVAILABLE MOTOR BUS TECHNOLOGIES, METHANOL BUSES HAVE ACCUMULATED THE MOST TEST MILES

METHANOL (DDC)			CNG			PARTICULATE TRAPS		
PROPERTY	UNITS IN SERVICE	TEST MILES	PROPERTY	UNITS IN SERVICE	TEST MILES	PROPERTY	UNITS IN SERVICE	TEST MILES
SCRTD	30	1,200,000	CLEVELAND RTA	1	24,000	SCRTD	11	93,000
DENVER	5	250,000	COLUMBUS	1	40,000	NYCTA	5 (2)	64,000
GOLDEN GATE	2 (1)	85,000	DENVER	2	12,200	DAYTON	2	64,000
RIVERSIDE	3 (3)	275,000	SCRTD	9	13,000	SEPTA	1 (4)	30,000
TRIBORO	8	600,000	TORONTO	4	93,000	MILWAUKEE	1 (5)	38,000
PHOENIX	2	80,000	MISSISSAUGA	1	28,000			
MEDICINE HAT	8	350,000	ORANGE COUNTY	2	35,000			
WINNIPEG	2	230,000						
TOTAL	*58*	*3,070,000*		*20*	*245,200*		*20*	*309,000*

(1) DEMONSTRATION TERMINATED AT GOLDEN GATE 2/91; COACHES TRANSFERRED TO SCRTD AND OXNARD
(2) 400 TRAP-EQUIPPED BUSES TO BE DELIVERED BY JULY 1991; 3 BUSES EQUIPPED WITH ORTECH SYSTEM, 1 WITH DCI ELECTRIC REGENERATION AND 1 WITH WEBASTO SYSTEM
(3) WILL RECEIVE 3 PRODUCTION METHANOL ENGINES WITH CONVERTERS NEXT MONTH
(4) ONE 3M TRAP IN OPERATION; 20 ECS TRAPS TO BE DELIVERED
(5) CUMMINS INTEGRAL BY-PASS TRAP SYSTEM

GRAPHIC 15

METHANOL BUSES HAVE ACCUMULATED ABOUT 3 MILLION MILES; APPROXIMATELY 600,000 MILES HAVE BEEN ACCUMULATED ON DDC'S PRODUCTION INTENT ENGINE DESIGN (23:1 COMPRESSION)

NATURAL GAS BUS FIELD TEST RESULTS – JUNE 1991
(CUMMINS L10 ENGINE)

Customer	Unit	Mileage
CNG		
Columbia	9001	20,547
Consolidated	CNG#1	25,692
Mississauga	8823	23,641
TTC	9360	39,198
TTC	9361	50,973
TTC	9370	20,568
SCRTD	1800	4,559
SCRTD	1801	4,712
SCRTD	1808	4,459
SCRTD	1809	2,459
OCTD	4266	2,573
OCTD	4,267	390
Dallas 1	139	1,175
Dallas 2	138	2,114
Brooklyn	901	3,607
Union Gas	902	
Ft. Worth	881	881
Ft. Worth	882	1,042
Ft. Worth	883	1,187
San Diego	9000	141

Source: Memo from Cummins Engine Company, July 1991, Gary Farrell

HOWEVER, A NUMBER OF NATURAL GAS BUS DEMONSTRATIONS ARE JUST NOW GAINING MOMENTUM

PROPERTY	NUMBER OF UNITS PLANNED	NOTES
SCRTD	10	7 UNITS PUT INTO SERVICE MAY 1991
HAMILTON	15	PART OF 50 CNG BUS DEMO SPONSORED BY MINISTRY OF TRANSPORT; TO BE DELIVERED 9/91
TORONTO	21	
MISSISSAUGA	10	BUSES TO BE DELIVERED 10/91
FORT WORTH	3	DELIVERED 2/91, ORDER PLACED FOR 9 MORE CNG BUSES
DALLAS	2	DELIVERED 1/91—NOT IN REVENUE SERVICE
PIERCE TRANSIT	15	TO BE DELIVERED LATE 1991; REQUEST FOR BIDS BEING PREPARED FOR 16 ADDITIONAL CNG BUSES IN 1992
NEW JERSEY	5	TO BE DELIVERED 7/91; FIRST 5 IN REVENUE SERVICE EQUIPPED WITH CATALYTIC CONVERTER
PORT AUTHORITY OF ALLEGHENY COUNTY (PITTSBURGH, PA)	5	TO BE DELIVERED 4/91; REQUEST TO LESGISLATURE TO AMEND LAWS PROHIBITING PLACEMENT OF STORAGE TANKS ON ROOF
SALT LAKE CITY	5	TO BE DELIVERED 8/91
TRI COUNTY METROPOLITAN (PORTLAND)	2	TO BE DELIVERED 7/91; 120 BUS BID REQUEST INCLUDING 5 ALTERNATIVE FUELED OUT THIS FALL
HOUSTON	10	LNG BUSES ARE CURRENTLY BEING BUILT
BALTIMORE	10	LNG BUSES ARE CURRENTLY BEING BUILT

GRAPHIC 44

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RELIABILITY OF ALL NEW MOTOR BUS TECHNOLOGIES IS RELATIVELY UNPROVEN

METHANOL BUSES

- Reliability has improved dramatically but is still short of diesel bus levels
- Total mileage on newest engine configuration is still relatively low for a production intent design
- Highest mileage on any single bus (with newest engine configuration) is around 40,000 miles

CNG BUSES

- Cummins engine has experienced numerous "start up" problems as did earlier methanol engines
- A host of engine modifications have been implemented by Cummins and are currently on test
- Cummins is scheduled to complete their internal dynamometer durability test program by July 1991

RELIABILITY OF ALTERNATIVE FUEL COACHES HAS BEEN POOR BUT DRAMATIC IMPROVEMENTS HAVE BEEN MADE OVER THE LAST YEAR

- In the long term, increased unscheduled maintenance costs (over diesel coaches) should be slight as manufacturers acquire durability experience and refine their engine designs.

- Some inherent increases in scheduled maintenance costs will, however, be experienced due to more complex fuel systems, electrical systems, and emission controls equipment on the alternative fuel vehicles. More frequent inspections and preventative maintenance appears to be required.

- Additionally, some fundamental reliability/durability questions remain with all the alternative fueled coaches:
  - Methanol engine durability: cylinder heads cracking
  - CNG engine reliability: turbocharger failures/overheating
  - Particulate trap diesel: filter plugging/regeneration controls

TROLLEY BUS TECHNOLOGY IS FUNDAMENTALLY MATURE

- Trolleys have operated successfully in the U.S. since the early 1920s
- Trolley buses are employed extensively in Europe
- AC propulsion, while fairly new to trolley buses, is being used commonly on light and heavy rail vehicles around the world
- Battery powered APUs appear quite reliable (based on Vancouver and European experience) - - - - care must be exercised, however, in defining the application and in preventing over extensive use of the off-wire capability

ALTERNATIVES TECHNOLOGY ANALYSIS

- Capital Costs
- Technology Maturity/Reliability
- Operating Costs
- Emission Reductions
- Safety
- Other Considerations/Advanced Technologies

DEMONSTRATION TESTING HAS SHOWN ALTERNATIVE FUELS TO BE GENERALLY LESS ENERGY EFFICIENT THAN DIESEL BUSES

FUEL ECONOMY TEST RESULTS OF ALTERNATIVE FUEL BUS DEMONSTRATIONS

Property	Fuel Type	"Raw" Fuel Consumption	Alternative Fuel Diesel Equivalent Fuel Consumption (MPG)	Sister Diesel Fleet Fuel Consumption (MPG)	Efficiency vs. Diesel
SCRTD	Methanol	1.1 MPG	2.4	3.2	75%
Denver	Methanol	1.57 MPG	3.42	4.12	83%
Triboro	Methanol	1.12 MPG	2.44	3.05	80%
				Average Methanol Fleet	79%
Columbus	CNG	2.32 mi/therm	3.15	4.0	79%
SCRTD	CNG	2.12 mi/therm	2.88	3.9	74%
Toronto	CNG	2.28 mi/therm	3.1	4.4	70%
				Average CNG Fleet	74.3%

***Assumptions:** 1 gallon diesel fuel = 136,000 BTU higher heating value*
1 gallon methanol = 62,400 BTU higher heating value
1 therm CNG = 100,000 BTU higher heating value

***Source:** Personal communication with maintenance and operations staff at each transit property listed; Data provided by Detroit Diesel Corporation and Cummins Engine Company; BAH analyses*

***Note:** For additional details, see Task 3 Report, "Low Emission Transit Alternatives"*

THE ENERGY CONSUMPTION OF TROLLEY FLEETS CAN ALSO BE COMPARED TO DIESEL FLEETS AT VARIOUS TRANSIT PROPERTIES

Property	Diesel Fleet Fuel Economy (MPG)	Trolley Fleet Fuel Economy (kWH/mile)	Relative Efficiency of Trolley Fleet Compared to Diesel Fleet* (MUNI = 100%)
Seattle	4.0	4.6	68%
Muni	2.9	4.3	100%
Vancouver	4.1	4.15	74%
Philadelphia	2.9	6.5	66%

** Miles per kWH (Trolley) ÷ Miles per gallon (diesel): MUNI = 100%*

Source: ***1990 Transit Operating and Financial Statistics; personal communications with transit property staff; BAH analyses***

TROLLEYS APPEAR TO EXHIBIT THE BEST ENERGY CONSUMPTION CHARACTERISTICS (VIS-A-VIS THE DIESEL FLEET) AT MUNI WHERE ROUTES HAVE SEVERE GRADES.

NOTES

1) Based on current average fuel economy for RTD's entire diesel fleet; and

1 gallon diesel = 136,000 BTU's higher heating value

2) Based on a 2.7:1 Methanol/Diesel fuel consumption ratio; and

1 gallon methanol = 62,400 BTU's higher heating value

3) Based on 80% efficiency versus diesel fueled engines (same efficiency as methanol engines). Natural gas engines in revenue service are currently operating at only 74% efficiency. These engines however are in relatively early stages of development compared to methanol engines (and diesel engines). Conservatively, the efficiency of natural gas engines will increase to at least 80% of diesel cycle engines. DDC and Cummins are both developing direct injection natural gas diesel cycle versions of their transit engines. These engines hold the promise for efficiency levels near those of conventional diesel engines (See Task 3 Report, "Low Emission Transit Alternatives" for additional details).

4) Assumes a 2-1/2 percent efficiency improvement versus CNG buses due to an anticipated weight savings of 1,500 to 2,000 lbs compared to CNG buses (Based on BAH transit bus fuel economy computer simulation model – See Task 3 Report for additional details); and

1 gallon LNG = 84,600 BTU's higher heating value

5) Based on testing of advanced propulsion systems by BAH for MUNI in 1985 (See Vehicle Technology section of this report for details).

6) Projected power consumption of ARTICS with advanced AC propulsion operating in Los Angeles (See Task 3 Report for additional details).

BASED ON TEST DATA FROM RTD'S ALTERNATIVE FUEL TEST PROGRAMS AND OPERATIONS IN OTHER CITIES, THE ESTIMATED FUEL ECONOMY FOR VARIOUS FLEET TYPES ARE SHOWN BELOW

FLEET	FUEL CONSUMPTION	DIESEL GALLON EQUIVALENT	NOTES
Diesel Baseline	3.6 MPG	3.6 mpg	1
Methanol	1.3 MPG	2.8 mpg	2
CNG	2.1 Miles/THERM	2.8 mpg	3
LNG	1.82 MPG	2.9 mpg	4
Trolley (40 ft)	3.0 Kwh/Mile	N/A	5
Trolley (Artic)	4.5 Kwh/Mile	N/A	6

GRAPHIC 14

FUEL PRICE PREDICTIONS

- Diesel: Prices have fluctuated substantially in recent months due to the Mid East Crisis but appear to be stabilizing. RTD has paid as low as $.64 and as high as $1.12 per gallon over the last year.

- Methanol: The biggest variable associated with the fuel cost analysis is the future price of methanol. Under what Booz·Allen believes is an optimistic scenario developed by the CEC, the future price/gallon will be approximately 45¢. This is the price we have used in our cost model. The CEC price scenario is based on the development of a mature supply infrastructure triggered by significant demand in the light duty (cars and light duty trucks) market segment. Recent developments in reformulated gasoline as well as improved catalytic convertor technology threaten the market for methanol in the light duty fleets.

- CNG: This is the current price set by PUC for natural gas purchased for transportation purposes. Future natural gas prices are expected to generally parallel petroleum prices but will exhibit greater stability

- LNG: Preliminary quotations for delivered price to SCRTD from major LNG suppliers in the Central/South U.S.

- Electricity: Preliminary Estimate based on mixed peak/off peak consumption (applies to both DWP and SCE)

FUEL COSTS WILL VARY SUBSTANTIALLY AMONG THE ALTERNATIVES

	Diesel with Trap	Methanol	CNG(1)	LNG	Trolley 40 Ft.	Trolley Artic*
Miles/Bus/Year	42,000	42,000	42,000	42,000	42,000	42,000
Miles/Unit Fuel	3.6/gal	1.3/gal	2.1/therm	1.8/gal	0.33/kWh	0.22/kWh
Units Fuel/Yr/Bus	11,667 gal	32,308 gal	20,000 therms	23,333 gal	126,128 kWh	189,189 kWh
Fuel Cost/Unit: NOMINAL	$0.80/gal	$.45/gal	$0.46/therm	$0.40/gal	$0.09/kWh	$0.09/kWh
Fuel Cost/Mile: NOMINAL	$0.22	$0.35	$0.22	$0.22	$0.27	$0.41
Annual Fuel Cost/Bus: NOMINAL	$9,240	$14,538	$9,240	$9,240	$11,351	$17,010
Percent change : compared to diesel		+57%	0%	0%	+23%	+82%

* As will be detailed in "Alternative Cost Comparison" section of this report, a reduced number of vehicles and vehicle miles are needed with articulated vehicles for equivalent passenger throughput.

(1) ***Does not include the cost of compressing the gas. These costs are treated as separate operating and capitol costs and are included later in the analyses. In general, however, cost of compression will add about 5 to 7 cents per therm or about 3¢ per mile.***

Note: ***See "Energy Issues" section of this report and/or Task Report 3, "Low Emission Transit Alternatives" for more information on fuel pricing. The 1990 Dept. of Energy Annual Energy Outlook Report and the California AB234 Fuels Report are also excellent references on this subject.***

SCRTD MAINTENANCE LABOR HOURS BY REPAIR CATEGORY (ALL BUS FLEETS)

Repair Code	Functional Area	Percent of Total Labor Maintenance Hours	Trolley's Impact on Vehicle Servicing and Maintenance Requirements
11	Air Conditioning	5.70	
12	Air System	1.68	
13	**Brake Systems**	**3.93**	Significantly Reduced
14	Bus Exterior	4.68	
15	Bus Interior	1.74	
16	Chassis and Suspension	5.74	
17	**Transmission**	**3.89**	Eliminated
18	**Cooling System**	**2.61**	Eliminated
19	Doors	3.10	
20	Electrical System	4.18	
21	**Engine**	**5.97**	Eliminated
22	**Fueling and Exhaust**	**12.67**	Eliminated
23	Lights	1.69	
26	Steering	1.06	
27	Tires/Wheels	.82	
28	**Road Call**	**5.73**	Significantly Reduced
99	**Planned Maintenance**	34.30	Approximately 1/3 of this category is related to drivetrain maintenance. This portion would be significantly reduced.
	Total	100.00%	

Source: "Review of Maintenance Operations at SCRTD", Final Report, Booz·Allen & Hamilton, June 1988

FOOTNOTES

(1) Direct maintenance cost per mile including material and labor; taken from RTD's VMS data system.

(2) The methanol fleet is currently operating with 24% higher direct maintenance costs than the diesel fleet. In the longer term, maintenance costs should drop closer to diesel levels. We have assumed a 15% higher direct maintenance cost for alternative fuel motor coaches.

(3) Assumes 25% lower direct maintenance cost than diesel: For the trolley fleet, San Francisco Muni reports 21% lower maintenance cost per vehicle service mile compared to the diesel fleet. Seattle reports 40% lower maintenance costs per vehicle service hour. Vancouver maintenance personnel report reduced costs in the 20 to 30 percent range.

(4) Articulated trolleys are assumed to require a 75% higher maintenance costs per mile than 40 ft. trolleys.

Note: Good comparative maintenance cost data between trolley and diesel coach operation at most cities is complicated by accounting system design and the common use of overhead departments. A survey of maintenance personnel at cities operating trolleys indicates that maintenance cost reductions in the 20 to 30 percent range are reasonable. See "Review of Trolley Systems in Other Cities" section in this report for added detail.

VEHICLE MAINTENANCE COSTS FOR ALTERNATIVE FUEL COACHES WILL BE HIGHER THAN FOR CONVENTIONAL DIESEL COACHES

	Cost in Dollars/Vehicle Mile			
Category	Diesel	Methanol	Difference	Percent Difference
Lubricant	0.008	0.008	0	+0%
Tires	0.055	0.055	0	+0%
Direct Parts	0.290	0.401	0.111	+38%
Direct Labor	0.350	0.410	0.06	+17%
Total	0.703	0.874	0.171	+24%

Source: SCRTD Staff: Alternative Fuels Section

Maintenance costs shown in the above chart for SCRTD's fleet reflect routine preventative maintenance while ignoring development costs for the methanol fleet, such as replacement of prematurely failed engines. Direct maintenance costs for methanol buses are $0.874 per vehicle mile, 24 percent higher than for the diesel fleet. The increase is caused largely by higher parts costs, such as more frequent replacement of injectors, and replacement of glow plugs, which are not needed in the diesel engines. As the development program continues, these costs will likely decrease. For the purposes of comparison, we have assumed that methanol maintenance costs will be 15% higher than the diesel fleet average. While good data is severely lacking, interviews with fleet managers around the country suggest that this level of additional maintenance is a reasonable estimate for natural buses at a mature level of development as well.

TROLLEY BUS MAINTENANCE IS SIGNIFICANTLY LESS THAN THAT REQUIRED FOR MOTOR BUSES - - - BUT OVERHEAD WIRE MAINTENANCE WILL YIELD NET MAINTENANCE COST PER MILE LEVELS THAT ARE ABOUT EQUAL FOR ALL THE NEW TECHNOLOGY COACHES

- **Maintenance associated with the engine, transmission, cooling, and exhaust system will be eliminated on trolleys**
- **Solid state controllers and AC propulsion systems should keep trolley propulsion system maintenance to a minimum**
- **Maintenance on brakes will be reduced due to regenerative braking effects - - - Vancouver reports brake maintenance on trolley coaches is reduced about 50% over the diesel fleet**
- **All costs associated with refueling of buses will be completely eliminated - - - and oil changes are also eliminated**
- **Catenary maintenance at Muni and Vancouver is estimated at $.21 and .17$ per vehicle mile respectively. BAH interviews with these and other properties operating trolleys suggests that maintenance costs for the power distribution system are nominally in the $.20 to $.30 cents per vehicle mile range. Catenary maintenance for Los Angeles is expected to be comparatively low, due in large part to very favorable climatic conditions. Large temperature swings, freezing, rain and snow all contribute to increased maintenance for the overhead wire system. Also, RTD's system would be newly installed with the latest available catenary technology. For study purposes, catenary maintenance cost is conservatively estimated at $.25 per mile.**

DIRECT MAINTENANCE COSTS FOR TROLLEY BUSES SHOULD BE 20 TO 30 PERCENT LESS THAN DIESEL BUSES - - - WHILE DIRECT MAINTENANCE ON ALTERNATIVE FUEL MOTOR BUSES WILL LIKELY INCREASE BY 10 TO 20 PERCENT OVER TODAY'S DIESEL BUSES

	COSTS PER MILE					
	Diesel Baseline	**Methanol**	**CNG**	**LNG**	**Trolley 40 Ft.**	**Trolley Artic**
Miles/Bus/Yr.	42,000	42,000	42,000	42,000	42,000	42,000
Vehicle Maintenance Cost/Mile:	$.70 (1)	$.81 (2)	$.81 (2)	$.81 (2)	$.52 (3)	$.92 (4)
Trolley Wire Maintenance per vehicle service mile	0	0	0	0	$.25	$.25
Total Maintenance Cost/Mile	$.70	$.81	$.81	$.81	$.77	$1.17
Annual Direct Maintenance Cost/Bus including catenary	$29,400	$34,020	$34,020	$34,020	$32,340	$49,140

Note: ***See "Comparison of Trolley Systems" section in this report as well as Task Report 3, "Low Emission Transit Alternatives" for additional information on maintenance issues.***

ALTERNATIVES TECHNOLOGY ANALYSIS

- Capital Costs
- Technology Maturity/Reliability
- Operating Costs
- Emission Reductions
- Safety
- Other Considerations/Advanced Technologies

EMISSION FACTORS FOR ELECTRIC POWER CONSUMPTION BY TROLLEY BUSES HAVE BEEN DEVELOPED BASED ON THE POWER GENERATION CHARACTERISTICS PREVIOUSLY DESCRIBED AS WELL AS THE FOLLOWING ASSUMPTIONS:

- **30% of the power will be supplied by SCE and 70% by DWP. This split approximates the number of route miles in each utilities' respective service area.**

- **Transmission losses through the DWP's and SCE's system are 11.8 and 11.0 percent, respectively (data provided by utility companies)**

- **Transmissions losses through the trolley substation and catenary system are estimated at 5%**

- **The peak power required by trolley operations will not materially affect the system generation profile - - - i.e., the marginal power generation profile is the same as the base profile (this argument is supported later in the report)**

NOTES/SOURCES

1) EPA (Ann Arbor) Test Data from a 1985 DDC V6-92 engine

2) EPA supplied data on a 1990 V6-92TA DDEC engine

3) DDC supplied data on 1991 V6-92TA DDEC equipped with a Donaldson Particulate Trap (testing performed by EPA)

4) DDC supplied data on a "production intent" methanol V6-92TA engine (Mr. John Fisher, Manager of Certification Testing at DDC)

5) Cummins supplied data on a pre-production natural gas L10 engine (Dr. Vinod Duggal: Director, Alternative Fuels Programs)

6) BAH analysis: assumes a 30/70 split between SCE and DWP supplied power. Also takes into account transmission losses through the utility distribution system as well as trolley overhead wire system. These emission factors represent then the equivalent motor coach factors on a gram-per-horsepower hour basis.

AVERAGE TROLLEY BUS EMISSION FACTORS (ON A GRAMS PER HP-HOUR BASIS) CAN BE COMPARED WITH AVAILABLE ENGINE DYNAMOMETER TEST DATA FOR DIESEL AND ALTERNATIVE FUEL ENGINES

EMISSION FACTORS FOR TRANSIT BUSES
(G/HP-HR: EPA Transient Cycle Test Data)

	HC	CO	NOx	Particulates	Notes (see above)
"Old" Diesel*	.85	2.1	8.5	.5	1
New Diesel (DDEC)	.5	1.25	5.0	.23	2
Diesel with Particulate Trap	.27	1.6	4.4	.05	3
Methanol with Convertor	.1	0.5	2.5	.05	4
CNG with Convertor	.9	0.3	4.4	.06	5
Trolley Coach (total emissions)	.034	0.083	0.88	.049	6
Trolley Coach (in-basin emissions)	.023	0.038	0.090	.006	6

*** 1985 Pre-DDEC diesel emissions**

EXAMPLE CALCULATION FOR DETERMINING EMISSION RATES PER VEHICLE MILE - - -

- Example: NOx emissions for a Methanol engine
  - Brake specific fuel consumption = .974 lbs/HP-HR
  - Brake specific emission rate = 2.5 grams per HP-HR
  - Route specific full consumption = 1.3 MPG
  - Fuel density = 6.65 lbs. per gallon

- Mean load (HP-HR/mile) = $\dfrac{\text{fuel density (lb/gal)}}{\text{Brake specific fuel consumption (lbs/HP-HR) x route specific fuel consumption (mpg)}}$

- Emission rate (grams/mile) = Brake specific emission rate x Mean load

- Emission rate = 2.5 grams/HP-HR (x) $\dfrac{\text{6.65 lbs/gal}}{\text{.974 lbs/HP-HR (x) 1.3 mpg}}$

- Emission rate = 13.13 grams per mile

- Emission rate = 28.88 lbs per 1,000 miles

THESE "DYNAMOMETER" EMISSION FACTORS CAN THEN BE COMBINED WITH OBSERVED FUEL CONSUMPTION DATA TO DEVELOP EMISSION FACTORS ON A PER MILE BASIS - - - AND THUS ESTABLISH EMISSION INVENTORIES FOR EACH NEW VEHICLE TECHNOLOGY.

- **Assumptions include:**
  - **Brake specific emission rates (grams/HP-HR) in urban service are equal to those produced by the engine during certification testing over the Federal Transient Emissions Cycle.**
  - **Brake specific fuel consumption is similarly equal.**
  - **The mean load on the engine is proportional to fuel consumption. (Mean load factor represents the average percentage of maximum rated output power that the engine operates at during revenue service - - - transit engines typically operate at a 25 to 30 percent load factor.)**

THIS METHOD FOR CALCULATING ON-ROAD EMISSIONS TAKES INTO CONSIDERATION THE ACTUAL FUEL CONSUMPTION RATES OF THE VARIOUS TECHNOLOGIES AND IS THE METHOD APPROVED BY THE CALIFORNIA AIR RESOURCES BOARD. AN EXAMPLE CALCULATION IS SHOWN ON FACING PAGE.

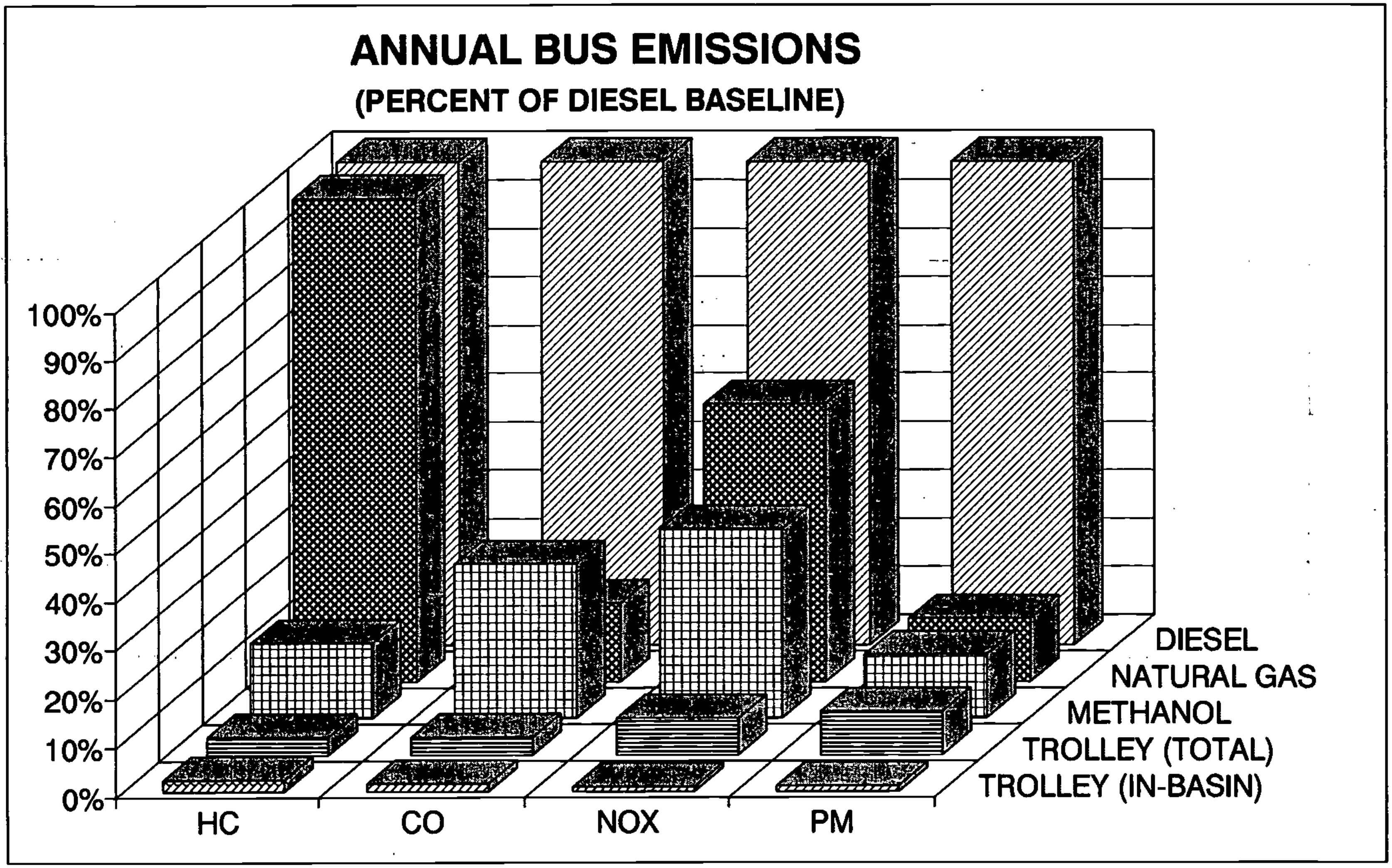
ASSUMPTION/NOTES

	Notes	On-Road Fuel Consumption	BSFC (Lbs/HP-HR)	Comments
"Old" Diesel	1	3.4 mpg	.50	Non-DDEC diesels assumed to have 5% poorer fuel economy than new DDEC diesels
New Diesel	2	3.6 mpg	.478	Baseline data: Based on certifications testing – Mr. John Fisher, Mgr. Certifications Testing, DDC
Diesel w/Trap	3	3.6 mpg	.478	There is a very small increase in fuel consumption with particulate traps, but it is insignificant
Methanol	4	1.3 mpg	.974	Based on in-progress certification testing at DDC – Mr. John Fisher, Mgr. Certification Testing
NG	5	2.1 miles/Therm	N/A	The mean load factor for a natural gas engine is assumed to be the same as for a diesel engine
Trolley	6	0.33 miles/KwH	N/A	BAH predicted fuel consumption for trolley coaches

EMISSION FACTORS FOR EACH VEHICLE TECHNOLOGY ON A PER MILE BASIS ARE SHOWN BELOW

	Lbs. per 1,000 miles				
	HC	CO	NOx	PM	Notes
"Old" Diesel*	7.7	19.0	80.74	3.63	1
New Diesel (DDEC)	4.4	11.2	44.8	2.06	2
Diesel with Trap	2.42	14.34	39.4	.45	3
Methanol with Convertor	1.16	5.8	28.88	.58	4
NG with Convertor	8.1	2.7	40.8	.54	5
Trolley Coach (total)	.31	.75	7.7	.43	6
Trolley Coach (in-basin)	.2	.34	.81	.05	6

*** 1985 Pre-DDEC diesel engine**



Source: Data from Engine Manufacturers, Utilities, SCRTD Alternative Fuels section staff; BAH analyses

ANNUAL EMISSION REDUCTIONS FROM TROLLEY BUS OPERATION ARE DRAMATIC

EMISSIONS PER BUS PER YEAR (LBS) (@ 42,000 MILES/BUS)						Trolley (in-basin) Percent Reductions Versus Methanol
Effluent	Average* Diesel	Methanol	Natural Gas	Trolley (in basin)	Trolley (total)	
HC	254	49	340	9	13	81%
CO	634	244	113	14	32	94%
NOx	2,636	1,214	1,714	34	323	97%
Particulates	120	24	23 37	2	18	92%
Total pounds	3,644	1,530	2,190	59	386	96%

** 50/50 split between new (1990) and old (1985) diesel engines*

Source: Manufacturer emissions data, DWP & SCE power plant emissions data, SCRTD Alternative Fuels Section Staff and BAH analyses

ADDITIONALLY, AS THE VEHICLES AGE, THE EMISSION RATES FROM ALTERNATIVELY FUELED ENGINES WILL UNDOUBTEDLY INCREASE WHILE TROLLEY COACH EMISSIONS WILL REMAIN UNCHANGED OR BE REDUCED AS STATIONARY POWER PLANTS IMPROVE - - - THUS INCREASING THE RELATIVE BENEFITS BEYOND THE FIGURES INDICATED ABOVE.

ALTERNATIVES TECHNOLOGY ANALYSIS

- Capital Costs
- Technology Maturity/Reliability
- Operating Costs
- Emission Reductions
- Safety
- Other Considerations/Advanced Technologies

ALL OF THE ALTERNATIVE FUELS ARE CONSIDERED MORE VOLATILE THAN DIESEL FUEL -- BUT PROPER MAINTENANCE AND TRAINING CAN MAKE ANY OF THE FUELS COMPLETELY USABLE AND SAFE FOR THE TRANSIT ENVIRONMENT

- **Methanol is highly toxic and unlike petroleum, can be absorbed through the skin. In ventilated areas, the ignitability of methanol is greater than diesel fuel but not as bad as gasoline. In enclosed spaces methanol is flammable over a wide temperature and oxygen content range. Methanol vapors are also heavier than air making increased ventilation, particularly in work pits, a necessity. Stage I and Stage II vapor recovery systems, (mandatory on all fueling installations) mitigate potential harmful effects of methanol vapors.**

- **Natural gas is generally considered safer than methanol since methane gas is non-toxic. Natural gas is lighter than air so that any stray gas from leaks will not accumulate in work pits. Groundwater contamination from liquid leaks is also eliminated. However, increased ventilation in the work area will be required.**

TO DATE THERE HAVE BEEN NO ACCIDENTS OR INJURIES FROM THE ALTERNATIVE FUELED BUSES OPERATING IN REVENUE SERVICE AT SCRTD

Source: SCRTD Alternative Fuels Section Staff

TROLLEY BUS OPERATION IS ALSO EXPECTED TO BE COMPLETELY SAFE FOR PASSENGERS, RIDERS, AND MAINTENANCE PERSONNEL

- **Other properties (San Francisco, Dayton, Seattle, Philadelphia) have been successfully operating trolleys for many years with excellent safety records**

- **As with alternative fuels, proper care and training will prevent accidents and injuries associated with repair of high voltage wires and equipment**

- **Some negative health effects have been associated with electromagnetic induction (stray magnetic fields) from high voltage power transmission wires**

  - **Studies to date have implicated only <u>very</u> high voltage alternating current (AC) lines (15,000 volts and higher)**

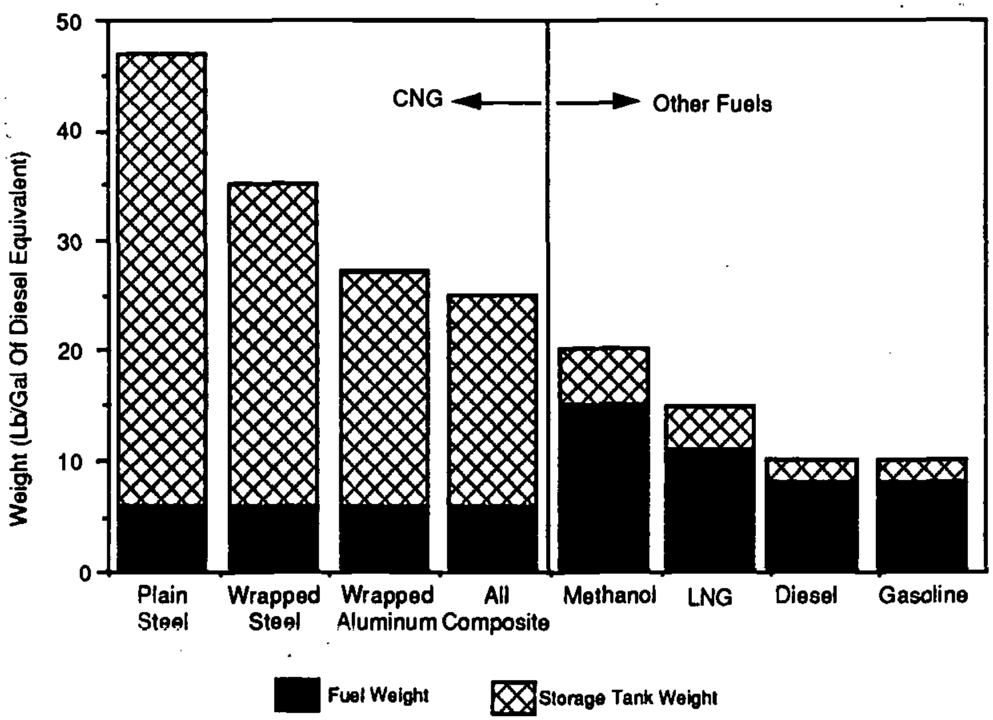
  - **No studies (that we are aware of) have focused on trolley type power transmission lines (750 volts, direct current)**

  - **Entire electric utility industry along with DWP and SCE have ongoing studies to evaluate this issue**

ALTERNATIVES TECHNOLOGY ANALYSIS

- Capital Costs
- Technology Maturity/Reliability
- Operating Costs
- Emission Reductions
- Safety
- Other Considerations/Advanced Technologies

COMPARISON OF FUEL AND STORAGE SYSTEM WEIGHTS FOR VARIOUS FUELS



Source: Gaseous Fuels: Technology, Performance, and Emissions; SAE Publication SP-89/798; p. 38.

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THE ON-BOARD FUEL WEIGHT OF ALTERNATIVE FUEL BUSES IS GREATER THAN DIESEL BUSES DUE TO ADDITIONAL FUEL TANKS AND LOW ENERGY DENSITY OF METHANOL AND CNG FUELS

- **Increased weight compared to diesel coach:**
  - **Methanol: + 1,600 lbs**
  - **CNG: + 2,600 lbs**
  - **LNG: + 1,000 lbs**
  - **Trolley: Varies from same to plus 2,000 lbs depending on size of APU**
- **Weight differences could be mitigated by compromising operating range of alternative fuel buses or limiting APU performance for the trolley buses - - - however, this could also limit the flexibility of the buses for use on all of RTD's routes**
- **Articulated trolley buses at MUNI and Seattle are relatively heavy at 44,000 lbs and 40,000 lbs, respectively. Advances in AC propulsion systems and RTDs comparatively less stringent duty cycle (little or no grades) should help manufacturers control the weight of the trolley coaches for the Los Angeles application**

ADVANCED BUS TECHNOLOGIES OFFERING "ZERO" EMISSION LEVELS WILL REQUIRE MAJOR TECHNOLOGICAL BREAKTHROUGHS - - - AND CANNOT BE PLANNED FOR

- **Batteries required to yield adequate performance in a heavy duty vehicle are 2 to 3 times over acceptable weight limits. Significant advances in material technologies are required for commercialization.**
- **The first fuel cell bus is currently being developed by the Dept. of Energy, the SCAQMD, and Georgetown University**
  - **Performance is constrained by fundamental size, weight, and efficiency limitations of the "reformer" component - - - a key element of the fuel cell technology**
  - **Batteries must be used to supplement performance - - - adding weight and limiting performance**
  - **Significant advances in materials and the energy conversion fuel cell process must occur before commercialization is practical.**
  - **Costs are essentially an order of magnitude over commercial heat engines.**
- **Roadway powered vehicles rely on an inductive coupling between an imbedded electrified rail buried just below the surface of the road and a transformer device on-board the vehicle. Electrical conversion efficiency is very poor, power transmission losses are high, and installation costs are high. Planned demonstration projects have recently been cancelled as additional laboratory research is needed.**

HYBRID BATTERY/FUEL CELL BUSES OFFER THE BEST CHANCE FOR ZERO EMISSION HEAVY DUTY PROPULSION.

Note: Part B of this study covers "advanced technologies" in more detail.

ALTERNATIVES COST COMPARISON

ROUTE STATISTICS USED FOR COST EVALUATION

LINE #	AVG. HEADWAYS	ROUTE LENGTH	ANNUAL VEHICLE MILES	P.M. PEAK BUSES	DAILY BOARDINGS
204	4	15.2	1,721,700	37	57,776
30	5	12.3	1,535,400	41	46,035
45	6	15.5	1,459,800	31	28,279
40	5	14.4	1,911,900	53	33,743
92	13	26.4	1,170,000	24	12,461
	TOTAL	83.4	7,798,800	186	178,295

GRAPHIC 40

TO EFFECTIVELY COMPARE THE TOTAL ALLOCATED COSTS PER MILE AMONG THE ALTERNATIVE BUS TECHNOLOGIES, THE DIFFERENTIAL COSTS ASSOCIATED WITH ESTABLISHING A MAINTENANCE DIVISION AND OPERATING A FLEET OF BUSES OVER A GIVEN SET OF ROUTES, CAN BE COMPARED. FOR THIS ANALYSIS, THE FOLLOWING ASSUMPTIONS ARE MADE:

- **Routes selected for evaluation include #30, #40, #45, #92, and #204 (these routes represent a typical cross-section of lines in RTD's system and are selected for costing purposes only)**

- **A total of (186) 40 ft. buses are required at peak to serve the five routes**

- **Costs for capital equipment (vehicles and catenary) will be amortized over the life of the asset at 3%:**
  - **Catenary: 30 years**
  - **Facilities: 20 years**
  - **Motor buses: 12 years**
  - **Trolley buses: 18 years**

POWER DISTRIBUTION AND CATENARY COSTS WERE DEVELOPED BASED ON THE FOLLOWING ASSUMPTIONS:

- A single set of wires to be installed on both sides of the street (single track, two-way system)

- A "feederless" system is used throughout (i.e., a sufficient number of appropriately sized substations are installed such that undergrounding of feeder cables are not necessary)

- Trolley wires are supported by joint use street light and traffic signal poles (existing poles are replaced with new specially designed poles)

- Since Route #40 shares a 3-1/2 mile section of Broadway with line #45 and line #30 shares a 1-1/2 mile section of Broadway with line #45, and line #30 shares a 1/2 mile section of 1st Street with line #40, electrification economics allow for the shared use of 8 substations and 5-1/2 miles of trolley overhead and support poles

TOTAL POWER DISTRIBUTION SYSTEM AND CATENARY COSTS

ROUTE #	ROUTE LENGTH	BASIC COST OF OVER-HEAD WIRE & SUPPORT POLES PER MILE	TOTAL BASIC COST/ ROUTE	TOTAL SUBSTATION COSTS PER ROUTE	TOTAL SPECIAL WORK PER ROUTE	TOTAL
24	15.2	980,000	14,896,000	4,742,400	1,216,000	20,854,400
30	12.3	980,000	12,054,000	3,837,600	984,000	16,875,600
45	15.5	980,000	15,190,000	4,836,000	1,240,000	21,266,000
40	14.4	980,000	14,112,000	4,492,800	1,152,000	19,756,800
92	26.4	980,000	25,872,000	8,236,800	2,112,000	36,200,800
		TOTAL	$82,124,000	$26,145,600	$6,704,000	$114,973,600
		LESS ECONOMIES DUE TO ROUTE INTERLINING (5.5 MILES)	980,000	1,716,000	440,000	7,546,000
		TOTAL WITH ECONOMIES	$76,734,000	$24,429,600	$6,264,000	$107,427,600

GRAPHIC 41

Note:* *These routes used for costing purposes only

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THE TOTAL POWER DISTRIBUTION SYSTEM INCLUDING SUBSTATIONS, OVERHEAD WIRE, AND SUPPORT POLES WILL AVERAGE APPROXIMATELY $1.5 MILLION PER ROUTE MILE EXCLUDING ANY SPECIAL AESTHETIC ENHANCEMENTS

TOTAL CATENARY COSTS FOR REPRESENTATIVE 5 ROUTES

	Total	Per Route Mile
Overhead Wire and Support Poles	$76,734,000	$924,506
Substations	$24,429,600	$294,332
Special Work	$6,264,000	$75,470
15% Engineering and Construction Management	$16,114,140	194,146
Total	$123,541,740	1,488,455

ANNUALIZED VEHICLE CAPITAL COSTS WILL BE MARGINALLY HIGHER FOR THE TROLLEY BUSES

VEHICLE FLEET CAPITAL COST SUMMARY						
Vehicles	**Diesel Baseline**	**Methanol**	**CNG**	**LNG**	**Trolley 40 ft.**	**Trolley Artic**
$ Per Unit	$210,000	$240,000	$255,000	$250,000	$400,000	$625,000
Base Fleet Size (Units:Peak)*	186	186	186	186	186	140
Spares Ratio	25%	25%	25%	25%	25%	25%
Total Units	233	233	233	233	233	174
Useful Life	12 years	12 years	12 years	12 years	18 years	18 years
Amortized Cost/Year @ 3% C.O.C.	$4,905,061	$5,605,784	$5,956,146	$5,839,359	$6,761,909	$7,923,112

*** *For Articulated coaches we have assumed a 3 for 4 replacement ratio of 40 ft. coaches***

- - - HOWEVER, 18 YEAR USEFUL LIFE FOR TROLLEYS IS A CONSERVATIVE ESTIMATE (18 YRS IS THE UMTA GUIDELINE FOR TROLLEY COACH USEFUL LIFE); ANNUALIZED FLEET COSTS WILL BE REDUCED FOR TROLLEYS IF THEY LAST AS LONG AS IN OTHER NORTH AMERICAN CITIES (20 TO 25 YEARS).

A SUMMARY OF FACILITIES RELATED CAPITAL COSTS ASSOCIATED WITH EACH NEW BUS TECHNOLOGY ARE SHOWN BELOW (ON AN ANNUALIZED BASIS)

	Diesel Baseline	Methanol	CNG	LNG	Trolley 40 ft.	Trolley Artic
Fuel Facility Modifications	0	$725,000	$2,250,000	$995,000	0	0
Maintenance Facility Modifications	0	$300,000	$300,000	$300,000	$750,000	$1,000,000
Total Annualized Capital Costs Excluding Catenary (20 yrs @ 3%)	0	$68,896	$171,400	$87,044	$50,412	$67,218
Annualized Catenary Costs (30 yrs @ 3%)					$6,303,009	$6,303,009
Total Annualized Capital Cost	0	$68,896	$171,400	$87,044	$6,353,421	$6,370,225

FOR MOTOR BUS ALTERNATIVES, CNG WOULD REQUIRE THE LARGEST INVESTMENT IN FUELING FACILITIES.

ANNUAL OPERATING COSTS FOR THE TROLLEY BUS SYSTEM WILL BE SIMILAR TO OTHER CLEAN FUEL ALTERNATIVES

	Diesel Baseline	Methanol	CNG	LNG	Trolley 40 ft.	Trolley Artic
Fuel Costs						
Cost per Mile	$.22	$.35	$.22	$.22	$.27	$.41
Total Fleet Miles (Annual)	7,800,000	7,800,000	7,800,000	7,800,000	7,800,000	5,850,000
Annual Fleet Fuel Costs	$1,716,000	$2,730,000	$1,716,000	$1,716,000	$2,106,000	$2,398,500
Operator Cost						
Reduced Operator Cost for Artics Due to Reduced # of Vehicles and Vehicle Fleet Miles (@ $2.10 per Mile)						
Total Miles						1,950,000
Total Dollars						($4,095,000)
Direct Maintenance Cost						
Cost per Mile	$.70	$.81	$.81	$.81	$.525	$.92
Total for Fleet	$5,460,000	$6,318,000	$6,318,000	$6,318,000	$4,095,000	$5,382,000
Total for Catenary (@ $0.25/Vehicle Mile)	—	—	—	—	$1,950,000	$1,462,500
Compressor Station Electric Costs*	—	—	$187,200	—	—	—
Total Annual Direct Operating Costs	$7,176,000	$9,048,000	$8,221,200	$8,034,000	$8,151,000	$5,148,000

* ***See Task 3 Report, "Low Emission Transit Alternatives" for additional details***

TOTAL ALLOCATED COSTS ARE HIGHEST FOR THE TROLLEY BUS - - - DUE TO THE ANNUALIZED CAPITAL COST OF THE OVERHEAD WIRE SYSTEM

	Diesel Baseline	Methanol	CNG	LNG	Trolley 40 ft.	Trolley Artic
Annualized Capital Costs						
Vehicles	$4,905,061	$5,605,784	$5,956,146	$5,839,359	$6,761,909	$7,924,112
Facilities	0	$68,896	$171,400	$87,044	$50,412	$67,216
Overhead Wire	0	0	0	0	$6,303,009	$6,303,009
Annual Direct Operating Costs						
Fuel	$1,716,000	$2,730,000	$1,716,000	$1,716,000	$2,106,000	$2,398,500
Reduced Operators Cost	0	0	0	0	0	($4,095,000)
Compressor Utilities			$187,200			
Maintenance (Including Catenary)	$5,460,000	$6,318,000	$6,318,000	$6,318,000	$6,045,000	$6,844,500
Total Allocated Fleet Cost	$12,081,061	$14,722,680	$14,348,746	$13,960,403	$21,266,330	$19,442,337

ALTHOUGH TOTAL ALLOCATED COSTS ARE HIGHEST FOR THE TROLLEY BUS SO ARE THE EMISSION REDUCTION BENEFITS

ANNUAL EMISSION REDUCTION S FROM SAMPLE ROUTES (LBS)

	NEW DIESEL	METHANOL	NATURAL GAS	TROLLEY BUS
HC	36,036	9,500	66,339	1,566
CO	91,728	47,502	22,113	2,652
NOx	366,912	236,527	334,152	6,318
PM	16,871	4,750	4,423	390
TOTAL	511,547	298,280	427,027	10,920
Difference vs. Diesel	—	213,268	84,521	500,627
Percent Reduction vs. Diesel	—	42%	17%	98%

GRAPHIC 51

Nota: Emissions from motor buses have been increased by 5 percent to account for engine wear and degradation in emission factors

BEST, NOMINAL, AND WORST CASE COST ASSUMPTION SCENARIOS FOR EACH VEHICLE TECHNOLOGY

	DIESEL	METHANOL	CNG	LNG	TROLLEY 40 FT	TROLLEY ARTIC*
Spares Ratio						
Best Case Scenario	20%	20%	20%	20%	20%	20%
Nominal Case Scenario	25%	25%	25%	25%	25%	25%
Worst Case Scenario	25%	30%	30%	30%	30%	30%
Useful Life						
Best Case Scenario	12	12	12	12	24	24
Nominal Case Scenario	12	12	12	12	18	18
Worst Case Scenario	12	12	12	12	18	18
Maintenance Cost vs. Diesel Baseline						
Best Case Scenario	—	+10%	+10%	+10%	-35%	+14%
Nominal Case Scenario	—	+15%	+15%	+15%	-25%	+31%
Worst Case Scenario	—	+25%	+25%	+25%	-15%	+49%
Fuel Cost/Unit						
Best Case Scenario	$.71/gal	$.40/gal	$.40/therm	$.36/gal	$.08/kWh	$.08/kWh
Nominal Case Scenario	$.80/gal	$.45/gal	$.46/therm	$.40/gal	$.09/kWh	$.09/kWh
Worst Case Scenario	$.96/gal	$.55/gal	$.56/therm	$.49/gal	$.11/kWh	$.11/kWh

GRAPHIC 53

* *Maintenance costs for artic trolley are on a per-vehicle basis - - - artic trolleys, however, are assumed to substitute for standard coaches on a 3 for 4 replacement ratio. Also, maintenance on artics is assumed to be 75% higher than a conventional trolley coach. Example, nominal case:*

Standard trolley - .75 of diesel maintenance (x) 1.75 = 1.31 or 31% increase over diesel baseline

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TO CALCULATE THE RANGE OF COST EFFECTIVENESS FOR EACH TECHNOLOGY, KEY OPERATING FACTORS WERE VARIED AS SHOWN ON THE FACING PAGE AND DESCRIBED BELOW

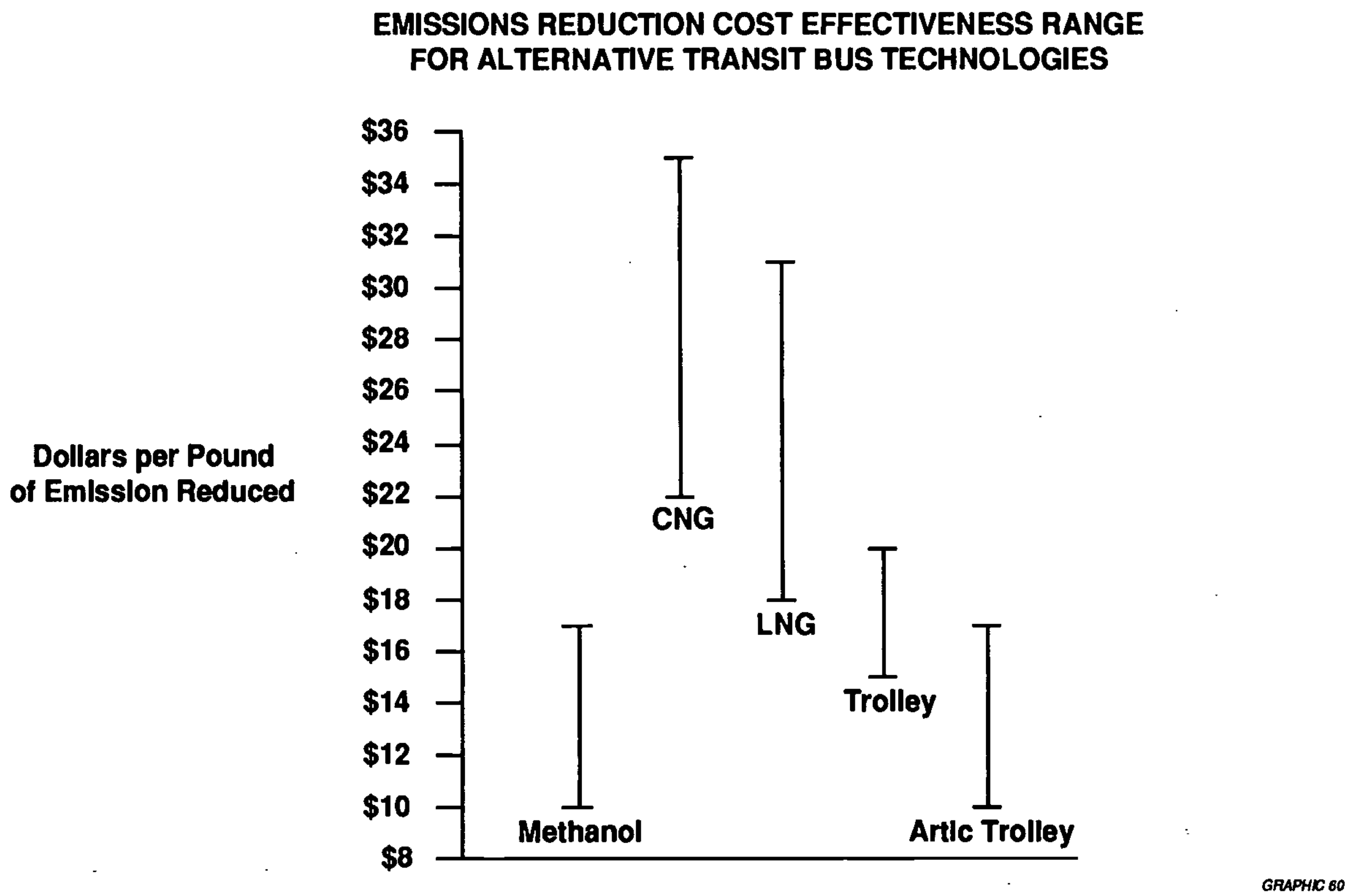
Spares Ratio: RTD currently operates at a 25 percent spares ratio for diesel buses. Spares ratio for alternative fuel technologies could be higher due to vehicle reliability. Trolley buses in other cities generally operate at a spares ratio similar to the diesel fleet.(1)

Useful Life: As previously discussed, trolley buses in other cities have lasted twice as long as diesel buses. UMTA guidelines list 18 years as useful life for trolleys

Maintenance Cost: Even at a mature level of technology development, alternative fuel buses are likely to require more maintenance than today's standard diesel bus. Trolley buses have demonstrated reduced maintenance costs in the range of 15 to 30 percent below diesel levels in other cities

Fuel Costs: Fuel cost range for methanol is taken from the California Energy Commission's AB 234 Fuels Report. Ranges for other technologies are simple proportions based on the methanol range.

(1) As noted in the "Operations and Maintenance Considerations" section of this report, the total fleet size (diesel plus trolley) will increase with trolley use due to the reduced interchangeability of the two modes and loss of the interlining savings.


EMISSIONS REDUCTION COST EFFECTIVENESS RANGE
FOR ALTERNATIVE TRANSIT BUS TECHNOLOGIES
Dollars per Pound
of Emission Reduced
$36
$34
$32
$30
$28
$26
$24
$22
$20
$18
$16
$14
$12
$10
$8
CNG
LNG
Trolley
Methanol
Artic Trolley
GRAPHIC 60

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GIVEN THE PLAUSIBLE RANGES FOR KEY COST ELEMENTS SUCH AS SPARES RATIO, MAINTENANCE COSTS, AND FUEL COSTS, A CONSIDERABLE OVERLAP IN EMISSION REDUCTION COST EFFECTIVENESS EXISTS FOR THE VARIOUS ALTERNATIVES

EMISSION REDUCTION COST EFFECTIVENESS (DOLLARS PER POUND OF EMISSIONS REDUCED)			
	Best	Nominal	Worst
Methanol	$10.08	$11.98	$16.98
CNG	$22.03	$26.09	$35.66
LNG	$18.37	$21.78	$31.52
Trolley 40 ft.	$15.15	$18.37	$20.25
Trolley Artic	$10.73	$14.70	$17.14

OBSERVATIONS AND CONCLUSIONS

- **Based on present levels of engine and emission control technology, methanol buses are the most cost effective in reducing air pollution from transit vehicles.**

- **Both CNG and LNG offer the potential for reduced operating costs compared to methanol - - - in the range of $1 million per year for a typical operating division. The emissions from natural gas engines will likely parallel those from a methanol engine as engine development work continues over the next few years. Natural gas buses will therefore likely become more cost effective than methanol buses in the future.**

- **In the long run, LNG vehicles may offer the lowest operating costs of any clean fuel alternatives due to vehicle weight savings and refueling advantages over CNG, as well as competitive fuel pricing.**

- **Trolley buses offer reasonable emission reduction cost effectiveness <u>and the greatest total levels of pollution reduction</u>.**

- **The costs associated with establishing the overhead wire system must be considered as an investment in the future - - - and necessary to reduce emission levels beyond those achievable from alternative fuel coaches only, as well as for noise reduction, improved ride and other trolley benefits**

ROUTE SELECTION

SAN FRANCISCO TROLLEY ROUTES				
Route #	Headways (min) Peak/Base	Equipment (vehicles) Peak/Base	Daily Boardings	Daily Vehicle Miles
1	3/6	31/16	31,608	2,020
3	10/20	7/4	6,558	544
4	10/20	8/4	6,313	520
5	4/7	27/15	21,588	2,181
6	8/12	11/9	13,920	1,327
7	8/12	9/7	10,437	753
8	8/15	10/6	8.017	653
14	4/4	31/30	59,566	3,984
21	6/10	16/9	14,091	1,126
22	7/8	17/14	25,146	1,715
24	8/10	14/13	19/307	1,596
30	3/6	21/17	45,408	2,129
33	20/20	5/5	4,124	759
41	5/N.A.	15/N.A.	4,114	281
45	7/7	21/16	7,311	657
47	9/12	7/5	12,120	709
49	9/12	15/12	17,181	1,081

TOP SCRTD LINES				
Route #	Headways (min) Peak/Base	Equipment (vehicles) Peak/Base	Daily Boardings	Daily Vehicle Miles
30	4/5	41/26	46,035	5,119
60	4/8	45/25	30,822	6,204
20	5/8	89/51	59,857	11,149
18	5/10	28/16	30,534	3,647
16	5/10	31/12	23,674	2,575
10	5/10	33/17	24,056	3,895
45	8/8	31/22	28,279	4,866
200	8/8	14/12	20,052	1,727
2	6/10	33/23	25,000	5,129
251	6/10	26/17	19,279	3,313
28	6/10	72/35	43,913	8,741
40	4/12	53/29	33,743	6,373
1	7/10	36/23	29,811	3,561
204	8/10	37/32	57,776	5,739
68	8/10	23/18	20,611	3,254
14	6/12	32/17	27,162	3,977
53	6/12	21/12	15,691	3,016
420	7/12	41/23	21,006	7,113
4	7/12	52/32	41,957	7,310
66	4/15	27/10	25,327	3,281
33	10/10	37/19	24,452	5,813
207	9/12	27/17	37,416	3,998
424	9/12	46/20	19,302	8,628

ROUTE SELECTION

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Route #	Headways (min) Peak/Base	Equipment (vehicles) Peak/Base	Daily Boardings	Daily Vehicle Miles
1	3/6	31/16	31,608	2,020
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5	4/7	27/15	21,588	2,181
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7	8/12	9/7	10,437	753
8	8/15	10/6	8.017	653
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21	6/10	16/9	14,091	1,126
22	7/8	17/14	25,146	1,715
24	8/10	14/13	19/307	1,596
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4	7/12	52/32	41,957	7,310
66	4/15	27/10	25,327	3,281
33	10/10	37/19	24,452	5,813
207	9/12	27/17	37,416	3,998
424	9/12	46/20	19,302	8,628

ROUTE SELECTION - - - DISCUSSION

General

An ideal electrified trolley bus system would consist of a confined network of high density routes such that the ratio of vehicle service miles to route miles is high. Such a system would provide maximum utilization of the overhead catenary system. Long routes with relatively few peak buses and long headways will be the least cost effective. Short routes with a large number of peak buses and short headways will be the most cost effective. Also, routes that are hilly and have many stops/starts will favor trolley operation, since diesel fuel consumption and emissions are comparatively high on such routes.

San Francisco MUNI provides an excellent example of the "confined network" concept. In total, MUNI's trolley system exhibits the highest ratio of vehicle service miles and boardings per route mile of any trolley system (See page 48 for a comparison of operation statistics among trolley systems). However, as shown on the facing page, when considered individually, SCRTD's highest service level routes show headways less than or equal to many of MUNI's existing trolley routes, and have higher daily boardings and vehicle service miles. Many of MUNI's trolley routes, however, operate over shared sections of the catenary system thus increasing the system's cost effectiveness. Multiple routes for example operate on various sections of Market Street. In contrast, SCRTD's route structure is more radial in design with less overlapping of routes on shared streets. Careful planning and route selection will be required to maximize cost effectiveness while meeting other system design objectives.

TROLLEY ROUTE CONVERSION "PACKAGES" DEVELOPED BY RTD STAFF

GROUP I

Line #	Street Name(s)	One-Way Route Miles	Headways (min.) Base	Headways (min.) Peak	Bus Requirements Base	Bus Requirements Peak
204	Vermont	15.2	5	3	32	39
207	Western	14.9	8	6	17	27
206	Normandie	15.2	15	8	11	17
200	Alvarado	8.0	8	8	12	13
105	Vernon-La Cienega	15.8	12	10	14	18
Totals		53.9	—	—	86	114

GROUP II

Line #	Street Name(s)	One-Way Route Miles	Headways (min.) Base	Headways (min.) Peak	Bus Requirements Base	Bus Requirements Peak
30	W. Pico-E. First-Floral	12.3	6	4	26	44
40	Hawthorne-Union St.	14.4	12	4	29	58
45	Broadway-Mercury	15.5	8	8	22	31
68	Washington-Brooklyn	15.0	10	8	18	23
Totals		57.2	—	—	111	156

GROUP III

Line #	Street Name(s)	One-Way Route Miles	Headways (min.) Base	Headways (min.) Peak	Bus Requirements Base	Bus Requirements Peak
16	W. Third	9.3	10	5	12	31
18	W. Sixth-Whittier	11.8	10	5	16	28
66	E. Olympic-W. Eighth	10.0	15	4	10	28
Totals		31.1	—	—	38	87

GROUP IV

Line #	Street Name(s)	One-Way Route Miles	Headways (min.) Base	Headways (min.) Peak	Bus Requirements Base	Bus Requirements Peak
4	Santa Monica	20.0	8	5	34	54
92	Glendale Blvd.	26.4	15	10	13	24
180-181	Colorado-Yosemite	17.9	10	10	18	21
164-165	Victory-Vancouver	44.0	30	15	12	23
210	Vine-Crenshaw	20.0	13	9	18	24

RTD OPERATIONS AND PLANNING STAFF IDENTIFIED CANDIDATE ROUTES FOR TROLLEY BUS CONVERSION EARLY IN THE STUDY

- **Four groups or "packages" of routes were developed by RTD staff based on a variety of criteria including high service frequency, ridership, degree of interlining and scheduling complexity, service disruptions, and the ability to be operated out of a single division without excessive increases in deadhead mileage.**

- **Group I included routes 204, 207, 206, 200, and 105. These routes would operate out of Division 5 and run primarily in the North-South direction.**

- **Group II included routes 30, 40, 45, and 68 and would operate out of Division 2. Routes 40 and 45 operate north-south while routes 30 and 68 operate east-west.**

- **Group III included routes 16, 18, and 66 and would operate out of Division 1. These routes operate in the east-west direction.**

- **Group IV included routes 4, 92, 180-181, 164, 210, and Exposition Corridor. This group represented routes that would broaden the geographic coverage of the trolley system but were evaluated by RTD staff as difficult to implement. This group was not developed with the intent of implementing as a "package".**

THE ROUTES MEETING SCAQMD CONTROL MEASURE GUIDELINES (HEADWAYS LESS THAN 15 MINUTES), AS WELL AS THE ROUTES IDENTIFIED BY RTD STAFF EARLY IN THE STUDY, SERVED AS A STARTING POINT FOR IDENTIFYING A "PHASE I" TROLLEY SYSTEM

OPERATOR	LINE	HEADWAY PEAK	HEADWAY BASE	HEADWAY AVG	DAILY VEHICLE MILES	PM PEAK BUSES	BASE BUSES	DAILY VEHICLE HOURS	VEHICLE MILES PER RT. MILE	DAILY BOARDINGS	ROUTE LENGTH	BOARDINGS PER RT. MILE	PASS. PER HOUR	DAILY BOARDINGS PER BUS
RTD	30	4	5	4.5	5,119	41	26	484	420	46,035	12.2	3,773	95.0	1123
RTD	60	4	8	6.1	6,204	45	25	527	302	30,822	20.6	1,500	58.5	685
RTD	20	5	8	6.6	11,149	89	51	997	851	59,857	13.1	4,569	60.1	673
RTD	18	5	10	7.6	3,647	28	16	320	320	30,534	11.4	2,678	95.3	1091
RTD	16	5	10	7.6	2,575	31	12	279	277	23,674	9.3	2,546	84.8	764
RTD	10	5	10	7.6	3,895	33	17	384	393	24,056	9.9	2,430	62.6	729
RTD	45	8	8	8.0	4,866	31	22	413	314	28,279	15.5	1,824	68.5	912
RTD	200	8	8	8.0	1,727	14	12	199	230	20,052	7.5	2,674	101.0	1432
RTD	2	6	10	8.1	5,129	33	23	447	196	25,000	26.2	954	55.9	758
RTD	251	6	10	8.1	3,313	26	17	303	245	19,279	13.5	1,428	63.6	742
RTD	28	6	10	8.1	8,741	72	35	732	343	43,913	25.5	1,722	60.0	610
RTD	40	4	12	8.2	6,373	53	29	583	385	33,743	16.6	2,039	57.9	637
RTD	1	7	10	8.6	3,561	36	23	408	217	29,811	16.4	1,818	73.1	828
RTD	204	8	10	9.1	5,739	37	32	546	452	57,776	12.7	4,549	105.7	1562
RTD	68	8	10	9.1	3,254	23	18	313	167	20,611	19.5	1,057	65.8	896
RTD	14	6	12	9.2	3,977	32	17	362	234	27,162	17.0	1,598	75.1	849
RTD	53	6	12	9.2	3,016	21	12	252	200	15,691	15.1	1,039	62.3	747
RTD	420	7	12	9.6	7,113	41	23	509	301	21,006	23.6	890	41.2	512
RTD	4	7	12	9.6	7,310	52	32	657	366	41,957	20.0	2,098	63.9	807
RTD	66	4	15	9.8	3,281	27	10	283	298	25,327	11.0	2,302	89.5	938
RTD	33	10	10	10.0	5,813	37	19	441	338	24,452	17.2	1,422	55.5	661
RTD	207	9	12	10.4	3,998	27	17	363	322	37,416	12.4	3,017	103.1	1386
RTD	210	9	12	10.6	3,466	23	18	299	173	21,300	20.0	1,065	71.2	926
RTD	424	9	12	10.6	8,628	46	20	521	303	19,302	28.5	677	37.1	420
RTD	55	6	15	10.7	2,901	19	11	248	228	11,759	12.7	926	47.4	619
RTD	105	10	12	11.1	2,833	19	14	257	130	19,276	21.8	884	75.1	1015
RTD	81	8	15	11.7	4,204	27	17	330	192	20,357	21.9	930	61.7	754
RTD	212	10	15	12.6	3,406	20	13	268	157	14,167	21.7	653	52.8	708
RTD	92	10	15	12.6	3,900	24	13	275	148	12,462	26.4	472	45.3	519
RTD	115	10	15	12.6	3,604	25	12	272	142	15,925	25.3	629	58.6	637
RTD	38	10	15	12.6	2,022	17	10	200	111	14,579	18.2	801	72.9	858
RTD	111	10	15	12.6	3,041	18	11	233	109	16,196	27.9	581	69.5	900
RTD	78	10	15	12.6	3,670	24	13	269	202	13,174	18.2	724	48.9	549
RTD	480	10	15	12.6	6,117	24	10	264	177	6,479	34.6	187	24.6	270
RTD	180	10	15	12.6	3,903	21	17	312	214	16,074	18.2	883	51.5	765
RTD	70	10	15	12.6	3,318	21	16	271	209	14,633	15.9	920	54.0	697
RTD	76	11	15	13.1	2,734	16	12	219	168	12,433	16.3	763	56.9	777
RTD	560	12	15	13.6	4,206	23	16	291.7	117	14,914	35.8	417	51.1	648
RTD	206	13	15	14.1	2,545	16	11	225	167	18,540	15.2	1,220	82.3	1159
RTD	26	8	20	14.3	4,469	35	15	387	171	25,610	26.2	977	66.1	732
RTD	94	9	20	14.8	5,203	24	18	343	160	16,664	32.6	511	48.7	694

COST EFFECTIVENESS CALCULATION METHODOLOGY

Total Allocated Cost per Route = Differential Vehicle Capital Cost (Trolley-Methanol)

(plus) Differential Operating Costs (Trolley-Methanol)

(plus) Annualized Capital Cost of Overhead Wire (Trolley only)

where: Differential Vehicle Capital Costs = [Trolley Fleet Costs Amortized Over 18 Years at 3% Interest Rate]

(minus) [Methanol Fleet Costs Amortized Over 12 Years at 3% Interest Rate]

and: Differential Operating Costs = [Trolley Fleet Operating Costs – Methanol Fleet Operating Cost]

and: Annualized Overhead Wire Costs = Total Installation Costs (Excluding Aesthetic Improvements) Amortized Over 30 Years at 3% Interest Rate

Total Emissions Reduced per Route = $\left[\frac{\text{Methanol Bus Emissions}}{\text{Mile}} \times \text{Fleet Miles}\right]$

(minus) $\left[\frac{\text{Trolley Bus Emissions}}{\text{Mile}} \times \text{Fleet Miles}\right]$

GRAPHIC 24

THE FOLLOWING CRITERIA WERE USED IN SELECTING A SMALLER SUBSET OF ROUTES FOR INITIAL IMPLEMENTATION

Cost Effectiveness: The "cost effectiveness" of converting a route from motor bus to trolley bus operation can be measured both in terms of the amount emissions reduced and in terms of the number of people served (mobility). The investment needed to achieve the reduction in emissions should be based on the differential costs between the proposed system (trolleys) and the baseline system to which it is being compared. Since diesel buses will be replaced over the next decade with alternative fuel buses, the baseline technology to which trolleys are compared is methanol powered buses.

Note: In contrast, when methanol and trolley coaches are compared versus a diesel bus as in the previous section, the baseline emissions and costs should be those of the diesel bus system.

Community Acceptance: Based on input from the Public Awareness Program and numerous meetings with local city officials along candidate routes

Geographic Coverage: Wide geographic coverage with operation in areas served by all local utilities

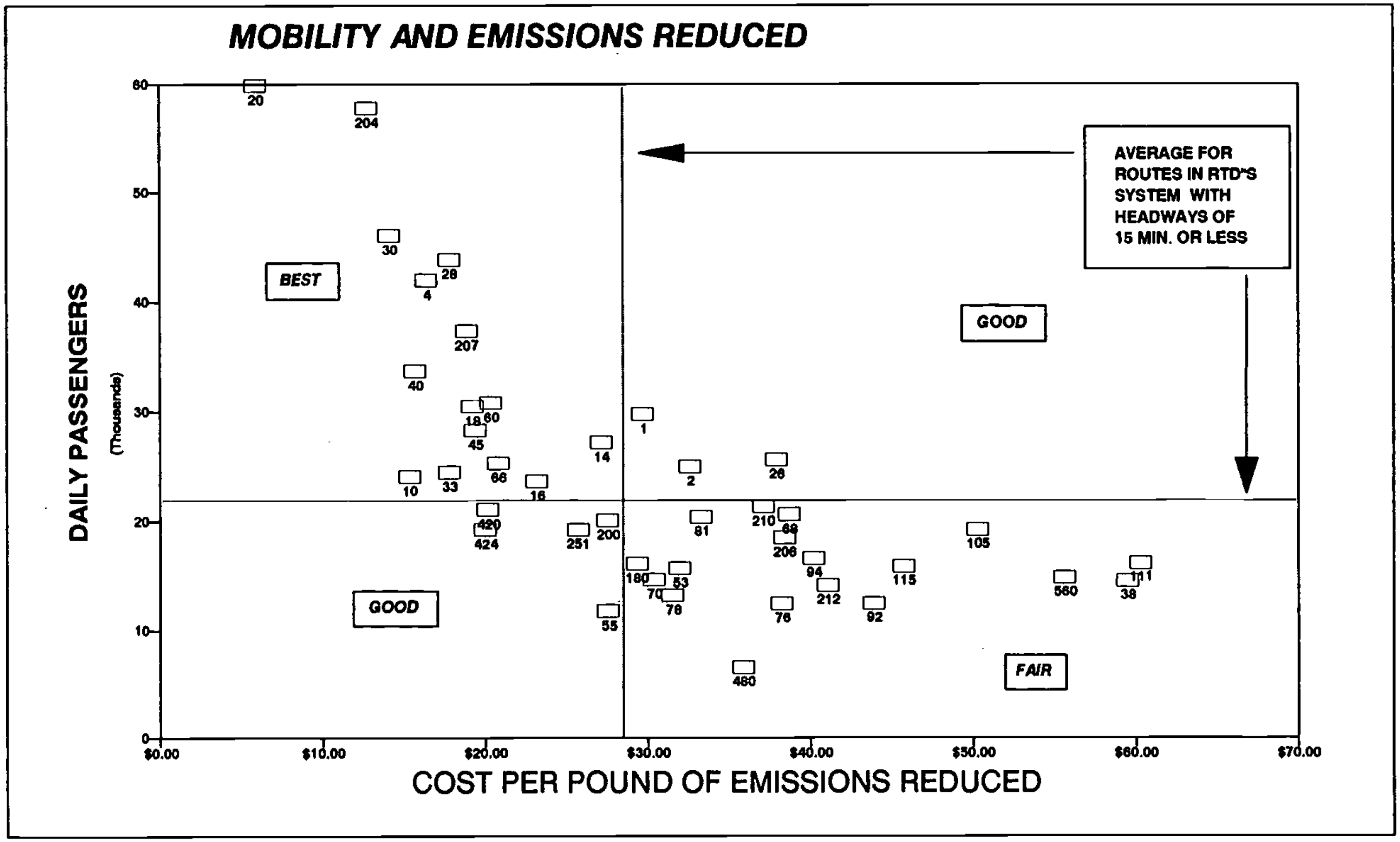
System Connectivity: Routes that intersect light and heavy rail lines so as to increase coverage of premium transit service

Scheduling & Operations: Complex routes that are highly interlined, have "turnback" buses or incorporate branching were deemed less desirable than more "clean" routes (such characteristics can cause a substantial increase in vehicle requirements in order to maintain a "100%" trolley route – a feature deemed desirable for initial route conversion)

TROLLEY CONVERSION COSTS AND EMISSIONS REDUCED FOR TOP 40 ROUTES

OPERATOR	LINE	ANNUALIZED PREMIUM FOR TROLLEY VEHICLE PURCHASES	ANNUAL SAVINGS FROM TROLLEY OPERATION	AMMORTIZED CATENARY COST	TOTAL ANNUALIZED COST FOR TROLLEY CONSVERSION	TOTAL ANNUAL METHONAL EMISSIONS	TOTAL ANNUAL TROLLEY EMISSIONS	TOTAL EMISSIONS REDUCED (LBS)	$/POUND OF EMISSIONS REDUCED
RTD	20	$157,598	($417,400)	$994,508	$734,706	128,698	4,870	123,829	$5.93
RTD	204	$65,518	($214,868)	$964,142	$814,792	66,251	2,507	63,744	$12.78
RTD	30	$72,601	($191,652)	$926,183	$807,133	59,093	2,236	56,857	$14.20
RTD	10	$58,435	($145,840)	$751,575	$664,170	44,967	1,701	43,266	$15.35
RTD	40	$93,850	($238,601)	$1,256,421	$1,111,670	73,569	2,784	70,785	$15.70
RTD	4	$92,080	($273,698)	$1,518,333	$1,336,715	84,390	3,193	81,197	$16.46
RTD	33	$65,518	($217,620)	$1,305,767	$1,153,665	67,100	2,539	64,561	$17.87
RTD	28	$127,495	($327,271)	$1,935,875	$1,736,099	100,908	3,818	97,090	$17.88
RTD	207	$47,811	($149,681)	$941,367	$839,496	46,152	1,746	44,405	$18.91
RTD	18	$49,581	($136,551)	$865,450	$778,480	42,103	1,593	40,510	$19.22
RTD	45	$54,894	($182,183)	$1,176,708	$1,049,419	56,173	2,125	54,048	$19.42
RTD	424	$81,455	($323,021)	$2,163,625	$1,922,059	99,598	3,769	95,830	$20.06
RTD	420	$72,601	($266,303)	$1,791,633	$1,597,931	82,110	3,107	79,003	$20.23
RTD	60	$79,684	($232,259)	$1,560,087	$1,407,513	71,613	2,710	68,904	$20.43
RTD	66	$47,811	($122,844)	$835,083	$760,049	37,877	1,433	36,444	$20.86
RTD	16	$54,894	($96,389)	$706,025	$664,529	29,720	1,125	28,595	$23.24
RTD	251	$46,040	($124,054)	$1,024,875	$946,861	38,250	1,447	36,803	$25.73
RTD	14	$56,664	($148,880)	$1,290,583	$1,198,367	45,905	1,737	44,168	$27.13
RTD	55	$33,644	($108,598)	$964,142	$889,188	33,485	1,267	32,218	$27.60
RTD	200	$24,791	($64,659)	$569,375	$529,507	19,936	754	19,182	$27.60
RTD	180	$37,186	($146,121)	$1,381,683	$1,272,748	45,054	1,705	43,349	$29.36
RTD	1	$63,747	($133,316)	$1,245,033	$1,175,464	41,106	1,555	39,551	$29.72
RTD	70	$37,186	($124,218)	$1,207,075	$1,120,042	38,301	1,449	36,851	$30.39
RTD	78	$42,498	($137,412)	$1,381,683	$1,286,769	42,369	1,603	40,766	$31.57
RTD	53	$37,186	($112,930)	$1,146,342	$1,070,597	34,820	1,318	33,503	$31.96
RTD	2	$58,435	($192,015)	$1,989,016	$1,855,437	59,205	2,240	56,964	$32.57
RTD	81	$47,811	($157,394)	$1,662,575	$1,552,991	48,530	1,836	46,694	$33.26
RTD	480	$42,498	($229,009)	$2,626,716	$2,440,205	70,611	2,672	67,939	$35.92
RTD	210	$40,728	($129,767)	$1,518,333	$1,429,294	40,012	1,514	38,498	$37.13
RTD	26	$61,977	($167,319)	$1,989,016	$1,883,674	51,590	1,952	49,638	$37.95
RTD	76	$28,332	($102,376)	$1,237,442	$1,163,398	31,566	1,194	30,372	$38.31
RTD	206	$28,332	($95,277)	$1,153,933	$1,086,988	29,377	1,112	28,266	$38.46
RTD	68	$40,728	($121,819)	$1,480,375	$1,399,284	37,561	1,421	36,139	$38.72
RTD	94	$42,498	($194,789)	$2,474,883	$2,322,592	60,060	2,273	57,787	$40.19
RTD	212	$35,415	($127,509)	$1,647,391	$1,555,297	39,315	1,488	37,828	$41.12
RTD	92	$42,498	($146,023)	$2,004,200	$1,900,675	45,024	1,704	43,320	$43.87
RTD	115	$44,269	($134,930)	$1,920,691	$1,830,030	41,603	1,574	40,029	$45.72
RTD	105	$33,644	($106,060)	$1,654,983	$1,582,568	32,702	1,237	31,464	$50.30
RTD	560	$40,728	($157,461)	$2,717,816	$2,601,082	48,551	1,837	46,714	$55.68
RTD	38	$30,103	($75,704)	$1,381,683	$1,336,082	23,342	883	22,459	$59.49
RTD	111	$31,874	($113,851)	$2,118,075	$2,036,097	35,104	1,328	33,776	$60.28

COST EFFECTIVENESS OF THE TOP 40 SCRTD ROUTES WERE EVALUATED IN TERMS OF EMISSIONS REDUCED AND MOBILITY DELIVERED



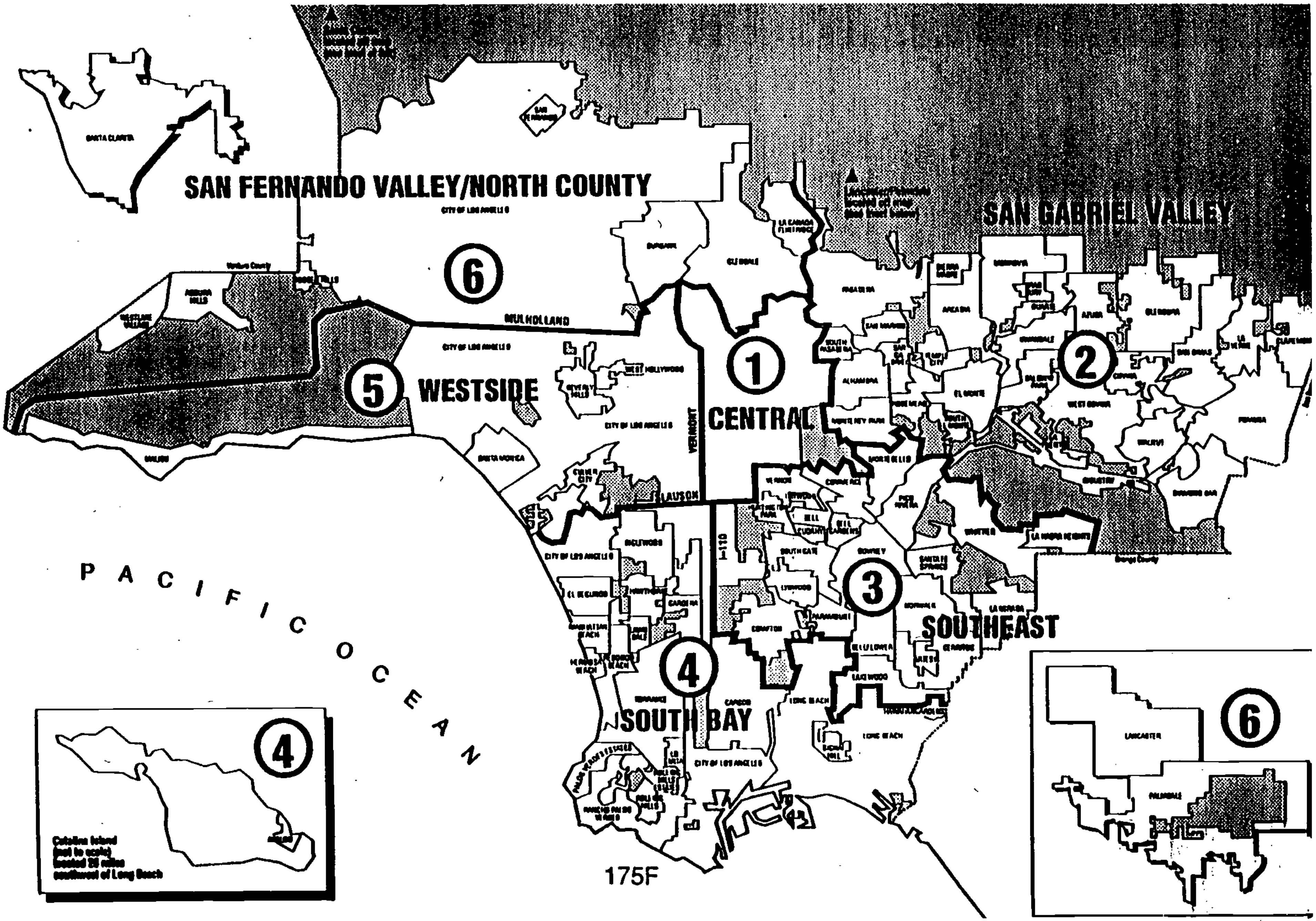
SIXTEEN OF THE ROUTES DISTINGUISHED THEMSELVES AS BEING HIGHLY COST EFFECTIVE - - - THESE ROUTES ARE SHOWN ON THE FACING PAGE.

IN ADDITION TO THESE 16 ROUTES, THREE ADDITIONAL ROUTES WERE ADDED TO A LIST OF ROUTES FOR FURTHER STUDY BECAUSE OF STRONG COMMUNITY SUPPORT

- **Routes selected for more detailed review then included:**

Route #	Description	
20	Wilshire Blvd.	
204	Vermont	
424	L.A. – Ventura Blvd.	
33	Venice Blvd.	
420	L.A. – Van Nuys – Panorama City	
4	Santa Monica Blvd.	
30	W. Pico – Floral	
45	Broadway – Mercury Ave.	
207	Western Avenue	
40	Hawthorne Blvd – L.A. – Union Station	
10	Melrose Ave.	
60	Long Beach Blvd. – Santa Fe Ave.	
28	W. Olympic Blvd. – York Blvd. – Eagle Rock	
18	W. Sixth St. – Whittier Blvd.	
66	E. Olympic Blvd. – W. Eighth St.	
16	W. Third St.	
180	Hollywood – Glendale – Pasadena	Added due to strong community support
92	L.A. – Glendale – Burbank – San Fernando	
76	L.A. – El Monte via Main St. – Valley Blvd.	

MULTI-MODAL PLANNING AREAS



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WIDE GEOGRAPHIC COVERAGE IS CONSIDERED AN IMPORTANT ELEMENT OF THE SYSTEM PLAN

LINES	20	204	424	33	420	4	30	45	207	40	10	60	28	18	66	180	76	16	92
AREA: 1. CENTRAL AREA	◒	◒	◒	●	◒	●	●	●		●	●	◒	●	●	●		◒	●	◒
2. SAN GABRIEL VALLEY							●	◒					◒			●	●		
3. SOUTH EAST AREA								●				●		●	●				
4. SOUTH BAY		●							●	●		●							
5. WEST SIDE	●	◒		●		●	◒		●	●	●		●	◒				●	
6. SAN FERNANDO VALLEY			●		●											◒			●
DIRECTION: • NORTH/SOUTH		●		◒				●	●	◒		●	◒						●
• EAST/WEST	●		●	◒	●	●	●			◒	●		◒	●	●	●	●	●	

AREAS CORRESPOND TO MULTI-MODAL PLANNING AREAS SHOWN ON MAP ON THE FACING PAGE.

◒ PARTIAL COVERAGE

● MAJOR COVERAGE

GRAPHIC 20

POTENTIAL SERVICE DISRUPTIONS ALONG THE PLANNED ROUTES WERE ALSO EVALUATED

HISTORICAL AND POTENTIAL SERVICE DISRUPTIONS
(1989 and 1990 Service Data) (Days)

LINES	20	204	424	33	420	4	30	45	207	40	10	60	28	18	66	180	76	16	92
PARADES, STREET FAIRS, ETC.	10	3	2	12	2	4	7	9	4	8	7	9	9	4	2	5	7	2	6
RACES	5	2	4	3	3	5	2	2	3	2	3	1	5	3	1	3	1	2	1
TRAFFIC/ACCIDENTS	5	2	4	2	4	0	3	5	11	4	5	3	1	7	5	1	2	1	6
FIRE/POLICE BLOCKADES	9	5	6	5	15	5	16	14	3	11	11	5	10	14	3	4	3	5	2
UTILITIES/CONSTRUCTION	12	6	6	22	6	17	14	10	0	12	12	20	15	6	6	13	11	3	6
TOTAL DISRUPTIONS	41	18	22	44	30	31	42	40	21	37	38	38	40	34	17	26	24	13	21
PLANNED CONSTRUCTION		METRO RAIL (A)		Orange Line (AA)		METRO RAIL (B)			METRO RAIL (C)				ORANGE LINE (AA)	ORANGE LINE (AA)			METRO RAIL (D)		

(A): VERMONT/117TH ST., WILSHIRE/VERMONT, VERMONT/BEVERLY, VERMONT/SANTA MONICA, VERMONT/SUNSET

(B): VERMONT/SANTA MONICA

(C): WILSHIRE/WESTERN, HOLLYWOOD/WESTERN

(D): WILSHIRE/ALVARADO

(AA): ALTERNATIVE ANALYSIS. THE ORANGE LINE IS UNDER STUDY.

GRAPHIC 21

SCHEDULING AND OPERATIONS FACTORS

SCHEDULING AND OPERATIONAL CONSIDERATIONS

LINES	20	204	424	33	420	4	30	45	207	40	10	60	28	18	66	180	76	16	92
INTERLINING SAVINGS AM	14		16	7	3	2	1	2	1		3	2	5		1	1			
PM	11		10	6	5	2	3			5			12					3	
PEAK TO BASE RATIO	1.75	1.16	2.30	1.95	1.78	1.63	1.58	1.41	1.59	1.83	1.94	1.80	2.06	1.75	2.70	1.24	1.33	2.33	1.85
ROUTE BRANCHES	21,22 320, 322*	- 354*	- 425	-	-	- 304*	31	46 345*	- 357*	- 42	11 48	61 360*	27 83,84,85 328*	-	67	181	-	-	93 410
PEAK BUSES EXCLUDING INTERLINE SAVINGS AM	85	39	57	40	36	50	40	33	26	47	33	44	62	25	31	19	15	23	23
PM	89	37	46	37	41	52	41	31	27	53	33	45	72	28	27	21	16	28	17
PEAK HEADWAYS AM	4	6	6	7	5	8	3	10	9	4	4	3	3	5	4	10	10	4	8
PM	5	8	9	10	7	12	4	8	12	4	5	6	6	5	4	10	11	5	10

* : LIMITED BRANCH

GRAPHIC 22

LINES THAT INCLUDE HEAVY INTERLINING AND BRANCHING COULD COMPLICATE TROLLEY IMPLEMENTATION

- Routing – Lines are sometimes composed of several routes (e.g., branches off a main line). Additional catenary wire may be provided to service these routes or the line can be restructured with the branch service being provided as part of a different line. Impact on passenger transfer volumes relative to the cost and utilization of additional catenary is a consideration. Also included in routing are short line locations (i.e., provide greater flexibility and efficiency in operations but require additional catenary investment).

- Express services – Express and other services which utilize the freeway or freeway segments present a particular problem. While trolley coaches do run on expressways in other countries they are best accommodated with preferential treatment; e.g., El Monte busway. Routes with freeway service would require restructuring of the line.

- Interlining – Interlining allows for more service to be provided during peak periods without additional equipment by deploying "trippers" with equipment otherwise assigned to a different line. The presence, or lack thereof, of interlining on any particular route will have an impact on equipment requirements and costs. All else being equal, routes with little interlining are preferred over heavily interlined routes.

- Peak to base equipment requirements – Similar to interlining is the issue of whether or not to procure equipment to meet the peak or base demand. If equipment for the peak is procured, then this equipment would be under-utilized in base. All else being equal, routes with a low peak to base ratio are preferred over routes with higher ratios.

- Limited service – Many of the District's most heavily utilized routes provide limited service. Every other vehicle assigned to a line makes limited stops. Providing for limited stop trolley service requires bypass catenary or a second set overhead wires, thus increasing implementation cost

ROUTES THAT ENHANCE THE OVERALL CONNECTIVITY OF THE TRANSIT SYSTEM ARE FAVORED FOR TROLLEY CONVERSION

SYSTEM CONNECTIVITY

LINES	20	204	424	33	420	4	30	45	207	40	10	60	28	18	66	180	76	16	92
20		X				X			X	X							X	X	
204	X			X		X	X		X	X	X		X	X	X	X		X	
424					X												X		
33		X							X	X							X	X	
420			X			X			X								X		
4	X	X			X								X				X	X	X
30		X						X	X	X				X	X		X	X	
45							X				X		X	X	X		X	X	
207	X	X		X	X		X			X	X		X		X	X		X	
40	X	X		X			X		X				X				X	X	
10		X						X	X								X	X	
60														X	X		X		
28		X				X		X	X	X							X	X	
18		X					X	X				X					X	X	
66		X					X	X	X			X					X		
180		X							X										X
76	X		X	X	X	X	X	X		X	X	X	X	X	X			X	X
16	X	X		X		X	X	X	X	X	X		X	X	X		X		X
92						X										X	X	X	
Total Lines Crossed	6	12	2	5	4	7	8	7	11	8	5	3	7	6	6	3	15	13	4

GRAPHIC 23

SUMMARIZING CANDIDATE ROUTES ACROSS ALL CRITERIA

SUMMARY OF ROUTE SELECTION CRITERIA

LINES	20	204	424	33	420	4	30	45	207	40	10	60	28	18	66	180	76	16	92
COST EFFECTIVENESS: • COST PER LB. EMISSIONS REDUCED (DOLLARS)	5.93	12.78	20.6	17.87	20.23	16.46	14.20	19.42	18.91	15.7	15.35	20.43	17.88	19.22	20.86	29.36	38.31	23.24	43.87
COMMUNITY ACCEPTANCE & SUPPORT	◒	◒	◕	◒	◕	◒	◕	◕	◒	◕	◒	◒	◒	◒	◒	●	●	◒	●
GEOGRAPHIC COVERAGE: • DIRECTION	E/W	N/S	E/W	N/S E/W	E/W	E/W	E/W	N/S	N/S	N/S E/W	E/W	N/S	N/S E/W	E/W	E/W	E/W	N/S	N/S E/W	N/S
• AREA(s)	1,5	1,4,5	1,6	1,5	1,6	1,5	1,2,5	1,2,3	4,5	1,4,5	1,5	1,3,4	1,2,5	1,3,5	1,3	2,6	1	2	1,6
UTILITY SOURCE(s)	LADWP SCE	LADWP SCE	LADWP	LADWP	LADWP	LADWP SCE	LADWP SCE	LADWP SCE	LADWP SCE	LADWP SCE	LADWP SCE	LADWP SCE	LADWP SCE	LADWP	LADWP SCE	LADWP LOCAL	LADWP	LADWP SCE	LADWP LOCAL SCE
EXTERNAL FACTORS • STREET CLOSINGS IN 1989 AND 1990	41	18	22	44	30	31	42	40	21	37	38	38	40	34	17	26	15	31	21
• MAJOR CONST. PLANNED		METRO RAIL		ORANGE LINE AA		METRO RAIL			METRO RAIL				ORANGE LINE AA	ORANGE LINE AA			METRO RAIL		
SCHEDULING & OPERATIONS	○	◒	◒	◒	◒	○	●	◒	◒	●	●	◒	○	●	●	●	◒	◒	◒
LINKS WITH RAIL, HOV, OR BUSWAY	METRO RED	METRO RED-GREEN HOV	METRO RED	ORANGE LINE AA			HOV	HOV	METRO RED-GREEN	HOV		PARAL-LELS BLUE LINE	ORANGE LINE AA	ORANGE LINE AA		TRANSIT CENTER	BUS-WAY		

Community Acceptance

- ● Strong Support
- ○ Weak Support

Geographic Coverage

Areas:
1. Central Business District
2. San Gabriel Valley
3. Southeast
4. South Bay
5. Westside
6. San Fernando Valley

Scheduling & Operations

- ● No Difficulties/Changes Required Are Few and/or Minor
- ◒ Some Difficulties/Changes Required
- ○ Difficult/Major Changes Required

GRAPHIC 25

BASED ON THESE ANALYSES OF CANDIDATE ROUTES AS WELL AS EVALUATION BY RTD'S OPERATIONS AND PLANNING PERSONNEL, RTD IDENTIFIED THE FOLLOWING 11 ROUTES FOR FURTHER STUDY AND POSSIBLE IMPLEMENTATION AS A "PHASE I" SYSTEM

ROUTE NO.	16	18	30	33	40	45	92	(1) 180	(2) 424	76	(3) 420/560
STREET NAME	W. 3rd ST	W. 6th WHITTIER	W. PICO FLORAL DR.	VENICE BLVD.	HAW-THORNE UNION STA.	BROAD-WAY	GLEN-DALE BLVD.	COLORADO BLVD.	VENTURA BLVD.	VALLEY BLVD.	VAN NUYS BLVD.
<u>COST EFFECTIVENESS</u>											
$/LBS OF EMISSIONS REDUCED*	+	++	+++	++	+++	++	0	0	++	0	N/A
<u>GEOGRAPHIC COVERAGE</u>											
DIRECTION	E/W	E/W	E/W	E/W	N/S	N/S	N/S	E/W	E/W	E/W	N/S
AREA COVERAGE	1, 2, 5	1, 3, 5	1, 2, 5	1, 5	1, 4, 5	1, 2, 3	1, 6	2, 6	1, 6	1, 2	6
<u>ELECTRICITY PROVIDER</u>	SCE DWP	DWP	SCE DWP	DWP	SCE DWP	SCE DWP	LOCAL, DWP,SCE	LOCAL, DWP	DWP	SCE DWP	LOCAL
<u>SYSTEM CONNECTIVITY</u>	+++	++	++	+	++	++	+	0	0	+++	+
<u>COMMUNITY SUPPORT</u>	STRONG	STRONG	STRONG	STRONG	STRONG	STRONG	VERY STRONG	VERY STRONG	VERY STRONG	VERY STRONG	STRONG

*) *0: Poor +: Fair ++: Good +++: Best*
1) *Modified route segment between Brand Ave. and Fair Oaks only*
2) *Modified route segment that ends at Universal City*
3) *This is a modified route segment between Ventura Blvd. and Glenoaks Blvd. on Van Nuys Blvd. It would connect the 424 and 92 routes.*

"PHASE I" CANDIDATE ROUTES - - - DISCUSSION

- **Line 204 on Vermont was rated as an excellent candidate for trolley bus conversion, however construction of MOS-2 for several years on Vermont will make trolley implementation difficult.**

- **Trolley buses cannot be implemented on shared right-of-way high speed freeway type service. Because the 424 currently operates on Hollywood freeway, the proposed trolley route conversion would have to end at Universal City. Once MOS-3 is completed, the non-highway portion of the 424 would provide excellent feeder service to the Red Line.**

- **The proposed "180" route is a modified route segment that would operate between Brand Avenue and Fairoaks only. This would avoid problems associated with the Rose Bowl Parade.**

- **The proposed "420/560" route would operate between Ventura and Glenoaks on Van Nuys Blvd. This route would connect the proposed 92 and 424 routes. Currently, portions of the 420 and 560 routes operate on Van Nuys Blvd. between Ventura Blvd. and Glenoaks Blvd.**

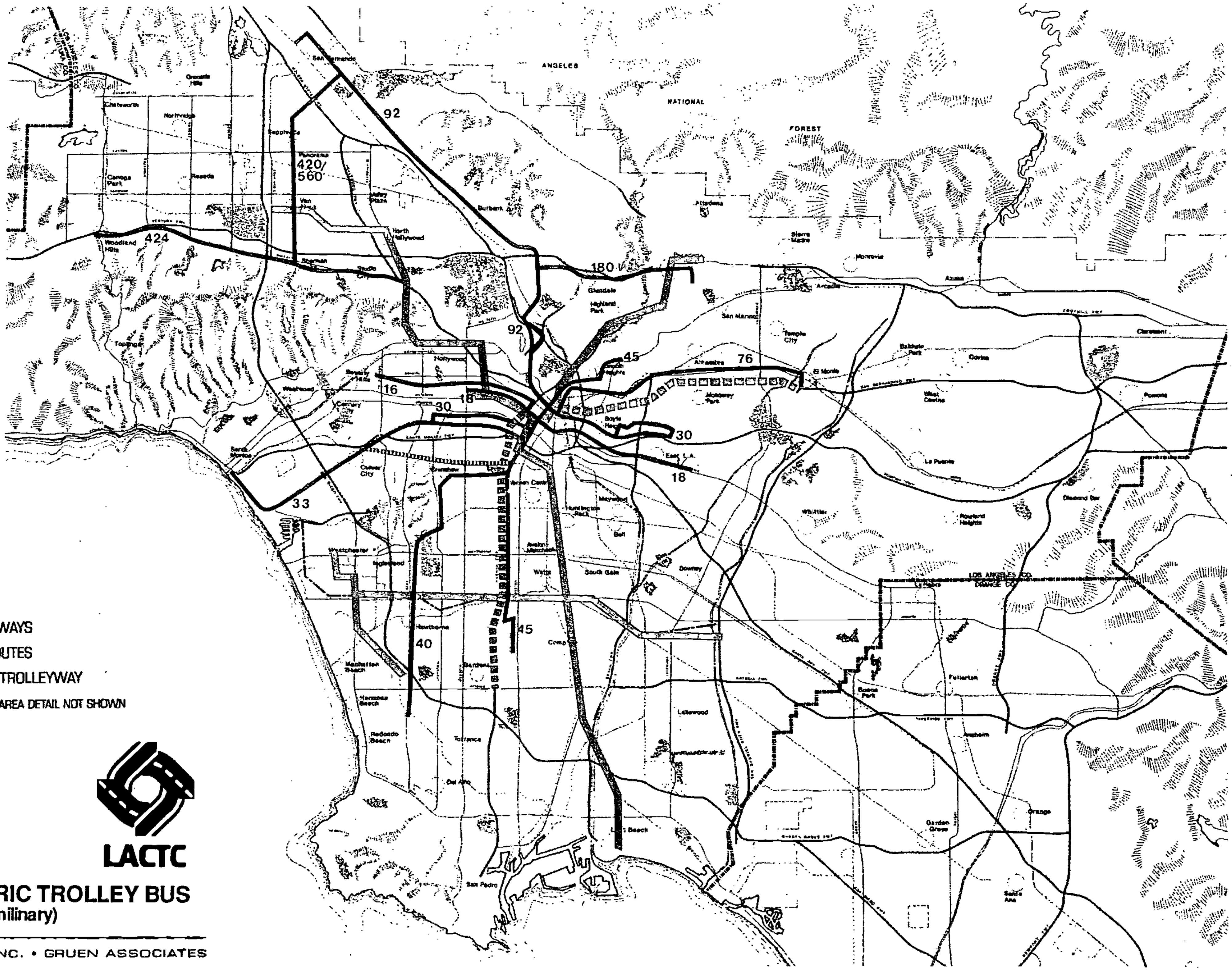
PHASE I CANDIDATE ROUTES - - - DISCUSSION (CONTINUED)

- **As previously noted, RTD staff developed "packages" of lines to be implemented that could be operated out of a single division. This "package" concept should be extended to the 11 routes identified for Phase I. In reviewing maintenance divisions from which the trolleys could be operated, Division 10 appears to offer advantages for accommodating the first package of routes to be converted (which might include 2 to 4 routes). The Division is located in the CBD and is a comparatively large division with 20 acres and a rated capacity of 238 buses. Division 10 had been used for articulated coach operation previously so that modifications to accommodate artic trolleys (if articulated vehicles are selected for initial implementation) should be minimal compared to other divisions. A reasonable first "package" of lines for RTD to consider is the #45, #40, and #30. These routes all operate on a portion of Broadway, thus increasing the cost effectiveness of this first package. Route #45 currently operates out of Division 10 and routes #40 and #30 could be relocated to Division 10 without excessive increases in deadhead mileage. Finally, routes #45 and #40 operate primarily in the north-south direction while #30 operates primarily east-west, thus providing good geographic coverage.**

THESE 11 ROUTES PROVIDE GOOD GEOGRAPHIC COVERAGE, ARE WELL ACCEPTED BY THE AFFECTED COMMUNITIES, AND ARE AMONG RTD'S MORE HEAVILY USED ROUTES

LINE	PM PEAK HEADWAY	BASE HEADWAY	DAILY MILES	PM PEAK BUSES	BASE BUSES	DAILY HOURS	DAILY BOARDINGS	ROUTE LENGTH	VSM PER ROUTE MILE
76	11	15	2,734	16	12	219	12,433	16	157
16	5	10	2,575	31	12	279	23,674	9	230
18	5	10	3,647	28	16	320	30,534	12	267
30	4	5	5,119	41	26	484	46,035	12	364
33	10	10	5,813	37	19	441	24,452	17	290
40	4	12	6,373	53	29	483	33,743	17	325
45	8	8	4,866	31	22	413	28,279	15	256
92	10	15	3,900	24	13	575	12,462	26	129
180(m)	10	15	1,288	21	17	103	16,074	6	164
424(m)	9	12	5,090	46	20	307	19,302	17	232
420/560(m)	12	15	1,094	23	16	76	14,914	9.4	101
		TOTAL	42,499	351	202	3,500	261,902	158	

Note: ***For routes #180, #424, and #420/560, the daily vehicle miles and delly vehicle hours have been adjusted based on the modified route lengths of 6, 17, and 9.4 miles, respectively. Baseline date for the #560 route only wes used for the "420/560 (m)" route.***



COMMITTED RAIL
COMMITTED BUSWAYS
ELECTRIC BUS ROUTES
EXPOSITION LINE TROLLEYWAY

*NOTE: DOWNTOWN AREA DETAIL NOT SHOWN

RTD

LACTC

PHASE I ELECTRIC TROLLEY BUS
(Premilinary)

BOOZ ALLEN HAMILTON INC. • GRUEN ASSOCIATES

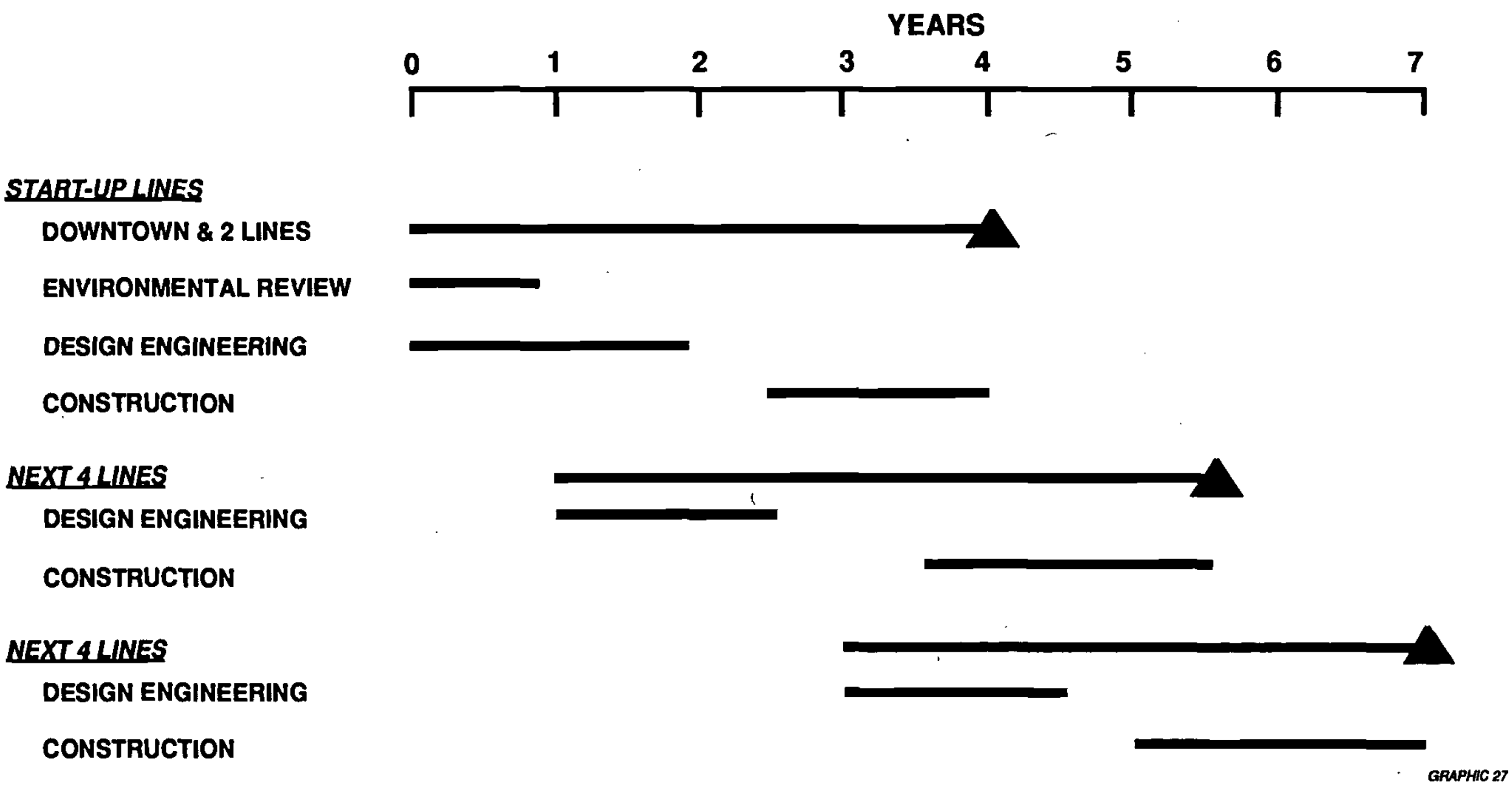
183-MAP

IMPLEMENTATION PLAN

A PLAN HAS BEEN OUTLINED FOR INAUGURATING TROLLEY BUS SERVICE ON THE FIRST 10 ROUTES

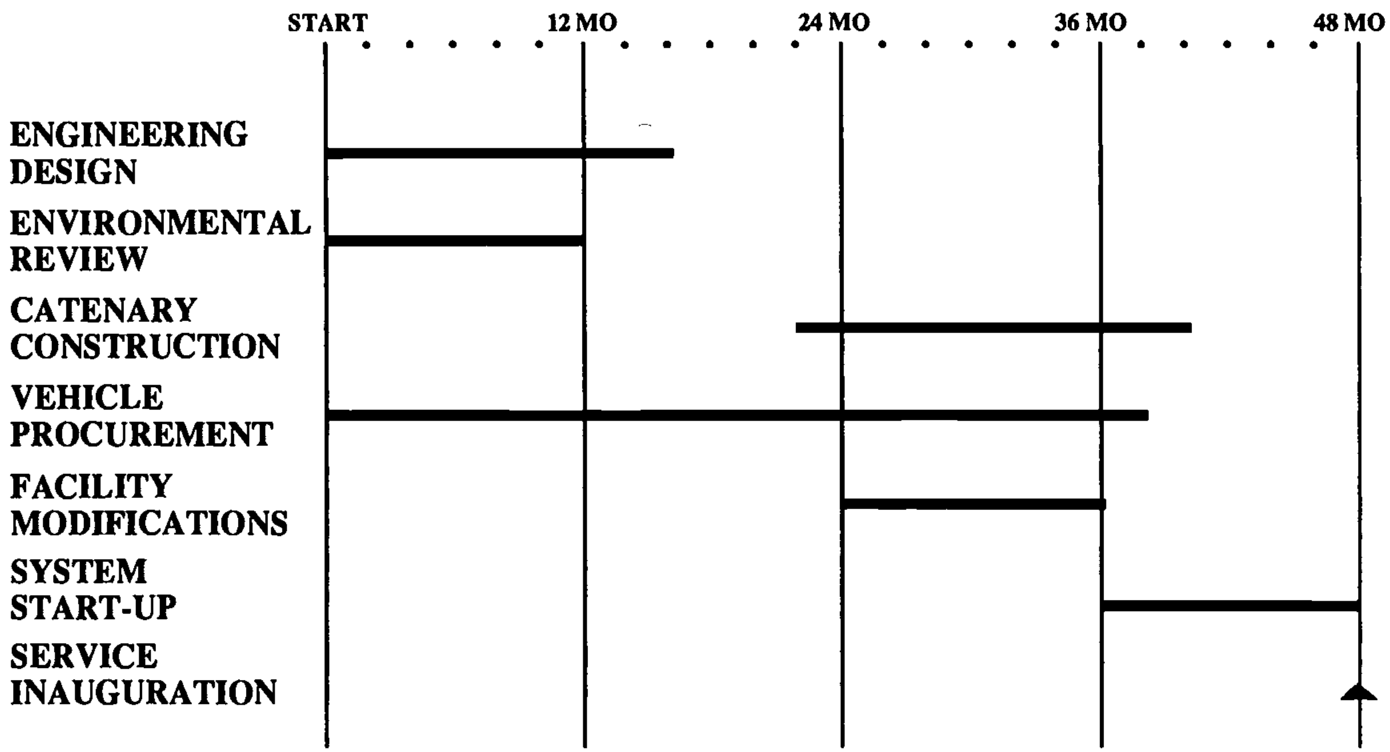
- **Schedule**
- **Budget**
- **Engineering Design**
- **Construction**
- **Vehicle Procurement**
- **System Start-Up**
- **Program Management**

A PHASE I TROLLEY SYSTEM CAN BE CONSTRUCTED IN 7 YEARS



IMPLEMENTATION OF AN ELEVEN ROUTE SYSTEM WOULD REQUIRE A STAGGERED APPROACH DUE TO PRACTICAL LIMITATIONS OF ENGINEERING, DESIGN, AND CONSTRUCTION RESOURCES.

TROLLEY BUS SERVICE ON THE FIRST LINES COULD BE OFFERED WITHIN 48 MONTHS, ON A VERY AGGRESSIVE BASIS



GRAPHIC 28

TWO TO THREE LINES ARE RECOMMENDED FOR INITIAL CONVERSION - - - PERMITTING RTD TO GAIN A SOLID TECHNOLOGY, OPERATIONS, AND IMPLEMENTATION EXPERIENCE BASE WITHOUT STRAINING INTERNAL, AS WELL AS CONTRACTED RESOURCES.

TASK DESCRIPTIONS

Route Characterization

- Survey Route: Define topography; intersections; turns; other special catenary requirements. Develop overall approach including potential for undergrounding of utilities along with feeder cables if necessary

- Aesthetic Enhancements: Evaluate alternative aesthetic improvement plans; obtain agreements with local city officials, business, and property owners on specific aesthetic improvement plan (Financing plan will also be established with cities early on design phase).

Power Requirements

- Number of buses; service plan; peak and base loading; potential for bunching of vehicles; future expansion plans and power supply requirements; substation sizing and specifications; general spacing and substations

Design Approach

- Establish agreements with city officials, DWP, and Bureau of streetlighting for joint use of streetlight and traffic signal poles for trolley wire support.

- Define safety and maintenance plan for overhead wire and power distribution system: establish working agreements with DWP and SCE for power supply and trolley system interface designs.

Detail Specifications and Bid Package

- Number of poles/locations; number of substations/locations; establish working agreements with property owners for substation installation.

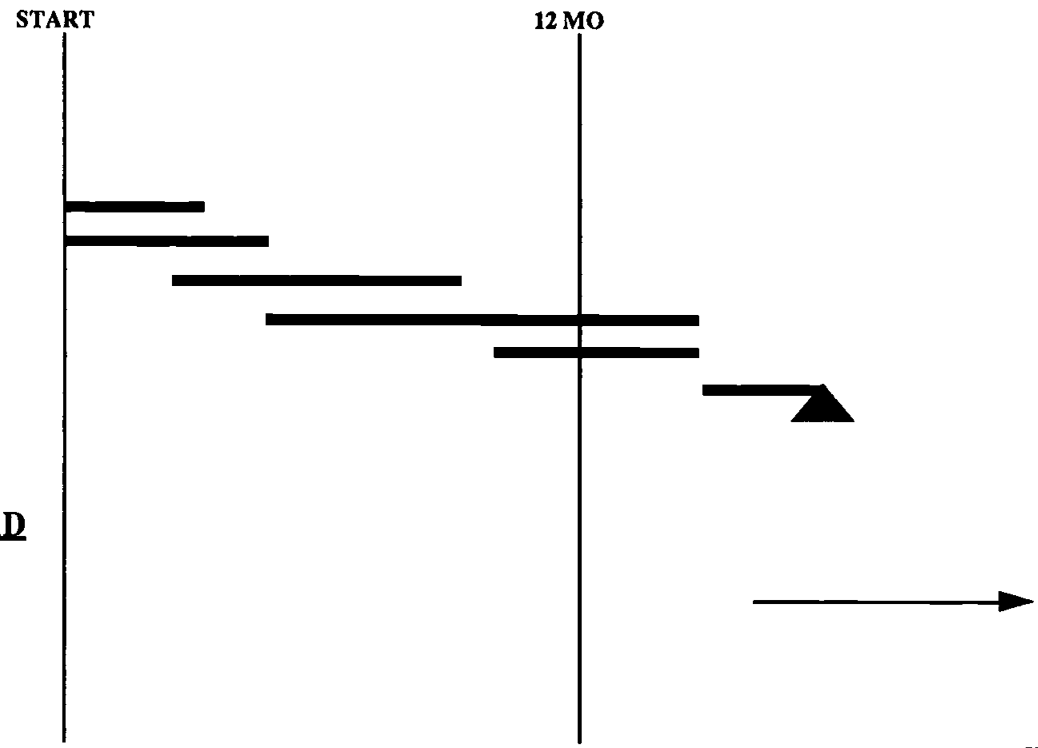
ENGINEERING DESIGN WILL REQUIRE 16 TO 18 MONTHS TO DEVELOP A CONSTRUCTION BID PACKAGE (OR PACKAGES) READY FOR ADVERTISEMENT

ENGINEERING DESIGN TASKS

- Route Characterization
- Power Requirements
- Design Approach
- Detail Approach
- Specification
- Bid Package

AFTER CONSTRUCTION AWARD

- Construction Monitoring

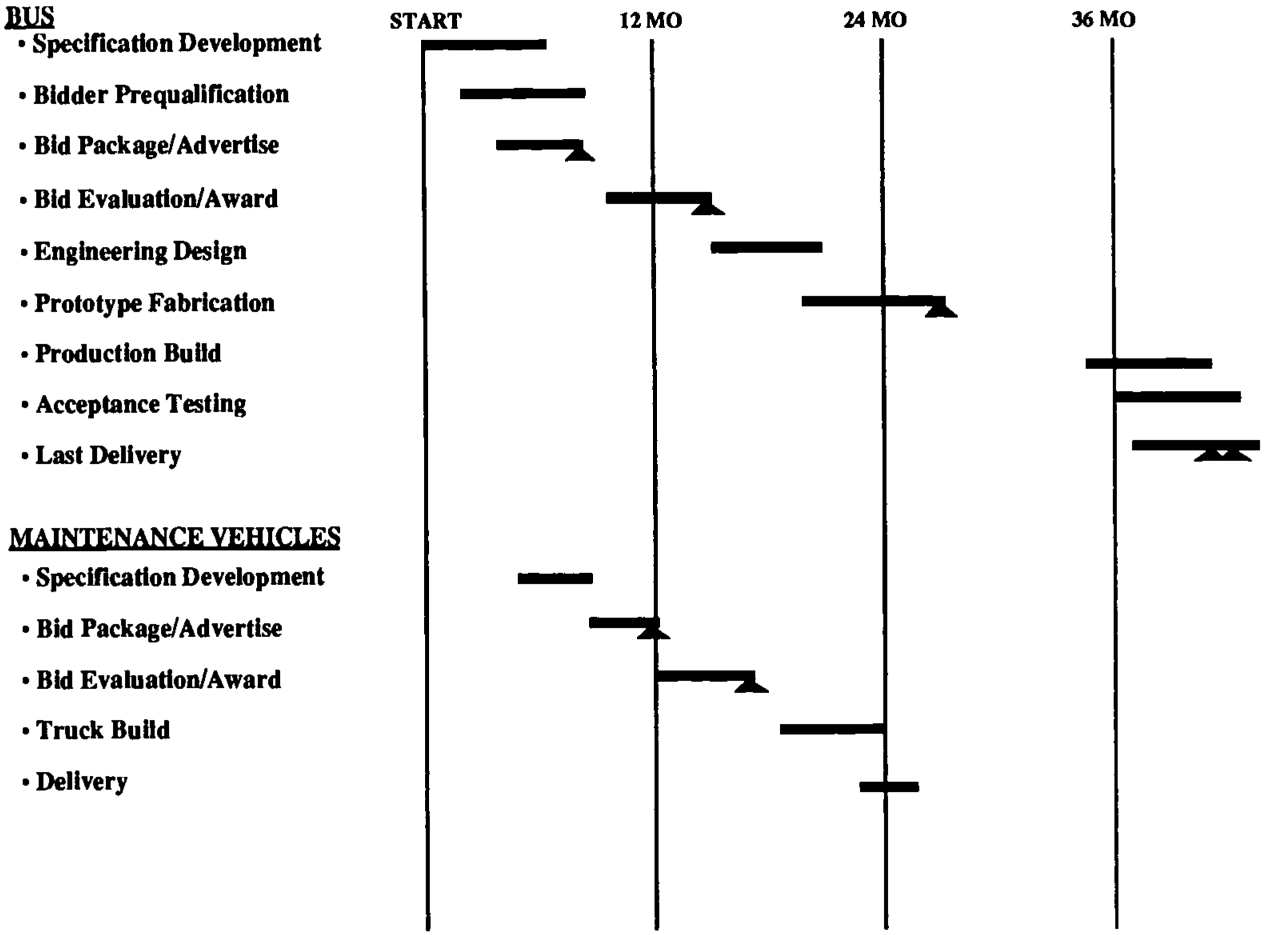


GRAPHIC 29

TASK DESCRIPTIONS

- Develop a nominal and worst duty cycle for the trolley bus propulsion system
- Coordinate design with catenary specifications
- Establish performance requirements: acceleration, power consumption; weight; capacity
- Determine off-wire maneuvering capabilities
  - Speed; grades; range
  - Air system power needs
- Establish APU specifications
  - weight; recharging capabilities
  - nominal and worst cost duty cycle
- Define maintenance requirements and associated diagnostic tools
- Establish performance/design specs for optional equipment
  - Air conditioning
  - Wheel chair lifts
- Establish specifications for entrance/exit doors and location
- Specification for maintenance trucks for overhead wire repair must also be developed

PROCUREMENT OF 40 FOOT TROLLEY BUSES IS EXPECTED TO REQUIRE 42 MONTHS



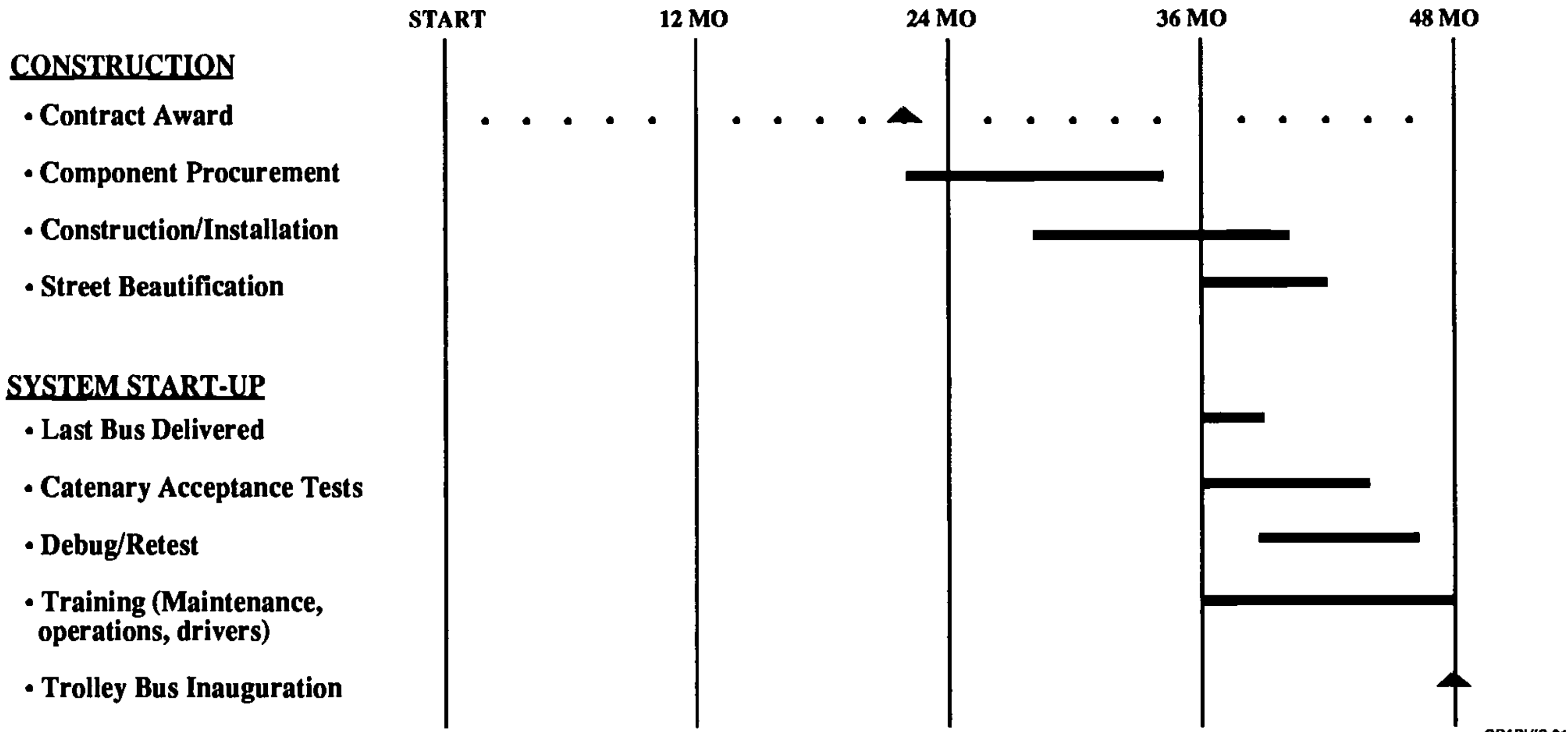
GRAPHIC 30

CONSTRUCTION TASKS ISSUES

- Obtain working agreements with local city officials, property owners and business for managing disruptions during construction phase
- Limit contractors site obstructions by contract
- Coordinate work with current and planned projects by others which may affect construction
- Plan for day and night work in all trolley overhead installation contracts
- String trolley wire at night: plan traffic diversions with police
- Order long lead items (e.g., special work and substations) under direct purchase order and allocate to contractor on an as-needed basis

THE ROLE UTILITIES MAY PLAY IN ESTABLISHING THE POWER DISTRIBUTION SYSTEM (INCLUDING SUBSTATIONS) SHOULD BE ESTABLISHED EARLY SO THAT CONSTRUCTION OF OVERHEAD WIRE SYSTEM CAN BE PROPERLY PLANNED.

CATENARY CONSTRUCTION WILL REQUIRE 16 MONTHS – SUBSTATIONS MAY REQUIRE SEPARATE AND EARLY PROCUREMENT



GRAPHIC 31

IMPLEMENTATION OF THE "PHASE I" SYSTEM WILL COST APPROXIMATELY $600 MILLION

BUSES: 260 ARTICULATED	@	$625,000/EACH	=	$162.5M
MAINTENANCE VEHICLES: 5 TRUCKS	@	75,000/EACH	=	.38M
CATENARY: 158 MILES	@	$780,000/MILE	=	$123.24M
SPECIAL WORK: 158 MILES	@	$80,000/MILE	=	$12.64M
ADDITIONAL FOR SHARED-USE POLES:	@	$200,000/MILE	=	$31.60M
POWER SUPPLY: SUBSTATIONS	@	$312,000/MILE	=	$49.30M
LANDSCAPING	@	$300,000/MILE	=	$47.40M
ENGINEERING DESIGN AND CONSTRUCTION MANAGEMENT	@	15%	=	$63.06M
PROGRAM MANAGEMENT	@	1.5%	=	$7.25M
FACILITIES (TWO)		Convert Existing Facilities		Construct New
		$1.0M		$60.00M
TOTAL		*$499M*		*$557M*
TOTAL WITH 15% CONTINGENCY		*$574M*		*$641M*

GRAPHIC 32

ROUTE CHARACTERIZATION, VEHICLE SPECIFICATION DEVELOPMENT, POWER DISTRIBUTION DESIGN, AND AESTHETIC IMPROVEMENT PLANS CAN BEGIN IMMEDIATELY UPON BOARD APPROVAL OF THE PROJECT

PROJECT CASH FLOW ANALYSES

	Total* Millions	Year 1991	1992	1993	1994	1995	1996	1997	1998
Program Management	$7.25	$.5	$1.5	$1.0	$1.0	$1.0	$.8	$.8	$.5
Engineering, Design and Construction Management	$63	$.75	$5.0	$15	$15	$15	$10	$1.5	$.75
Aesthetic Improvements	$47.4		$5.0	$10	$10	$10	$10	$2.4	
Substations	$49.4		$10	$10	$10	$10	$9.4		
Overhead Wire Installation	$117.4		$10	$40	$35	$35	$25	$20	$2.4
Vehicles	$163.0				$40	$40	$40	$40	$3.0
Facilities Modifications	$1.0			$.5		$.5			
Total	$499	$1.25	$31.5	$76.5	$111	$111.5	$95.2	$64.7	$6.7

** Estimates do not include 15% contingency or investments in new operating facilities.*

PROGRAM MANAGEMENT WILL SPAN THE ENTIRE PROJECT

Management Tasks

- Procurement Strategy
- Environment Impact Assessments
- Public Issues
- Public Agency/Utility Interface
- System Safety Plans
- Construction Award
- Bus Builder Award
- Right-of-Way Issues
- Training Requirements/Coordination
- Facility Modifications
- City/County/Agency Terms & Conditions
- Budget Development/Monitoring

A SINGLE PRIME CONTRACTOR TO DIRECT IMPLEMENTATION OFFERS ADVANTAGES FOR RTD AND THE LACTC

- **Ensure technical compatibility among tasks**
  - **Vehicle specifications and catenary designs**
  - **Utility power supply and trolley bus power distribution systems (including expansion requirements)**
  - **Community needs and technical feasibility considerations of alternative overhead wire support systems**

- **Coordinate operations plans**
  - **Scheduling/Facilities/Minimization of non-revenue miles**
  - **Vehicle Maintenance/Storage**
  - **Catenary maintenance: Interface with other city and county agencies (Fire dept., Bureau of streetlighting, LADOT, others)**
  - **Safety, training**

- **Financial Planning**

- **Will help prevent costly delays, ensure all tasks are being properly addressed and prevent overlaps in assignment responsibilities and duties.**

FINANCING PLAN

SEVERAL SOURCES OF FUNDING ARE AVAILABLE TO RTD TO HELP IMPLEMENT THE PHASE I TROLLEY BUS PROGRAM

State Sources

- Flexible Congestion Relief Fund (FCR)
- Subvention to counties
- Transportation Development ACT/Local Transportation Fund (TDA/LTF)
- Transit Capital Improvement Program

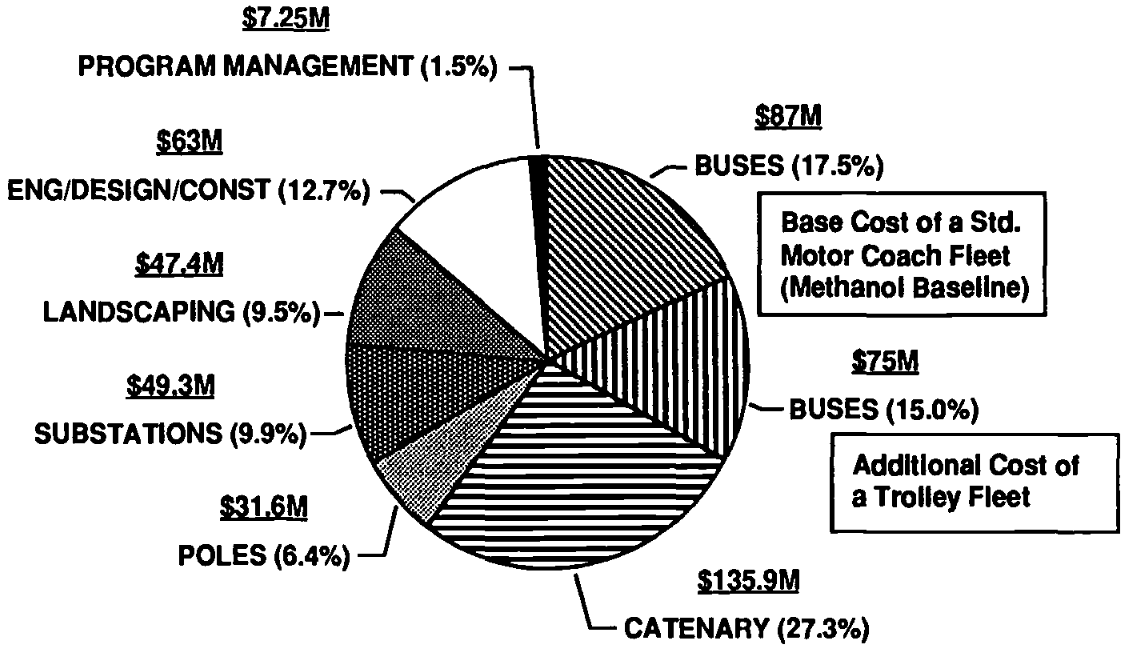
Local Funding

- Proposition A
- Proposition C

Other Sources

- Sole/Transfer of Pollution Rights
- Utilities

CAPITAL REQUIREMENTS CAN BE GROUPED INTO THE FOLLOWING CATEGORIES



NEW OPERATING DIVISIONS, IF ESTABLISHED, WOULD REQUIRE ADDITIONAL INVESTMENT.

ESTIMATED LOCAL RETURNS FOR PROP A & C FISCAL YEAR 1991-92					
	PROP A		PROP C	TOTAL	
CITY	Fiscal Year 1990-91 LOCAL RETURN	1991-92 *ESTIMATED LOCAL RETURN	1991-92 **ESTIMATED LOCAL RETURN	1991-92 ESTIMATED LOCAL RETURNS	SELECTED BUS ROUTES FOR POTENTIAL ELECTRIFICATION
Alhambra	$867,679	$911,063	$728,850	$1,639,913	76
Beverly Hills	$391,597	$411,177	$328,941	$740,118	16
Burbank	$1,088,024	$1,142,425	$913,940	$2,056,365	92/93
Carson	$1,013,815	$1,064,506	$851,605	$1,916,110	45
Commerce	$135,289	$142,053	$113,643	$255,696	18
Compton	$1,066,332	$1,119,649	$895,719	$2,015,367	45
Culver City	$470,374	$493,893	$395,114	$889,007	33, 333, 560
El Monte	$1,094,874	$1,149,618	$919,694	$2,069,312	76
Glendale	$1,995,662	$2,095,445	$1,676,356	$3,771,801	92/93
Glendora	$546,866	$574,209	$459,367	$1,033,577	180/181
Hawthorne	$774,061	$812,764	$650,211	$1,462,975	40
Inglewood	$1,171,367	$1,229,935	$983,948	$2,213,884	40
Lawndale	$315,675	$331,459	$265,167	$596,626	40
Los Angeles City	$39,200,839	$41,160,881	$32,928,705	$74,089,586	16, 18, 30, 33, 40, 45, 76, 92/93, 180/181, 333, 424, 560
Monterey Park	$751,228	$788,789	$631,032	$1,419,821	30, 18
Pasadena	$1,528,714	$1,605,150	$1,284,120	$2,889,269	180/181
Rosemead	$550,291	$577,806	$462,244	$1,040,050	76
San Fernando	$235,758	$247,546	$198,037	$445,583	92/93
San Gabriel	$407,581	$427,960	$342,368	$770,328	76
Torrance	$1,626,899	$1,708,244	$1,366,595	$3,074,839	40
TOTAL	$55,232,925	$57,994,571	$46,395,657	$104,390,228	

* Fiscal year 1991-92 Prop A funds are estimated using a 5% inflationary figure.

** Fiscal year 1991-92 Prop C funds are estimated at 80% of the estimated 1991-92 Prop A funds.

LOCAL FUNDING SOURCES

- **Proposition A – Because 25 percent of the funds are divided among the 86 cities and the unincorporated areas of Los Angeles County, by population, funds are available on the local level for transportation projects. Interested cities could allocate funds from this source towards aesthetic enhancements and other supporting expenses. Table above shows available, unallocated monies from Proposition A which could be pledged to electric trolleys by various cities along various proposed routes.**

- **Proposition C – While a majority of the funds are approved for specific projects, forty percent of the funds are discretionary. Under preliminary discretionary fund monies will be divided into four subgroups. One of these subgroups will fund projects needed to achieve federal and state mandates especially in the air quality area. The electric trolley routes should compete well for these funds. In addition, all cities and the County receive allocated Prop. C funds. Table above show allocated monies from Proposition C which could be pledged to electric trolleys by various cities along various proposed routes.**

STATE FUNDING SOURCES

- Subvention to Counties and Cities – This program, funded by Proposition 111, is estimated to provide $3 billion in direct state payments to counties and cities over the next 10 years. These are funds that are direct and not programmed. The city or county has full discretion over the use of these funds for capacity-building, transportation improvements. Interested cities could allocate funds from this source towards aesthetic enhancements.

- Transportation Development Act/Local Transportation Fund (TDA/LTF) – Revenue from the LTF comes from the 1/4 cent of sales tax in Los Angeles County. The funds can be used for operations or capital improvements; however, there is a requirement that a minimum of 15% of the funds be used for capital improvements. The fund is currently used predominantly for transit and would therefore not be viewed as "new" money to the entire transit system.

- Transit Capital Improvement Program – This is a capital improvement and guideway funding program which is funded through the Transit Planning and Development Act. The funding is received from 3/4 of one cent of sales tax on gasoline. The projects approved for funding under this program are determined through a yearly bid application process. The CTC approves a list of prioritized projects submitted by Caltrans. Projects under this program require a minimum of 50% local matching funds. San Francisco MUNI current accesses this sources for improvements to their trolley bus system.

STATE OF FUNDING SOURCES - - - CONTINUED

- Flexible Congestion Relief (FCR) Program – Under this program, regions throughout the state compete for funding for projects designed to relieve traffic congestion by increasing the capacity of the transportation system. The regional transportation planning agencies, in this case SCAG, are responsible for proposing projects in their Regional Transportation Improvement Programs (RTIP). Each project is expected to be the most cost effective alternative in reducing traffic congestion along a corridor. The FCR program is funded through Proposition 111, which allocates $3 billion for this purpose. A total of @230 million has already been secured for Los Angeles County through this program and an additional $500 million may be allocated to Los Angeles County. These funds are administered through the Los Angeles County Transportation Commission (LACTC). Eligible projects include "new guideway roadbed, and the upgrade of existing roadbed facilities, way structures, and superstructure track work, including mainline facilities, double tracking crossovers, sidings and storage tracks, grade crossings, signalization, trolley overheads and electrification." The purchase of rehabilitation of guideway or rolling stock is ineligible for FCR program funding.

OTHER FUNDING SOURCES

- Sale/Transfer of Pollution Rights – Air Pollution rights could be sold by a company that reduces their pollution below the limit set AQMD to other companies who need the credits to expand or open new facilities. The price of pollution credits can range from $500 to $3500 per ton of pollutant annually. The price of pollution credits may rise with the tightening of emission requirements for new and expanding companies. If SCRTD reduces their pollution emissions to below the amount mandated by SCAQMD, the sale of the pollution credits would be a potential source of revenue to fund the electrification of the coaches.

- Utility Company Funding – Several meetings have been held with the Southern California Edison company and DWP to discuss the possibility of financing the construction of the substations required in Phase I.

- Annual operating costs are expected to be reduced in the range of $8M to $12M due to articulated coach operations savings

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