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OPERATIONS COMMITTEE
MAY 20, 2004

SUBJECT: STATUS UPDATE ON ELECTRIC TROLLEY BUSES

ACTION: RECEIVE AND FILE

## RECOMMENDATION

Receive and file consultants report on applications of Electric Trolley Buses.

## ISSUE

Current California Air Resources Board (CARB) regulations will require future procurement of Ultra Low Emission Vehicles (ULEV) beginning in 2007, and Zero Emission Vehicles (ZEV) beginning in 2010. The attached report provides a status update on Advanced Electric Trolley Bus applications, which is one of the vehicle technologies that can currently meet these requirements.

## BACKGROUND

While the current Long Range Plan does not include provisions for electric trolley buses, earlier versions of the LACTC Long Range Plan did include electric trolley buses as part of the future transit fleet mix.

In the early 1990's, trolley-buses were removed from subsequent Long Range Plans in favor of other transit modes, particularly light rail vehicles. However, recent CARB regulatory changes scheduled for implementation in 2010 will require ZEV for a portion of MTA's future transit bus replacements. This change has caused Metro Operations to reconsider the feasibility of using trolley buses for a portion of MTA's fixed route bus service.

Advanced trolley bus designs now offer far greater flexibility than early trolley-bus systems, and may be an appropriate technology for certain Metro bus lines. In particular, recent technical developments with trolley-buses include "Off-wire" capabilities for limited distances (such as getting to/from bus yards), and improved catenary systems that are not as visibly intrusive as older trolley bus systems. The electric wheel motor system also makes trolley buses extremely quiet, which makes these vehicles especially conducive to applications in/near pedestrian and residential corridors.

## ALTERNATIVES CONSIDERED

There are three ways MTA may meet future ULEV and ZEV requirements for bus procurements:

Regulatory Changes – MTA has the option of taking no immediate action. If there are not viable ULEV or ZEV vehicles commercially available by 2010, CARB could be forced to either delay implementation of regulations, or relax the standards set by these regulations. Staff does not recommend this course of action.

Technological breakthrough – Both Battery and Fuel Cell technologies are expected to be capable of meeting ULEV and ZEV requirements in the future. However, at this time, it does not appear that either of these technologies will be suitable to heavy-duty transit service. Furthermore, at this time, it is not expected that fuel cells will develop sufficiently to be a commercially viable, cost-effective means for meeting 2010 requirements.

Electric Trolley Buses – Currently, electric trolley buses are the only proven, cost-effective Zero Emission vehicles running high capacity transit service. Several transit operators are in the process of expanding their electric trolley bus system, including San Francisco Muni, King County Metro (Seattle), MBTA (Boston) and Dayton, OH.

## NEXT STEPS

MTA's Vehicle and Systems Technology Department should continue participating in technical development projects and testing, particularly with fuel cell and hybrid vehicles, and with trolley buses. MTA should also stay abreast of technological developments related to ULEV's and ZEV's. MTA will also monitor the status of any pending regulatory changes with CARB and AQMD regulations that could alter MTA's vehicle acquisition strategies.

## ATTACHMENTS

A. Trolley Bus Feasibility Analysis

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Deputy Chief Executive Officer

Roger Snoble
Chief Executive Officer

ATTACHMENT A

# ARIELI ASSOCIATES
MANAGEMENT, OPERATIONS AND ENGINEERING CONSULTING

Report No. 1302

# TROLLEY BUS FEASIBILITY ANALYSIS

PREPARED FOR THE ADVANCED TRANSIT VEHICLE CONSORTIUM
UNDER CONTRACT NO. OP 3320661

## INTRODUCTION

California Air Resources Board (CARB) Adopted Urban Bus Transit Rule for 2010 Emission Standards requires that MTA, starting in 2010, set aside 15% of all bus purchases to acquire Zero Emission Vehicles (ZEVs). Currently, none of the buses in MTA's inventory can be classified as ZEV, nor are there any transit buses available on the market that can be classified as ZEV. California emission standards are well ahead of the rest of the United States and manufacturers will not develop suitable vehicles unless incentivized by large customers such as the MTA. Failure to meet the 2010 Emission Standards will result in regulatory punitive fines and potential litigation.

The first part of this report will examine the potential of ZEV technologies and assess their technological, commercial and economic maturity and feasibility. It will also discuss electric trolleybuses, review their history and current applications, and its advantages and disadvantages. The second half of this report will cover the engineering and economics of the electric trolleybuses. To conclude, a strategic proposal for the implementation of the electric trolleybuses within MTA's transit system will be discussed.

It is important to note that this is not the first time the subject of incorporating electric trolleybuses into MTA's bus system has come before the MTA Board of Directors. In the 1992 30-Year Integrated Transportation Plan, electric trolleybuses were the preferred solution to meet CARB air regulations. The plan provided for 18 routes, 300 miles of overhead wires and 400 peak electric trolleybuses by 2004 to be increased to 1,100 peak electric trolleybuses by 2010. Eventually, the Board voted to terminate the project. Appendix B will review the history of the project and compare it with the current proposal.

## POTENTIAL ZERO EMISSIONS VEHICLE TECHNOLOGIES

Although the CARB regulation addresses specifically the requirement for zero emissions at the street level, there are other attributes such as reduced noise levels, reduced release of "green house" gases, and the release of the lowest possible emissions into the environment that must be incorporated in a new vehicle design.

Operating vehicles using electric power motive is the way to attain the quality attributes listed above. Electric power vehicles operate with electricity supplied by large, fixed-power stations under stable conditions and offer significant environmental advantages over large numbers of individually powered ICEs using fossil fuels. There are several technologies that result in "electric vehicles/buses".

1. *Vehicles drawing electricity from energy stored in batteries.* If developments in storage battery technology can produce batteries that can compete in terms of size, weight, cost, ease of recharging and efficiency with a tank of diesel fuel, then all vehicles could be electric.

   This is unlikely to happen in the foreseeable future. Figure 1 shows that both gasoline (CNG and diesel fuels have similar specific energy and specific power) and hydrogen have a higher specific energy than other electrical storage devices. An advantage of the high specific energy of liquid or gaseous fuels is it provides vehicles with long-range capabilities. Conversely, the high specific power can provide peak power requirements.

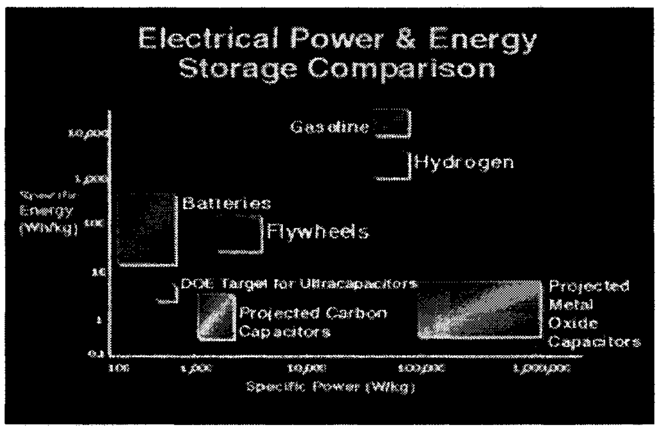



Figure 1: Plot of energy versus power for various fuels and energy storage devices.

2. *Vehicles drawing electricity from fuel cells.* Fuel cells represent a halfway house between storage batteries and fuel burning engines. A fuel cell takes in hydrogen plus oxygen from the air and combines the two, producing electricity plus water as the byproduct. If supplied with hydrogen, the fuel cell can be viewed as a storage battery, but not a very efficient and expensive one. There are problems with distributing the hydrogen to and storing it on vehicles. In Figure 1, fuel cells are approximately half-way between the liquid hydrogen and batteries (~ 2,000 Wh/kg specific energy and ~ 5,000 W/kg specific power).

3. *Vehicles generating electricity on-board.* If the fuel cell is supplied with a hydrocarbon fuel e.g. gasoline, natural gas or diesel fuel, hydrogen can be made from the fuel [by on-board 'reforming']. This system produces much the same range of byproducts as an internal combustion engine.

   The prospect that on-board fuel cells will provide efficient, clean, cheap, safe power in moving vehicles is new and experimental. The prospects for larger and stationary fuel cells, fed via a reformer with natural gas, as part of combined heat and power schemes are much better. Such fuel cells may provide clean, cheap electricity for electric vehicles. Fuel cells supplied with hydrogen produced by renewable sources, hold the promise of pollution free power and would require massive new infrastructures.

4. *Vehicles receiving electric power via an energy conductor system.* Where vehicles operate a fixed route at sufficient frequency, it is both practicable and economic to provide an energy conductor system. Thus in many railway, and virtually all light rail systems, electric propulsion via an energy conductor, a conductor rail or trolleybus overhead wire is the norm.

As is the case with light rail, objections have occasionally been voiced about the visual intrusiveness of overhead wires. Considering that the diesel bus generates 41 different substances listed as air contaminant emissions, the trolleybus eliminates these hazardous emissions through the utilization of overhead wires.

The overall technology evaluation matrix indicating the alternative technological paths and the configurations to be evaluated is shown in Appendix C.

## WHAT ARE ELECTRIC TROLLEYBUSES?

A trolleybus is an electrically propelled bus. Unlike a light rail, which uses rails as a return circuit and operates with a single overhead conductor wire, a trolleybus requires two overhead wires. Two swiveling current collectors allow a trolleybus to operate up to fifteen feet on either side of the wires. These collectors are spring loaded to press upward against the wires. Contact with between pole and wire is by a grooved shoe containing a carbon insert that slides along the wire. Modern collectors have pneumatic equipment for the lowering and lifting.

The trolleybus has been in existence as a method of public transportation for over 70 years and was at various times during that era a major mode of transport in many of the cities of Europe, Asia and North and South Americas.

A recent survey estimated there are still nearly 340 trolleybus systems operating throughout the world and between 1990 and 2000, 37 new systems opened and 29 systems closed.

Regrettably, many people are only familiar with the rather basic and austere type of trolleybus, favored by Russian and Chinese operators, which do not offer the comforts and appeal of more modern transit buses.

In several cities, new trolleybuses are being introduced that offer the same facilities and comfort level as transit buses, except with the added benefits of a smoother and quieter ride. Figure 2 illustrates some of the modern trolleybus designs.

Lausanne, Switzerland Budapest, Hungary Greenwich, Greater London UK

Figure 2- Trolleybuses in service. Notice how unintrusive the overhead wires are in an urban environment.

Despite the numerous development advances being made with internal combustion engine technology, alternate fuels and exhaust after treatment devices, transit buses will continue to emit polluting exhaust fumes. These advances and improved fuel standards will reduce pollutants from vehicles, but is this acceptable within the dense urban corridors of Los Angeles? It must be remembered that with buses stationary at bus stops and traffic lights, the air conditioning load, battery charging load, and transmission drag on an ICE engine, there will still be significant exhaust fumes emitted, which will adversely affect the environment within these corridors.

The only alternative currently available that does not pollute at street level is the trolleybus. Considerable advances in trolleybus technology, such as less obtrusive overhead, alternating current traction equipment and solid-state sub-stations, further enhance an already reliable system. In Vancouver, passengers prefer to ride on trolleybuses. There is also evidence that San Francisco and Seattle experienced 10-15% increases in usage where trolleybuses have been installed.

While this report strongly advocates the introduction of trolleybuses in Los Angeles, it is under no illusion that they will replace transit buses entirely. Clearly the economies of trolleybuses preclude their use in areas where bus frequencies and ridership are low.

## <u>ELECTRIC TROLLEYBUSES-ADVANTAGES AND DISADVANTAGES</u>

The advantages of electric trolleybuses are:

1. To the passengers:
    - Zero pollution emissions in the streets
    - Lowest possible noise levels
    - Powerful but smooth acceleration and braking
    - Sense of permanence of service
    - Best ride quality

2. To the public generally:
    - Lowest possible emissions into the environment as a whole
    - Lowest possible consumption of non renewable resources
    - Lowest possible release of greenhouse gases like $CO_2$

3. To the operator:
    - High mechanical reliability and efficiency
    - Long service life
    - No idling motor losses
    - Greater acceleration and hill climbing performance
    - Lower power costs
    - Lower maintenance costs

Tables 1 through 3 in Appendix A clearly demonstrate some of the advantages provided by the utilization of the electric trolleybuses.

The disadvantages of electric trolleybuses are:

1. High capital cost

An equivalent trolleybus will cost about 30% more than the ICE equivalent. However, the normal working life of trolleybus will be 20 years compared to 14 for an ICE bus. Therefore, the annual depreciation for an electric trolleybus is only 9% more than that of a CNG bus.

The installation of the power supply and overhead wiring network is undoubtedly capital intensive, when compared to normal buses. However, provided the network is intensively used, and can remain in use for a prolonged period, its costs can be amortized over many years.

2. Running costs

The cost of maintaining a modern trolleybus is certainly lower than that of a diesel. In San Francisco, the difference amounts to about 68:100 for trolleybus/diesel bus or, approximately 56% of that for a CNG bus.

The maintenance cost of the overhead wiring and substations is an extra burden, which must be carried by the trolleybus operator. However, even taking this into account, the total maintenance costs of the trolleybus system and vehicles should be at least 20% less than for diesel/CNG buses. Comparative fuel costs are similar.

3. Inflexibility

It is often perceived that trolleybuses can only run in procession, and on fixed routes. However, while this was once true, the use of modern, remotely controlled overhead switches allow for possible overtaking maneuvers to take place, as well as segregated use of bus stops.

Another problem is the re-routing of trolleybuses to go through new development areas. Again, this does not apply to most of the main urban bus routes, which have remained basically unchanged for many years. Where a major road construction/repair is unavoidable, there is always adequate notice, which gives the trolleybus operator sufficient opportunity to modify the overhead network. As a last resort, trolleybuses could be moved for short distances under the auxiliary power mode to meet a temporary disruption.

4. Visual intrusion of overhead wiring

It is impossible to make overhead wiring for trolleybuses completely invisible, but with good design, and use of high quality components, its visual impact can be reduced. Sacramento has introduced an innovative overhead wire masking scheme using specially trimmed trees along the routes. In fact, in the average Los Angeles urban environment, it is likely to be unnoticeable to most people.

Great simplification could occur if street light poles could carry the trolleybus wiring. This would require a higher quality lighting standard, at minimal extra cost. Where possible, suspension wires should be fixed to buildings, which will reduce the number of poles required.

## ELECTRIC TROLLEYBUSES-ENGINEERING

Much of the engineering of trolleybuses is similar to internal combustion engine buses. Modern North American and European trolleybus designs are usually derived from proven internal combustion engine bus designs- see Figure 3. Trolleybus electrical equipment is very flexible, consisting mainly of modules connected by flexible cables that need no special consideration for accessibility, cooling, or noise and vibration. Trolleybuses, therefore, present easier design challenges compared to ICE systems.

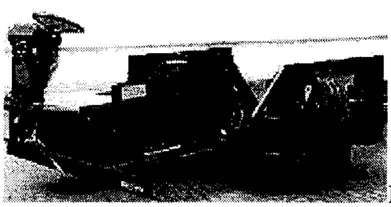


Figure 3- Common subassembly for ICE bus and trolleybus.

Although trolleybus suspension, steering and mechanical braking are the same as ICE buses, trolleybuses provide the opportunity to use the motor(s) as effective electric brakes, dramatically reducing the wear and tear on mechanical braking components and tires.

The energy generated by electric braking is either dissipated in resistors on the vehicle, or fed back into the overhead line, a system known as regenerative braking. Depending on the type of route and pattern of service, energy savings from regenerative braking can be substantial - up to one-third less energy consumption.

Many trolleybuses operate without any source of power other than overhead wires. In modern traffic situations, the ability to operate from overhead wires is considered essential. Modern battery systems or auxiliary small [ICE] generator systems permit operation at 10 to 20 mph, for considerable distances, independent of overhead wires.

Instead of a diesel engine and transmission, a trolleybus usually has a single electric motor, similar in size to an internal combustion engine bus automatic gearbox, connected directly to the driving axle. There is no gearbox or clutch, and all gearing is done in the axle, which has a higher reduction ratio to cope with faster running trolleybus motors.

Recent developments have permitted driving axle designs with an AC motor per wheel, or within the wheel, eliminating differentials and half shafts, permitting further simplification and greater flexibility in overall layout and facilitating low floors. Such designs are just entering service.

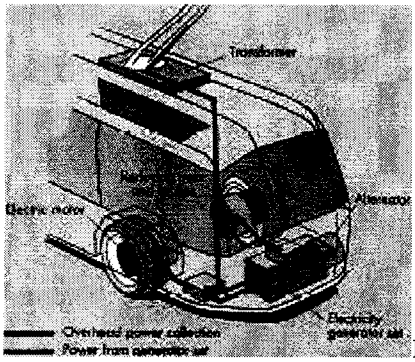


Figure 4-Trolleybus electrical equipment

The latest control technology for trolleybuses use alternating current [AC] motors, controlled by inverters that create variable voltage and frequency AC for the motors, from the DC overhead line supply. The supply voltage is between 600v and 750v.

AC motors and control systems have many advantages over traditional DC systems, including greater reliability, less maintenance, greater efficiency, and sophisticated control over acceleration and 'jerk' rates. The efficiency advantages should be substantial - up to one-third less power consumption than DC systems. Maintenance and reliability advantages should also are substantial - at least ten times more reliable than previous generation installations.

There have been considerable improvements in detail design, such as the automatic lowering of poles in the event of de-wirement or under the direct control of the driver without the driver having to leave the driver seat. Improvements have also been made with automatic re-wiring, in conjunction with special overhead fitments.

Advances in materials science and better understanding of motion dynamics have led to considerable improvements in overhead wire design. Modern suspension systems can cope easily with vehicle speeds of up to 50 mph while being lighter in construction and less visually obtrusive. Together with the latest development in electronic power feeder systems, these advances have reduced costs, improved efficiency and freed the trolleybus from having to take junctions and crossings any more slowly than other traffic.

Modern light rail systems, operated on right-of-way corridors, are a more environmentally friendly alternative to ICE buses. With effective traffic management to give buses sufficient priority, electric trolleybuses would give the public a similar traveling experience to modern light rail, and at a fraction of the capital cost. Features of light rail include a reliable congestion-free operation, a smooth fume-free ride, a level boarding from raised platforms and real-time information systems. These same features are available with modern trolleybuses.

## ELECTRIC TROLLEYBUSES-ECONOMICS

Electric trolley vehicles, with their lighter infrastructure, are inherently cheaper to construct than equivalent light rail systems, with a carrying capacity that approaches parity. The recent expansion of light rail systems has a beneficial effect for trolleybuses, as much of the electrical equipment is the same and standardization will see lower costs. Compared to ICE buses, which also share components with trolleybuses, much depends on recent integration developments and sizeable production runs.

Generally the maintenance costs of a trolleybus have shown to be far below those of an ICE bus because there is less that needs frequent mechanical attention. Also, electric braking dramatically reduces maintenance required on mechanical brakes –(not a small item of expense on an ICE bus used on stop-start services). Supplied with power from modern efficient, clean, green generating plant, trolleybus energy costs should be less than CNG. On intensive urban services, a trolleybus system should be able to finance its overhead power supply infrastructure from maintenance and energy cost savings.

Compared with a light rail infrastructure [wires and rails] trolleybus infrastructure [wires] can be put in at around 10% of the cost and disruption associated with light rail. Tables 4 through 6 in Appendix D supports these arguments.

With effective traffic management to give buses sufficient priority, electric trolleybuses could give the traveling public much the same experience as light rail, but at a fraction of the capital cost.

For trolleybuses there are two possible financial structures: one is for MTA to invest in both wiring and vehicles. Another is long-term, 20 to 50 years arrangement, where a power distribution company pays for the wiring and its maintenance and MTA pays for the vehicles and their operations. The second structure could be fully commercial if the MTA were charged full "absorption costs" of the wiring over the life of the arrangement.

Commercial finance should not be a problem with a long-term arrangement. In effect, the successful power distributor (that might be asked to pay a license for monopoly rights) would be able to forecast cashflows over life of the arrangement quite accurately. All the foregoing is predicated on the project being economically sensible in the first place.

## ELECTRIC TROLLEYBUSES FOR LOS ANGELES COUNTY-A STRATEGIC PROPOSAL

We envision a system that will reach 300 peak trolleybuses (15% of 2000 peak buses), operating on very high-density routes. The routes should be selected on criteria based on the highest possible daily boardings, the largest number of vehicle required, and the shortest possible routes. These criteria will ensure that MTA will need to open the minimum number of trolleybus routes and will keep the capital expenses for wiring and sub-stations to an absolute minimum. The vehicles should be 60 feet, articulated with multiple, wide doors for fast passengers loading and unloading. In addition the vehicles must have secondary power source to enable limited off-wire travel. No specially constructed, dedicated maintenance facilities will be required. Trolleybuses and buses will share those facilities.

We suggest public-public and public-private partnerships with LADWP and other electric power suppliers to build and maintain wiring and sub-stations. The partnerships should be broadly similar to those entered by MTA for the construction and operation of the CNG refueling stations.

MTA will fund the purchase of the vehicles through the usual bus acquisitions Federal, state and local funds. The same will be true for the operating funds. The partnering utilities will have no difficulty in getting funding for a project that can normally guarantee a monopoly based cashflow for 20+ years.

RECOMMENDATION

We recommend that MTA:

- Formally add electric trolleybuses to its long- and short-range plans as the primary (but not exclusive) option to meet the 2010 CARB's emission standards.
- Formalize the electric trolleybus feasibility study to include potential routes identification and project costs.
- Enter into formal, preliminary negotiations with LADWP and Edison Electric to form public-public and public-private partnerships.

APPENDIX A

TABLE 1-COMPARATIVE TOXIC AIR CONTAMINANTS
(based on CBD duty cycle) (in g/km)

| | PM | $NO_x$ | CO |
|---|---|---|---|
| Diesel Bus | 1.3-3.5 | 22.0-38.0 | 10.0-30.0 |
| Clean Diesel Bus | 0.1-0.35 | 10.8-21.0 | 3.1-24.3 |
| CNG Bus | 0.016-0.051 | 3.6-13.0 | 5.6-6.0 |
| Diesel-Electric Hybrid Bus | 0-0.2 | 6.6-8.6 | 0.08-2.5 |
| CNG-Electric Hybrid Bus | 0 | 0.25 | 0.12 |
| Trolleybus | 0 | 0 | 0 |

TABLE 2- TOTAL GREENHOUSE GAS EMISSIONS*
(based on NYC duty cycle)

| | Approximate Greenhouse Gas Emissions (in g/km of $CO_2$ equivalent) |
|---|---|
| Diesel Bus | 3,975 |
| Clean Diesel Bus | 4,975 |
| CNG Bus | 5,200 |
| Diesel-Electric Hybrid Bus | 3,750 |
| CNG-Electric Hybrid Bus | 5,000 |
| Trolleybus | 0 |

* Includes $CO_2$, $NO_X$, $CH_4$, NMCH, and CO)

TABLE 3- NOISE LEVELS (based on the Seattle, WA experience)

| | Noise Level , in dbA |
|---|---|
| Hearing Loss | 90 |
| Diesel Bus | 80-90 |
| CNG Bus | 75-80 |
| Fuel Cell | 70 |
| Trolleybus | 50-60 |
| Quiet street | 60 |

The RTD Board of Directors approved the implementation of the Electric Trolley Bus (ETB) program on June 11, 1992. Subsequently, on July 21,1992, the LACTC approved partial funding for ETB with authorization to do environmental work for twelve-lines and construct two prototype segments. The 30-Year Plan included Phase I, a twelve-line project, estimated at $1.1 billion as an unfunded program. The only funds approved for ETB were $8 million for environmental work and feasibility study and $50 million to complete the design and construction of two short segments on MTA Line 30/31 and Long Beach Line 40.

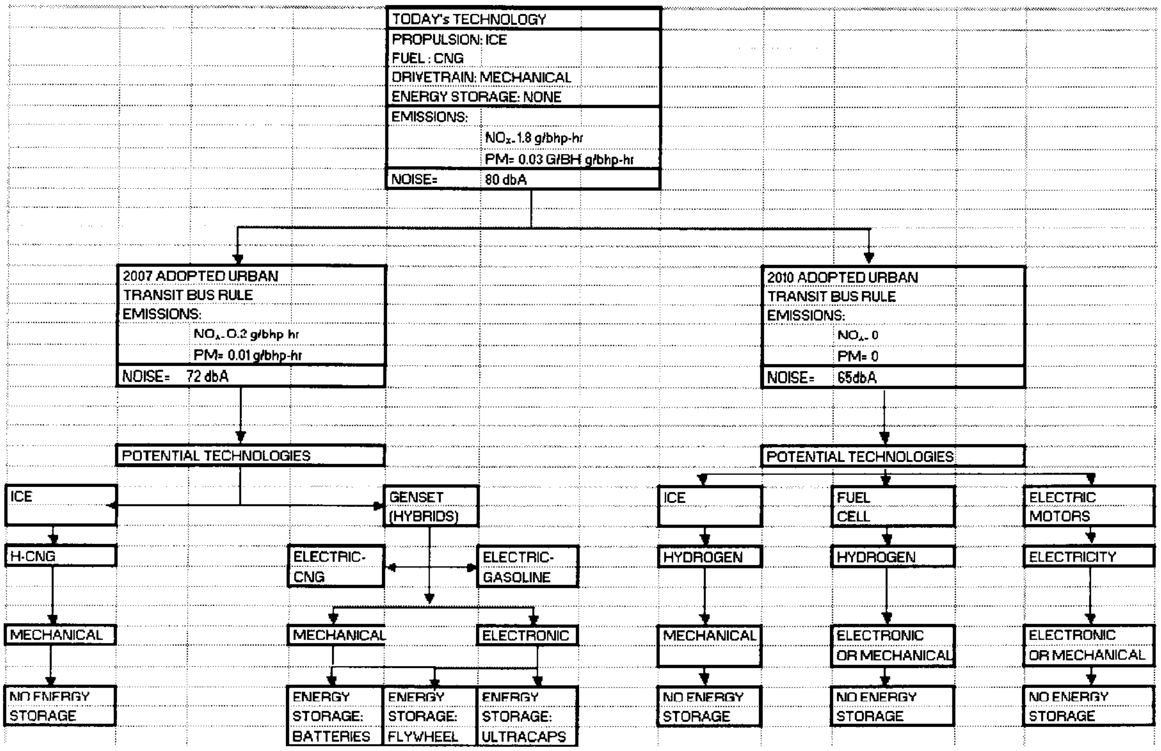
In June 1993, the FTA approved MTA Lines 40 and 45 for a Turnkey Demonstration Project. The designation was not accompanied with any commitment of federal funds. On October 25, 1993, the Long Beach Transit Board declined further participation in the ETB project unless funding was provided for their entire four line system.

On December 15, 1993 the MTA Board considered recommendation from workshop regarding Electric Trolley Bus (ETB) Program. Director Braude made a motion to reaffirm commitment to the ETB program. Several Board members questioned the cost of the project and whether it was the appropriate decision given the realistic development in technology. Public speakers were both in favor and against the ETB project.

Director Wilson made a substitute motion to suspend activities and reprogram available funds. This motion was approved on a Roll Call vote. The vote was 8 to 4 in favor, with one Director absent.

On May 24, 1994 $36,975,000 of the funds allocated to Project 29244, Electric Trolley Bus (ETB) were deobligated and programmed for other projects.

# Appendix C


TODAY's TECHNOLOGY
PROPULSION: ICE
FUEL : CNG
DRIVETRAIN: MECHANICAL
ENERGY STORAGE: NONE
EMISSIONS:
$NO_x$- 1.8 g/bhp-hr
PM= 0.03 G/BH g/bhp-hr
NOISE= 80 dbA
2007 ADOPTED URBAN TRANSIT BUS RULE
EMISSIONS:
$NO_x$- 0.2 g/bhp hr
PM= 0.01 g/bhp-hr
NOISE= 72 dbA
2010 ADOPTED URBAN TRANSIT BUS RULE
EMISSIONS:
$NO_x$- 0
PM= 0
NOISE= 65dbA
POTENTIAL TECHNOLOGIES
ICE
H-CNG
MECHANICAL
NO ENERGY STORAGE
GENSET (HYBRIDS)
ELECTRIC-CNG
ELECTRIC-GASOLINE
MECHANICAL
ELECTRONIC
ENERGY STORAGE: BATTERIES
ENERGY STORAGE: FLYWHEEL
ENERGY STORAGE: ULTRACAPS
POTENTIAL TECHNOLOGIES
ICE
HYDROGEN
MECHANICAL
NO ENERGY STORAGE
FUEL CELL
HYDROGEN
ELECTRONIC OR MECHANICAL
NO ENERGY STORAGE
ELECTRIC MOTORS
ELECTRICITY
ELECTRONIC OR MECHANICAL
NO ENERGY STORAGE

APPENDIX D

TABLE 4- OPERATING COSTS (BASED ON FTA's NATIONAL DATABASE)

| MODE | VEHICLE REVENUE HOUR | PER BOARDING |
|---|---|---|
| BUS | $101.59TO $102.79 | $1.47 TO $3.33 |
| TROLLEYBUS | $84.44 TO $101.78 | $1.31 TO $1.68 |

TABLE 5- CAPITAL COST*

| MODE | CONSTRUCTION DIFFERENTIAL | OVERHEAD WIRES | POWER SUBSTATIONS | VEHICLES DIFFERENTIAL |
|---|---|---|---|---|
| BUS | 0 | 0 | 0 | 0 |
| TROLLEYBUS | 0 | $0.6 MILLION/ MILE | $0.7 MILLION/ MILE | $132,000 EACH |

*SOURCES OF DATA: DATA: a) PRIVATE COMMUNICATIONS WITH TROLLEYBUS OPERATORS IN SEATTLE,WA; SAN FRANCISCO, CA; DAYTON, OH;BOSTON, MA; PHILADELPHIA,PA; AND VANCOUVER,BC; b) FTA'S NATIONAL DATABASE; c) APTA'S 2001 PUBLIC TRANSPORTATION FACT BOOK; d)SAN FERNANDO VALLEY EAST-WEST TRANSIT CORRIDOR, FINAL ENVIRONMENTAL IMPACT REPORT, 2002.

TABLE 6- CAPITAL COST COMPARISON

| PROJECT TYPE | NO. OF PROJECTS | COST RANGE PER MILE (ADJUSTED TO FY 2001) |
|---|---|---|
| LRT* | 18 | $12.4 MILLIONS TO $118.8 MILLIONS |
| TROLLEYBUS** | Unk | $0.3 MILLION TO $ 7.0 MILLIONS |

* BASED ON GAO-010984 (SEPTEMBER 2001) REPORT