Preliminaries to a Feasibility Analysis of the Maglev Proposal of The Southern California Association of Governments for the Region

(A Seed Grant Study Report)

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Summary

The Study

This is a seed grant study to perform a preliminary investigation of the system components and generalized costs of the magnetic levitation type of high speed rail system that is proposed for the Southern California Region, TGV-based high speed rail, and urban rapid transit with special focus on bus rapid transit (BRT). This technology overview summarizes the key aspects of these transit technologies and provides comparative cost information to feed a more comprehensive feasibility analysis.

Definition of High Speed Rail

High-speed rail (HSR) refers to high speed ground transportation by rail operating at speeds exceeding 125 mph (or 200 km per hour). Japan initiated the concept of high speed rail when the Shinkansen Line started operation between Tokyo and Osaka in 1964 with cruising speeds of 210 km/h. Notable HSR systems are operational in Japan, France, Germany and China. There are three wheel-on-rail type technologies that may be referred to as standard high speed rail: (a) the Japanese Shinkansen (called bullet train), (b) the French Train a Grande Vitesse (TGV) and (c) the German Inter City Express (ICE). Then there is the magnetic levitation (Maglev) system that has been tested for decades but has only recently seen one line in commercial operation in China.

The Southern California High Speed Rail Proposal

Originally studied as a way of accessing various airports in southern California, planners soon recognized the potential for the high speed system to serve large volumes of commuter traffic. The planned Maglev system now has the additional objective of helping to provide some relief for travel between major origins and destinations in the midst of roadway traffic congestion in the Los Angeles metropolitan region.

There are five main project segments with many alternative alignment options for each of the segments. There are specific station locations that are to be connected by each of the alignment options. The details of these alignments are in various project study reports (FRA, 2000; SCAG, 2002a; SCAG, 2002b; SCAG, 2006). The collection of reports provides varying levels of detail about the different segments. Differences in alignment affect distances, time, passenger and cost estimates.

Literature on High Speed Rail

The literature reveals certain general findings about high speed rail:

- There is usually a significant difference between maximum experimental speed and maximum operating speed. The latter is what should be applied in planning for high speed rail
- Increasing maximum speed has decreasing marginal gains in travel time savings. The lesson is not to seek the highest possible speed for a new system being planned, but one that would enable significant improvement from existing operations.
- Travel time reductions due to higher speed depend very much on the length of the run between stations. The lesson is to seek high speed systems for long distance spacing between stops; they will bring little gain to short distance trips.
- Marginal cost grows more than proportionally with increases in maximum speed. The lesson is not to necessarily seek the cutting edge of the technology if cost effectiveness is an objective.
- High-speed rail can play a key role in providing transportation for trips between 62 and 621 miles (100 km to 1000 km) in length.

Modal Comparisons

Comparison of standard high speed rail and Maglev technologies revealed the following:

Speed – Advancements in standard high speed rail technology in recent times have removed the higher **speed** advantage that Maglev previously had, making travel time differences between the two modes very small over typical spacing between stations.

Interconnection – HSR holds a huge advantage over Maglev in its ability to use existing infrastructure and thus facilitate better **interconnection** with existing rail networks.

Investment Cost – The maturity of the technology and its ability to use existing infrastructure enables HSR to be deployed at a lower **investment cost** than Maglev.

*Operating Cost*s – These are not certain for Maglev, but HSR consumes less energy per comparable unit of train capacity.

Maintenance Costs – Because Maglev trains lack physical contact with the guideway, this feature would suggest lower maintenance costs, but the highly complex electronics on both the guideway and the trains could result in costly repairs when the need arises.

Comfort – HSR has an advantage over Maglev in terms of ride comfort.

Findings

The data clearly indicate major differences and overlaps in the costs of the various technological options. The relatively short distances between proposed stations in southern California make other fully grade separated, urban transit modes contenders among the technological choices. If alignments chosen are feasible with relatively little tunneling, BRT would be the most economical choice in terms of capital costs per mile at $30 million or below. If much tunneling is involved, then all capital costs can easily approach or exceed $100 million per mile. In this case the rail modes would be more efficient choices. If the lower range of the costs for urban rapid rail (Metro) construction were the case then Metro could be an efficient choice. If the upper end of the costs for Metro construction were to be the case then HSR would be the more efficient choice. Maglev would have the disadvantages of: (a) higher capital costs than HSR; and (b) the inability to share existing facilities with other rail such as AMTRAK and the future intercity HSR to be implemented in the State of California.

Conclusions

There are differences of opinion between proponents of Maglev and high speed rail. There are major differences and some overlaps in actual construction costs and cost estimates associated with the various technological options for intercity and intra-city public transportation. These call for careful study rather than emotional appeal when considering these systems for deployment.

A more thorough study needs to be conducted toward the choice of technology for the Decentralized Airport Connector and Commuter system for Southern California. The detailed study needs to assess the appropriateness of the technology to choose in terms of speed of travel vis-à-vis associated capital and operating costs.

1.0 Introduction

Preamble

History has taught us that as the price of gasoline continues to rise, more and more travelers would find it more cost effective to switch away from single- or low-occupant auto travel to shared modes in higher capacity vehicles. Air travel is one of those shared modes traditionally suited for long distance travel. Rail and intercity bus are other shared modes intuitively suited for medium to long distance travel. Public transit is yet another shared mode typically used for short distance and community-based travel.

Even without shifts to higher capacity modes, Southern California, like many regions in the nation, has been faced with aviation capacity challenges in a rapidly expanding air travel market. One of the many different strategies that agencies are assessing for dealing with capacity issues is the idea of decentralizing operations in regional aviation markets. The idea involves use of available or potential capacity at surrounding secondary or former military airports to augment operations at central hub airports. The Southern California aviation market, for instance, has nine different commercial aviation facilities spread out over 38,000 sq. miles.

With a rapidly increasing population, economic expansion, and high levels of roadway and air traffic congestion, the Southern California Association of Governments (SCAG) envisions the use of Maglev (a variant of high speed rail) to connect the region's airports and augment the transportation infrastructure. The airports to be included in the SCAG vision are: Los Angeles International Airport (LAX); Ontario International Airport (ONT); John Wayne-Santa Ana International Airport (SNA); Bob Hope – Burbank (BUR); Long Beach (LGB); San Bernardino (SBD); March AFB (MIP); Palm Springs (PSP); and Southern CA Logistics (SCLA).

Rationale for Maglev in Southern California

Decentralization of airport operations should not affect seamlessness in passenger travel. High speed rail has the potential to connect the airports in the Southern California region to ensure seamless travel

for passengers. SCAG has proposed the use of Maglev technology as the solution to connecting airports, by providing needed speed, capacity, and efficiency that the existing regional transportation network lacks and thereby enhancing the future transportation needs of Southern California as the region continues to expand in both population and geographic extent.

SCAG projects the population of Southern California to grow by additional 6 million people over the next 30 years to nearly 23 million persons (SCAG, 2006). In an area perpetually plagued with high incidence of roadway and air traffic congestion, such growth could further decrease mobility of people and goods if commensurate improvements are not made in transportation infrastructure. The region's roadway network currently ranks among the most congested in the country. In 2005, the Texas Transportation Institute (TTI) designated Los Angeles as the number one congested very large city, Riverside-San Bernardino as the number one congested large city, and the Los Angeles-Long Beach-Santa Ana area as the number one congested very large urban area (TTI, 2005). The economic prosperity and quality of life that are dependent upon the efficiency of the transportation system could be in jeopardy as a result of further deterioration in conditions. For the region to sustain its economic vitality and quality of life, the transportation network will need to be reevaluated to determine what modifications could be made to create an efficiently accommodating system.

Twomey & Tomkins, 1995, referred to the Los Angeles World Airport (LAWA) system as a key and essential element of the regional transportation network and of its economic growth. LAWA is a system of airports owned and operated by the City of Los Angeles. This system includes Los Angeles International Airport (LAX), Ontario International Airport (ONT), Van Nuys (VNY) Airport, and Palmdale Regional Airport (PMD). Six other airports (listed in the previous section) are expected to contribute to the future aviation needs of the region. These other airports are operated and planned as independent facilities with little consideration for the needs of the greater region.

LAWA projections indicate that the region's airports lack the facilities to meet the expected passenger demand for 2015 (Los Angeles World Airports, 2004). LAX, the most dominant air facility in the system is constrained in its efforts to expand due to its proximity to residential neighborhoods and other urban facilities. Recent expansion plans for LAX were dropped as part of an agreement between the City of Los Angeles and neighbors of the aviation facility who are opposed to the plan. The alternate vision for the

aviation network is decentralization of airport operations away from LAX. In 2003, LAX handled 70% of the air passenger traffic, while Ontario and John Wayne were in second place with approximately 10% each. Under the decentralization scheme, LAX is projected to handle 45% of the air passenger traffic even as total passengers are expected to double by 2030, with Ontario's share increasing to 18% (SCAG, 2004).

Originally studied as a way of accessing various airports in the region, planners soon recognized the potential for the Maglev system to serve large volumes of commuter traffic. The planned Maglev system now has the additional objective of helping to provide some relief for travel between major origins and destinations in the midst of roadway traffic congestion in the Los Angeles metropolitan region.

Study Purpose

This report is a product of a seed grant research of background to the feasibility of a "Decentralized High Speed-Connected Airport System" in Southern California. Its objectives are to identify sources and factors of cost to enable the design of a more detailed study on the topic. The subsequent study is envisioned to look at the feasibility as well as relative costs of alternative methods of connecting the airports. Conceptual alternatives may include: TGV-based high speed rail; the proposed Maglev-based high speed rail and urban rapid transit.

2.0 Description of Proposed Southern California System

The process of planning for a Maglev system in southern California began with initial studies on the feasibility of the entire system. This was followed by more detailed studies of various segments. There are five main project segments (see Figure 1):

1. The Initial Operating Segment (IOS) from West Los Angeles (LA) to Ontario Airport
2. Extensions of the IOS to connect with LAX and March stations
3. A connection between Los Angeles International Airport (LAX) and Palmdale
4. A connection between Downtown LA and Anaheim
5. Connecting various locations in Orange County with LAX and major stops in LA.

There are many alternative alignment options for each of the segments listed. There are specific station locations that are to be connected by each of the alignment options. The details of these alignments are in various project study reports (FRA, 2000; SCAG, 2002a; SCAG, 2002b; SCAG, 2006). Appendix 1 has excerpts from these documents. The collection of reports provides varying levels of detail about the different segments. The varied alignments affect the distances, time, passenger and cost estimates. Table 1 summarizes selected estimates and characteristics for all segments except the Orange County segment for which there are many possible route choices yet to select from. Estimates suggest overall system costs would range between $110 million to $145 million per mile.

The Federal government provided funding for the initial study of Maglev for Southern California. Funding for capital costs is expected to come from programs under the Federal Transportation Infrastructure Finance and Innovation Act (TIFIA) as well as tax-exempt municipal bonds.

Detailed cost estimates have been developed for the IOS, LAX to March, and Palmdale segments. Table 2 is a summary of the capital costs and the operating and maintenance costs. These costs are compared in this report to other cost estimates for Maglev, High Speed Rail, and Bus Rapid Transit (BRT) systems.

Figure 1: Proposed System Configuration

Table 1: Characteristics of Proposed Southern California Maglev System

Segment	Distance Miles (kilometers)	Time (minutes)	Daily Passengers	Assumed Headway (minutes)	Total Cost ($ billions)	System Cost per mile ($millions)
IOS[1]	54 mi (86 Km)	32	65,600		7.8-8.3	144.4
LAX to March[2]			57 - 84,000	20	4.8	
LAX to Palmdale[3]	72 mi (115 Km)	42	102 - 153,000	10	8.2-11.9	113.9
LA to Anaheim[4]	30-33 mi (48-53 Km)	34-43	46,000	10	3.3-3.9	110 – 118.2

Data Sources:

1. http://www.scag.ca.gov/Maglev/pdf/1_Maglev_PE_Summary_of_IOS.pdf
2. http://www.scag.ca.gov/Maglev/pdf/lax_marchgp.pdf
3. http://www.scag.ca.gov/Maglev/pdf/lax_palmdale.pdf
4. http://www.scag.ca.gov/Maglev/pdf/orangeline.pdf

Table 2: Summary of Capital and Recurrent Cost Estimates on Three Segments

Segment	Capital Cost ($ billions)	Annual Operating and Maintenance Costs ($ millions)	Annual Passenger Miles (millions)	O & M Cost per Passenger-Mile
IOS	$ 7.8 – 8.3			
LAX to March	$ 4.8	$ 81	741	$0.11
Palmdale	$ 8.2 – 11.9	$ 146 - $212		

Initial Operating Segment

Additional information is provided in this section on the initial operating segment (IOS) as a sample of information available on the proposed Maglev project. The IOS has four stations from West LA to Ontario. There are three alignments under consideration. The criteria generally applied in the determination of alignments for this and other segments include (SCAG, 2006):

- Use of Public Rights-of-Way
- Develop fully grade-separated alignment
- Maximize Speed
- Minimize Impacts
- Minimize Costs

The alignment along Interstate 10 plans for stations at West LA, Union Station, West Covina, and Ontario Airport. The alignment along State Route 60 plans for stations at the same locations except Puente Hills instead of West Covina. The route via the Union Pacific Railroad (UPRR) right-of-way would include a stop at City of Industry instead of West Covina. Other segments portray similar types of variations in alignment. Details are included in Appendix 1.

IOS Cost Estimate

SCAG (2006) identifies eight main categories of cost for the project overall. Table 3 shows a cost comparison of the three different alignments of the IOS in these eight categories. The costs include those for system implementation, environmental impact mitigation, management, and other contingencies.

The estimates depict the SR-60 alignment as the most costly; however, this alignment also has the lowest cost per mile. Overall, the cost differences for each alignment are small, with the same costs for vehicle and maintenance facilities and operating equipment for all alignments.

Table 3: Major Capital Cost Components of Three Alignments on Initial Operating Segment

(Cost in $ millions)

Alignment	**I-10**	**SR-60**	**UPRR**
Distance (miles)	54.44	58.37	56.33
Cost Category:			
Guideway	$1,552.20	$1,667.50	$1,621.40
Structures, Foundations, Tunnels	$2,155.30	$2,442.40	$2,298.90
Stations	$939.10	$919.10	$936.00
Maintenance Facilities and Operation Equip.	$331.10	$331.10	$331.10
Communications, Signal, Power	$1,341.80	$1,438.70	$1,388.30
Vehicles	$920.90	$920.90	$920.90
Right-of-way	$324.00	$339.10	$314.50
Roadway Improvements	$246.90	$257.20	$255.50
Total Cost	$7,811.40	$8,315.90	$8,066.60
Cost per Mile	$143.50	$142.50	$143.20

3.0 Technology Overview

This study investigated the system components and generalized costs of magnetic levitation -based high speed rail, TGV-based high speed rail, and urban rapid transit with special focus on bus rapid transit (BRT). This technology overview summarizes the key aspects of these transit technologies and provides comparative cost tables.

3.1 High-speed Rail

High-speed rail (HSR) refers to ground transportation by rail operating at speeds in excess of 125 mph (or 200 km per hour). Japan initiated the concept of high speed rail when the Shinkansen Line started operation between Tokyo and Osaka in 1964 with cruising speeds of 210 km/h. Notable HSR systems are operational in Japan, France, Germany and China. There are three wheel-on-rail type technologies that may be referred to as standard high speed rail: (a) the Japanese Shinkansen (called bullet train), (b) the French Train a Grande Vitesse (TGV) and (c) the German Inter City Express (ICE). Then there is the magnetic levitation (Maglev) system that has been tested for decades but has only recently seen one line in commercial operation in China. The literature reveals certain general findings as follows (Vuchic and Casello, 2002):

- High-speed rail can play a key role in providing transportation for trips between 62 and 621 miles (100 km to 1000 km).
- Increasing maximum speed has decreasing marginal gains in travel time savings
- Travel time reductions due to higher speed depend very much on the length of the run between stations.
- Marginal cost grows more than proportionally with increases in maximum speed.
- There is usually a significant difference between maximum experimental speed and maximum operating speed. The latter is what should be applied in planning for high speed rail.

These findings are explained in additional detail in a subsequent chapter on Comparison of Modes.

3.2 Magnetic Levitation Based High Speed Rail

History

Major development in magnetic levitation (Maglev) technology started in 1970 and occurred simultaneously in Germany and Japan resulting in two different types of Maglev systems. The German-based Maglev system, the Transrapid, uses electromagnetic suspension to levitate the train cars while the Japanese-based Maglev system uses superconducting magnets to levitate train cars. While Maglev test lines are in place in Germany and Japan, the only commercially operating high-speed Maglev line is in Shanghai, China. Shanghai's Maglev began full operation in March, 2004. The Transrapid in Shanghai has a design speed of over 500 km/h (310 mph) and a regular maximum service speed of 430 km/h (267 mph) so that it covers the 20 miles from Pudong to the outskirts of the city in 7 minutes and 20 seconds.

Technology Outline

Vuchic and Casello (2002) summarized the technology as follows:

- *Electromagnetic Suspension (EMS)* – The German version uses attractive magnetic forces between train cars and a steel track to levitate vehicles. There are two versions of the German system. One is for inter-city travel, called the Transrapid. The other is for urban transit and is called the Transurban.
- *Electrodynamic Suspension (EDS)* – The Japanese version uses repulsive magnetic forces both in the train car and on the track to levitate vehicles. An example of an urban-to-urban Maglev that operates at comparatively low speeds was showcased in Aichi, Japan for the 2005 World Expo.
- *Maximum Experimental Speed* – was achieved on the Japanese test system at 581km/h (JR Central, 2008)
- Track Alignment – Maglev trains have the ability to climb grades up to 10% and negotiate tighter radii than steel wheel high-speed trains.
- Actual operational speed on a commercial system is 430 km/h (267 mph).

Proposed Systems

Several proposals have been advanced and dropped over the decades to deploy Maglev technology in both the system developer countries and abroad. The estimated system costs associated with a selection of these projects are summarized in Table 4. The Maglev 2000 proposal for Florida is a light profile intra-urban system for which costs are out of range with the other inter-city proposals.

Baltimore to Washington – This was proposed to use the German based Transrapid technology along a 40 mile corridor connecting downtown Baltimore and the Baltimore-Washington International Airport to Washington D.C. (MTA, 2000).

Tokyo to Osaka- Also known as the Chuo-Shinkansen line, this proposed 500 km route will use the Japanese based superconductive Maglev technology and is estimated to cost JPY 5.1 trillion for construction costs and rolling stock excluding stations (JR Central, 2007). The Chuo Shinkansen line has a test track in Yamanashi prefecture. At this test location, trains have reached speeds of 581 km/h and are declared by the system developers as commercially feasible. The Yamanashi test facility will undergo a 355 Billion yen renovation to extend its current 18.4 Km track to a 42.8 Km test track. (JR Central, 2008)

Table 4: Comparison of Maglev System Costs

System:	*Generalized*	*Transrapid*	*Transrapid*	*Maglev 2000*	*Chuo Maglev*
Location	*Worldwide*	*Shanghai-Pudong*	*Baltimore-Washington*		*Tokyo - Osaka*
Total System Cost ($ millions per mile)	$19-$88	$23-$70 *			$221 - S264
Track $ millions per mile)				$11	
Stations ($ millions each)			$133		
Rolling Stock ($ millions per train)			$35		
Operating Costs					
Energy (per passenger mile)				$0.01	
Other (per passenger mile)				$0.02	
Total (per passenger mile)				$0.03	
Maintenance	unavailable	unavailable	unavailable	unavailable	unavailable
Source	Vuchic, and Casello 2002	Yan, 2004	MTA, 2000	Powell and Danby, 2007	IRJ, 2005

***Notes:**

Estimated cost as-built: $ 70.27 m/mile

Estimated long-term project cost:	$ 35 to $40 m/mile
Estimated cost from China's Ministry of Railways:	$ 23.4 m/mile

Operating System

The only commercially operating Maglev system is the Transrapid Maglev line connecting Longyang Road station to the Shanghai Pudong International Airport. Construction of the station first began in 2001 and finished in 2004.

3.3 TGV Based High Speed Rail

History

The first TGV line was opened in 1981 and connected Paris and Lyon via a 417 km long track. Since its initial opening, the French TGV line has grown with new lines connecting to Lille, Marseilles, and the United Kingdom via the Channel Tunnel. It now boasts the fastest average operating speed (317 km/h or 200 mph) among standard high speed rail technologies.

Technology and Features

The literature reveals certain attractions with standard HSR as exemplified by TGV technology:

- *Steel wheeled rail technology*- they operate much like traditional rail, but with refinements and at much higher speeds.
- *Standard Gauge* – TGV utilizes standard gauge track (Nash et al, 2007) allowing TGV train cars to operate on non-high speed rail lines.
- *Bimodal Use*- high-speed trains can accommodate platform wagons loaded with cars, trucks and buses thus creating potential to use available route capacity for freight movement and improve financial efficiency of the system (Guirao et al, 2005).
- *Max Experimental Speed*- 515 km/h (Vuchic and Casello, 2002)
- *Track Alignment* – Ability to climb grades up to 4%

Proposed and Existing Systems

Europe has gone through extensive high-speed rail development in both infrastructure and acceptability. The existing system integrates lines that connect France, Great Britain, Switzerland, Germany and Belgium with new lines under construction to connect Sweden, Denmark, The Netherlands, Italy and Spain (Vuchic and Casello, 2002).

While high-speed rail technology has expanded in Europe, it has only begun to be explored in the United States. Planning efforts in the United States show widely varied levels of development. A survey revealed 21 proposed high-speed rail systems in 64 corridors to traverse more than 15,500 centerline miles (Schwieterman and Scheidt, 2007). Table 5 shows selected system costs. It reveals that the statewide, TGV-based system proposed for California is estimated to cost approximately $40 million to $60 million per mile, two to three times lower than the range of costs per mile for the proposed Southern California Maglev system.

Table 5: Selected TGV System Costs

System:	Generalized HSR	TGV	TGV
Location	Worldwide	California	California
Total System Cost ($ millions per mile)	$10-$40		$37.5 to $62.6
Track $ millions per mile)			
Stations ($ millions each)			$29.1 to $79.2
Rolling Stock ($ millions per train)			
Operating Costs			
Capital & maintenance		$0.21 / pass-mile	
operating only		$0.08 / pass-mile	$351.2 m / year
Equipment maintenance			$299.5 m / year
Source	Vuchic and Casello, 2002	Levinson et al, 1996	CHSRA and FTA, 2008

3.4 Urban Rapid Transit and BRT

The following information about BRT is intended to help decision-makers understand and compare the elements of this bus system to the high-speed rail technology. Additional information about systems around the world is available through the Federal Transit Administration and the National Bus Rapid Transit Institute (FTA, 2009). This section looks more specifically at system implementation and costs in

the US. There are many grades of BRT systems. This study looks at the system that is most comparable to a Maglev in terms of using a grade-separated transitway with large stations.

History

Bus Rapid Transit (BRT) was developed in Curitiba, Brazil as a way to provide a service that is very similar to light rail but at a much more affordable cost. The system was later adopted in other South American cities, while its value was being explored in Europe and North America. The only "complete" citywide networks of BRT systems are those found in Curitiba and Bogota. Several BRT systems are planned or implemented in several countries around the globe as a relatively low-cost urban transportation option.

Technology

New technologies are increasingly being used to create effective forms of BRT yet they remain relatively simple compared to Maglev or high-speed rail technologies. BRT runs like a light rail system. There is a specific route that the bus travels, riders pay in advance, and there are raised boarding platforms to the same level as the bus floor to reduce boarding times. A high performance BRT system has the following features:

- Grade separated right-of-way
- Advanced ticketing to reduce boarding time
- Raised platforms at stations to reduce boarding time and improve entry and exit
- Frequent, reliable service
- Applications of Intelligent Transportation Systems for priority treatments, traveler information, etc.

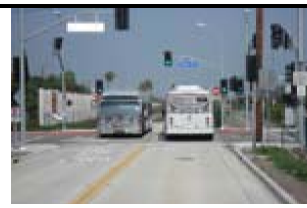
Operating Systems

There are many systems operating worldwide, including South America, Europe, Australia and Canada. There are varied forms of BRT systems in many cities in the US (FTA, 2009) such as the Las Vegas MAX, the Boston Silver Line, and the Los Angeles Orange Line.

System Costs:

A document of the Federal Transit Administration (FTA, 2009) identifies costs associated with running ways, stations, and vehicles of BRT systems. Capital costs for surface systems vary in the US between $2.7 and $23.07 million per mile. Table 6 summarizes infrastructure related costs and Table 7 identifies vehicle purchase costs. Notable features of BRT systems and vehicles in the cost table are defined next.

Table 6: Comparison of BRT System Costs – Infrastructure

Element: Running Ways	Cost (million per lane-mile)	Description/Example
At-Grade Transit Way	$6.5 - $10.2	 Orange Line, Los Angeles
Grade-Separated Transit Way	Aerial: $12 - $30 Below Grade: $60-105	 East Busway, Pittsburgh
Element: Stations	**Cost**	**Description/Example**
Intermodal Transit Station	$5-$20 million (cost of platforms, canopies, large station structure, passenger amenities, pedestrian access, auto access, and transit mode for all transit modes served; does not include soft costs)	 Intermodal Station (Miami-Dade)

Notable Features of BRT

Notable features of BRT systems are introduced in Table 6 and Table 7. They are defined briefly as follows:

At grade Transit Way: -- This refers to the situation where roads are created for the exclusive use of transit vehicles in available rights-of-way. Examples include: (a) a railroad corridor that is no longer in

use and where there is sufficient transit demand to warrant the investment that will support frequent bus service; and (b) adjacent to active rail corridors where there is sufficient cross-section to operate the BRT. In certain circumstances, right-of-way for exclusive lanes may be wide enough to accommodate only one single bi-directional lane. In such situations, transit service is limited to the peak direction only or service in both directions if frequencies are low and the single-lane section is short.

Table 7: Comparison of BRT System Costs – Vehicles

Element: Buses	**Cost**	**Description/Capacity**
Conventional Standard	$375,000 - $400,000	35 – 70 passengers
Stylized Standard	$425,000 - $450,000	35 – 70 passengers
Conventional Articulated	$700,000 - $750,000	31 – 90 passengers
Stylized Articulated (Partial Low-Floor)	$800,000 - $950,000	31 – 90 passengers
Specialized BRT Vehicle (Full Low-Floor)		31 – 90 passengers

Grade Separated Transit Way: -- Grade-separated transitways avoid cross street traffic with overpasses or underpasses, allowing transit vehicles to operate unimpeded at maximum safe speeds between stations. They are separated from congestion along local streets at intersections and adjacent highways. Underpasses or overpasses can be used at intersections, with the bulk of the right-of-way at grade, to reduce costs.

Intermodal Station: -- The intermodal terminal or transit center is the most complex and costly of BRT stations. This type of BRT facility often will have level boarding and a host of amenities and will accommodate transfers from BRT service to local bus and other public transit modes such as local rail transit, intercity bus, and intercity rail.

Conventional Standard Vehicle: -- Conventional standard vehicles are 40 to 45 ft in length and have a conventional ("boxy") body. The partial low-floor variety (now the norm among urban transit

applications) contains internal floors that are significantly lower (14 inches above pavement) than high floor buses. They typically have at least two doors and a rapidly deployable ramp for wheelchair bound and other mobility-impaired customers.

Stylized Standard Vehicle: -- Stylized standard vehicles have the features of a conventional step low-floor vehicle but they also incorporate slight body modifications or additions to make the body appear more modern, aerodynamic, and attractive.

Conventional Articulated Vehicle: -- These are longer, articulated vehicles that have higher passenger carrying capacity (50% more) than standard vehicles. Typically they have partial low floors with steps and also have two or three doors.

Stylized Articulated Vehicle: -- Stylized articulated vehicles are emerging in the U.S. to respond to the desires of BRT communities for more modern, sleeker, and more comfortable vehicles. Step-low floors, at least three doors with two double-stream and quick-deploy ramps facilitate boarding and alighting to shorten stop dwell times.

Special BRT Vehicle: -- Specialized vehicles employ a modern, aerodynamic body that has a look similar to that of rail vehicles. Special axles and drivetrain configurations create a full low floor in the vehicle interior. They also employ advanced propulsion systems and often include integrated ITS components and guidance systems.

Operating and Maintenance Costs

US experience with the introduction of BRT systems reveals typical increases in ridership. This is expected because of the usual increase in service frequency and general attractiveness of vehicles. This has translated into improvements in operating cost efficiency for the BRT-specific routes in terms of such performance indicators as: (a) passengers per revenue hour (b) subsidy per passenger-mile, and (c) subsidy per passenger. The Metro Rapid BRT line in Los Angeles, for instance, reported an increase in passengers per revenue mile from 51 to 59.7. This resulted in reduced subsidy per passenger mile from $0.20 to $0.15. The Silver Line BRT in Boston registered a 15% increase in riders per passenger hour. Additional details are included in Appendix 3.

4.0 Modal Comparisons

4.1 Maglev vs. Standard High Speed Rail

Magnetic Levitation (Maglev) technology is a version of guided high speed ground transportation. In this comparison, the differentiation is made by referring to one form as standard high speed rail (HSR) and the other as Maglev. HSR includes the Japanese Shinkansen (JS), French Train a Grande Vitesse (TGV), and German Intercity Express (ICE) technologies.

Vuchic and Casello (2002) compared Maglev with conventional high speed rail in the areas of travel speed, interconnection with other modes, investment costs, operation and maintenance costs, and rider comfort. They arrived at the following conclusions:

1. *Speed* – Advancements in standard high speed rail technology in recent times have removed the higher **speed** advantage that Maglev previously had, making travel time differences between the two modes very small over typical spacing between stations. The highest tested HSR speed on the TGV is 515 km/h, compared to the highest tested Maglev speed of 551 km/h, a 7% difference. In actual operation, the TGV trains average 317 km/h. The one commercially operating Maglev line in China, boasts a top speed of 431 km/h but an average of 262 km/h over its relatively short distance of 30 km. Note that even if the Maglev were 100 km/h faster in actual operation, a 100 km trip would take approximately 15 minutes by Maglev (at 400 km/h) and 20 minutes by HSR (at 300 km/h) resulting in approximately 5 minutes in travel time savings. (This example assumes instant acceleration and deceleration; if taken into account, the difference will be smaller than 5 minutes).

2. *Interconnection* – HSR holds a huge advantage over Maglev in its ability to use existing infrastructure and thus facilitate better **interconnection** with existing rail networks. HSR can jointly use tracks, yards, maintenance facilities and even entire sections of lines with other rail. The ability to extend its reach to other rail promotes further connectivity via settlements not directly on HSR lines. The ability to integrate with existing networks creates great convenience for passengers and reduces the need for transfers, which can extend door-to-door travel times significantly.

3. *Investment Cost* – The maturity of the technology and its ability to use existing infrastructure enables HSR to be deployed at a lower **investment cost** than Maglev, for which costs are

uncertain because it has extremely limited deployment experience. A USDOT report indicates that Maglev would cost 10% to 20% more than HSR, (USDOT, 1997). Maglev's capital cost is higher because it requires entirely separate rights-of-way and special facilities that are not compatible with existing systems.

4. *Operating Cost*s – These are not certain for Maglev, but it is expected to consume more energy than HSR because the linear induction motor (LIM) would require continuous use of energy as opposed to the rotating electric motor of HSR. The Vancouver Skytrain and Toronto's Scarborough line, both with LIM, for instance, are known to use 20% to 30% more energy for traction than similar rail vehicles with conventional rotating electric motors. Thus HSR consumes less energy per comparable unit of train capacity.

5. *Maintenance Costs* – Because Maglev trains lack physical contact with the guideway, this feature would suggest lower maintenance costs, but the highly complex electronics on both the guideway and the trains could result in costly repairs when the need arises.

6. *Comfort* – Visitors on both the German Transrapid Maglev and Japanese Maglev trains are known to experience considerable vibration and noise levels whereas HSR trains including the JR, TGV and ICE are known for very smooth rides and low internal noise. Thus HSR has an advantage over Maglev in terms of ride comfort.

4.2 Tenets for Adopting High Speed Rail

Vuchic and Casello (2002) postulated certain tenets to guide the adoption of high speed rail technology. They relate travel time to the maximum system speed, station spacing and cost.

The first relates travel time gains to the maximum speed of the system:

> "*Increases in maximum speed have decreasing marginal gains in travel time savings*" – the authors illustrate that over a 250 km distance for instance, an increase in maximum speed by 50 km/h from 150 km/hr to 200 km/h would result in nearly a 25 minute reduction in travel time. An additional 50 km/h increase to 250 km/h would reduce travel time by nearly 15 minutes and a further 50 km/h increase to 300 km/h would reduce travel time only slightly by nearly 10 minutes. If maximum speed were increased from 400 km/h to 450 km/h, there would be only a

4-minute reduction in travel time. Thus speed differentials at lower levels are more effective than at much higher levels. The lesson is not to seek the highest possible speed for a new system being planned, but one that would make significant difference to existing operations.

The second tenet relates travel time gains to the spacing between stations:

"*Travel time reductions due to higher speeds depend on the distance between stations*" – if maximum speed increased from 250 km/h to 300 km/h, the travel time reduction would be nearly 9.7 minutes over a 250 km distance. If the same speed change occurred over a 100 km distance, it would save just about 2.6 minutes and if over 50 km, it would save only 1.7 minutes. The lesson is to seek high speed systems for long distance spacing between stops; they will bring little gain, to short distance trips.

The third tenet relates cost differentials to the maximum speed of the system:

"*Marginal cost (of capital and operations) increases more than proportionately with increases in the maximum speed*" – the authors explain that cost increases are due to both (a) increased precision of guideway and vehicles and (b) increased energy consumption due to exponential increase in air resistance. The lesson is not to necessarily seek the cutting edge of the technology if cost effectiveness is an objective.

The authors assert therefore that "the optimal domain for high speed ground transportation systems is on long interstation lengths, such as 100 km. On short distances, the gains in travel times are so small that it is difficult to justify the high investment" cost.

These assertions are particularly important in light of the fact that entire route segments of the Southern California Maglev plan range in length between 50 km and 170 km. A close look at the distances between stations reveals that average station spacing varies from. 20 to 50 km. These facts would suggest the look at other, fully grade separated options, such as urban rapid rail (Metro) and bus rapid transit as viable options for consideration in Southern California.

4.3 Cost Comparisons: High Speed Rail, Maglev and Urban Rapid Transit

If station spacing would not justify the high cost of high speed ground transportation in terms of travel time savings, what about cost differentials? A synthesis of the cost information is presented next:

- The capital cost estimates for the southern California system indicate that the cost per mile is approximately $110 million for HSR and $114 for Maglev on the 80-km airport connector alternative of the Palmdale line. Alternative alignments of the IOS show an approximate capital cost of $140 per mile for Maglev (SCAG 2002b), a 27% increase over the unit cost for HSR.

- Recent cost data from Europe indicate that the 2002 cost to build a metro line varied widely upwards of $115 million per mile depending partially on efficiencies and partially on whether tunneling and aerial structures are involved. (Sunday Business Post, 3/30/2003).

- Similarly, cost to build bus rapid transitways varies widely (in 2003 dollars) from $6.5 - $10 million per mile for at-grade sections and $12 - $30 million per mile for aerial sections to $60 - $100 million per mile for sections below grade (FTA, 2009).

The data clearly indicate major differences and overlaps. The relatively short distances between stations in the planned Southern California system make other fully grade separated, urban rapid transit modes viable contenders among the technological choices. If alignments chosen are feasible with relatively little tunneling, BRT would be the most economical choice in terms of capital costs per mile at $30 million or below. If much tunneling is involved, then all capital costs can easily approach or exceed $100 million per mile. In this case the rail modes would be more efficient choices. If the lower range of the costs for urban rapid rail (Metro) construction were the case then Metro could be an efficient choice. If the upper end of the costs for Metro construction were to be the case then HSR would be the more efficient choice. Maglev would have the disadvantages of: (a) higher capital costs than HSR; and (b) the inability to share existing facilities with other rail such as AMTRAK and the future intercity HSR to be implemented in the State of California.

5.0 Conclusions

5.1 Observations

High-speed rail (HSR) refers to a form of guided ground transportation that operates at speeds in excess of 125 mph (or 200 km per hour). There are two groups of choices for high speed guided ground transportation. One group includes the more traditional type of rail that travels at high speeds and includes: a) the Japanese Shinkansen (called bullet train), (b) the French Train a Grande Vitesse (TGV) and (c) the German Inter City Express (ICE). The other group is the magnetic levitation system of which there are Japanese and German versions.

Several lessons are noteworthy for planning high speed rail systems. The maximum operating speed should be used not the maximum experimental speed as there are significant differences between the two. Agencies do not need to target systems with the highest maximum speed as there are decreasing marginal gains in travel time savings and marginal costs increase more than proportionally at very high speeds. High speed systems are best deployed for long distance spacing between stops; they bring little gain, to short distance trips.

The literature suggest therefore that high-speed rail can play a key role in providing transportation for trips between 62 and 621 miles (100 km to 1000 km) This assertion is particularly important in light of the fact that entire route segments of the Southern California Maglev plan range in length between 50 km and 170 km. A close look at the distances between stations reveals that average station spacing varies from. 20 to 50 km. These facts would suggest the look at other, fully grade separated options, such as urban rapid rail (Metro) and bus rapid transit as viable options for consideration for Southern California.

There are differences of opinion between proponents of Maglev and high speed rail. There are major differences and some overlaps in actual construction costs and cost estimates associated with the various technological options for intercity and intra-city public transportation. These call for careful study rather than emotional appeal when considering these systems for deployment.

5.2 Recommendation

A more thorough study needs to be conducted toward the choice of technology for the Decentralized Airport Connector and Commuter system for Southern California. The detailed study needs to assess the appropriateness of the technology to choose in terms of speed of travel vis-à-vis associated capital and operating costs.

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APPENDICES

Appendix 1-1: Initial Operating System (IOS)

Source:

SCAG, *Maglev Deployment Program: Summary of Preliminary Engineering for IOS*, Prepared by Lockheed Martin Integrated Systems and Solutions and IBI Group, August 2006; accessed online at: http://www.scag.ca.gov/Maglev/pdf/1_Maglev_PE_Summary_of_IOS.pdf

Proposed Alignments

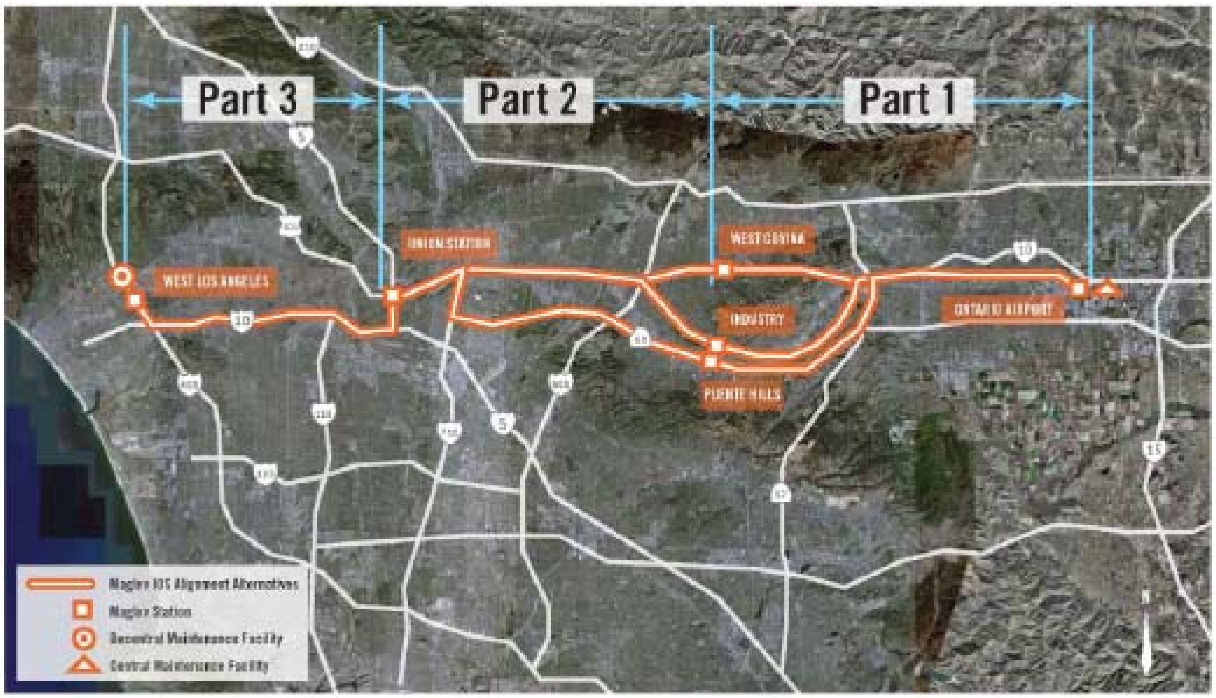


Table 1: I-10 Alignment

Item	Quantity	Unit	Unit Cost	Cost	Subtotal	Estimated Design/Constr. Contingencies	Estimated Program Implementation	Environmental Impact Mitigation	Contingencies, Management, & Mitigation Costs	Estimated Item/System Total Cost
Conversion from feet to meters	0.3048									
Conversion from miles to kilometers	1.6093									
Conversion from cubic yards (cu-yd) to cubic meters (cu-m)	0.7646									
Conversion from square feet (sq-ft) to square meters (sq-m)	0.0929									
Length of Alignment (miles)	54.44									
						10.0%	30.0%	3.0%	43.0%	
Guideway					$ 1,085,492,300	$ 108,549,230	$ 325,647,690	$ 32,564,769	$ 466,761,689	$ 1,552,254,000
Type 1 Guideway	534,100	LF	$ 1,943	$ 1,037,756,300						
Type 3 Guideway	40,800	LF	$ 1,170	$ 47,736,000						
						25.0%	30.0%	3.0%	58.0%	
Structures/Foundations/Tunnels					$ 1,364,124,200	$ 341,031,050	$ 409,237,260	$ 40,923,726	$ 791,192,036	$ 2,155,316,200
Substructure for Guideway Type 1 and 3	287,450	LF	$ 4,516	$ 1,298,124,200						
Elevated Walkways	20,000	LF	$ 800	$ 16,000,000						
Sound Walls	10,000	LF	$ 1,000	$ 10,000,000						
Tunnel substructure	-	LF	$ 15,000	$ -						
Retaining Walls	1	LS	$ 10,000,000	$ 10,000,000						
Ground Densification	1	each	$ 30,000,000	$ 30,000,000						
						25.0%	30.0%	3.0%	58.0%	
Stations/Maintenance Total Cost					$ 803,917,376	$ 200,979,344	$ 241,175,213	$ 24,117,521	$ 466,272,078	$ 1,270,189,500
Stations					$ 594,383,376					
Ontario Airport Station (Center Side Platform Mezzanine)	1	LS	$ 80,377,000	$ 80,377,000						
Ontario Airport Station Parking Structure	5927	Spaces	$ 19,173	$ 113,638,371						
West Covina Station (Center Platform)	1	LS	$ 44,184,000	$ 44,184,000						
West Covina Station Parking Structure	6388	Spaces	$ 19,173	$ 122,093,664						
Union Station (Center Side Platform Mezzanine)	1	LS	$ 80,377,000	$ 80,377,000						
Union Station Parking Structure	3500	Spaces	$ 19,173	$ 67,105,500						
West LA (Center Platform)	1	LS	$ 42,184,000	$ 42,184,000						
West LA Parking Structure	2317	Spaces	$ 19,173	$ 44,423,841						
Maintenance & Operations Facilities					$ 209,534,000					
Central Maintenance Facility & OCC (Building and Non-Maglev Equipment)	1	LS	$ 91,452,000	$ 91,452,000						
Decentral Maintenance Facility (Building and Non-Maglev Equipment)	1	LS	$ 27,332,000	$ 27,332,000						
Maglev Vehicle Equipment	1	LS	$ 70,000,000	$ 70,000,000						
Maglev Maintenance and Inspection Vehicles	1	LS	$ 10,000,000	$ 10,000,000						
Maglev Train Wash Facility	1	LS	$ 7,000,000	$ 7,000,000						
Parking Facility	250	LS	$ 15,000	$ 3,750,000						
						25.0%	30.0%	3.0%	58.0%	
Communications/Signal/Power					$ 849,264,000	$ 212,316,000	$ 254,779,200	$ 25,477,920	$ 492,573,120	$ 1,341,837,100
Power Substations/Distribution	54.44	Mile	$ 10,400,000	$ 566,176,000						
Operations/Control/Communications	54.44	Mile	$ 5,200,000	$ 283,088,000						
						10.0%	5.0%	0.0%	15.0%	
Vehicles Total Cost					$ 800,800,000	$ 80,080,000	$ 40,040,000	$ -	$ 120,120,000	$ 920,920,000
(8) Car Consists	10	each	$ 80,080,000	$ 800,800,000						
						0.0%	0.0%	0.0%	0.0%	
Right of Way					$ 324,049,875	$ -	$ -	$ -	$ -	$ 324,049,900
Right of Way	1	LS	$ 324,049,875	$ 324,049,875						
						25.0%	30.0%	3.0%	58.0%	
Roadway Improvements/Utility Relocation/Traffic Control					$ 156,240,400	$ 39,060,100	$ 46,872,120	$ 4,687,212	$ 90,619,432	$ 246,859,800
Roadway Improvements										
Roadway Improvements w/Drainage	1	LS	$ 45,000,000	$ 45,000,000						
Utility Relocation	1	LS	$ 50,000,000	$ 50,000,000						
Traffic Control During Construction (2.5% of structure+guideway)	1	LS	$ 61,240,400	$ 61,240,400						
					System Subtotal	Estimated Design/Constr. Contingencies	Estimated Program Implementation	Environmental Impact Mitigation	Contingencies, Management, & Mitigation Costs	Estimated Item/System Total Cost
Subtotal					$ 5,383,888,151	$ 982,015,724	$ 1,317,751,483	$ 127,771,148	$ 2,427,538,355	$ 7,811,426,500
Cost per Mile (Double Track System)					$ 98,895,815	$ 18,038,496	$ 24,205,575	$ 2,347,009	$ 44,591,079	$ 143,488,894

Table 2: SR-60 Alignment

Item	Quantity	Unit	Unit Cost	Cost	Subtotal	Estimated Design/Constr. Contingencies	Estimated Program Implementation	Environmental Impact Mitigation	Contingencies, Management, & Mitigation Costs	Estimated Item/System Total Cost
Conversion from feet to meters	0.3048									
Conversion from miles to kilometers	1.6093									
Conversion from cubic yards (cu-yd) to cubic meters (cu-m)	0.7646									
Conversion from square feet (sq-ft) to square meters (sq-m)	0.0929									
Length of Alignment (miles)	58.37									
						10.0%	30.0%	3.0%	43.0%	
Guideway ====================================>					$ 1,166,126,800	$ 116,612,680	$ 349,838,040	$ 34,983,804	$ 501,434,524	$ 1,667,561,300
Type 1 Guideway	575,600	LF	$ 1,943	$ 1,118,390,800						
Type 3 Guideway	40,800	LF	$ 1,170	$ 47,736,000						
						25.0%	30.0%	3.0%	58.0%	
Structures/Foundations/Tunnels ====================================>					$ 1,545,797,684	$ 386,449,421	$ 463,739,305	$ 46,373,931	$ 896,562,657	$ 2,442,360,300
Substructure for Guideway Type 1 and 3	288,970	LF	$ 4,813	$ 1,390,679,684						
Elevated Walkways	20,760	LF	$ 800	$ 16,608,000						
Sound Walls	10,310	LF	$ 1,000	$ 10,310,000						
Tunnel substructure	5,880	LF	$ 15,000	$ 88,200,000						
Retaining Walls	1	LS	$ 10,000,000	$ 10,000,000						
Ground Densification	1	each	$ 30,000,000	$ 30,000,000						
						25.0%	30.0%	3.0%	58.0%	
Stations/Maintenance Total Cost ====================================>					$ 791,187,744	$ 197,796,936	$ 237,356,323	$ 23,735,632	$ 458,888,892	$ 1,250,076,600
Stations					$ 581,653,744					
Ontario Airport Station (Center Side Platform Mezzanine)	1	LS	$ 80,377,000	$ 80,377,000						
Ontario Airport Station Parking Structure	5927	Spaces	$ 19,173	$ 113,638,371						
Puente Hills Station (Center Platform)	1	LS	$ 44,184,000	$ 44,184,000						
Puente Hills Station Parking Structure	6368	Spaces	$ 17,174	$ 109,364,032						
Union Station (Center Side Platform Mezzanine)	1	LS	$ 80,377,000	$ 80,377,000						
Union Station Parking Structure	3500	Spaces	$ 19,173	$ 67,105,500						
West LA (Center Platform)	1	LS	$ 42,184,000	$ 42,184,000						
West LA Parking Structure	2317	Spaces	$ 19,173	$ 44,423,841						
Maintenance & Operations Facilities					$ 209,534,000					
Central Maintenance Facility & OCC (Building and Non-Maglev Equipment)	1	LS	$ 91,452,000	$ 91,452,000						
Decentral Maintenance Facility (Building and Non-Maglev Equipment)	1	LS	$ 27,332,000	$ 27,332,000						
Maglev Vehicle Equipment	1	LS	$ 70,000,000	$ 70,000,000						
Maglev Maintenance and Inspection Vehicles	1	LS	$ 10,000,000	$ 10,000,000						
Maglev Train Wash Facility	1	LS	$ 7,000,000	$ 7,000,000						
Parking Facility	250	LS	$ 15,000	$ 3,750,000						
						25.0%	30.0%	3.0%	58.0%	
Communications/Signal/Power ====================================>					$ 910,572,000	$ 227,643,000	$ 273,171,600	$ 27,317,160	$ 528,131,760	$ 1,438,703,800
Power Substations/Distribution	58.37	Mile	$ 10,400,000	$ 607,048,000						
Operations/Control/Communications	58.37	Mile	$ 5,200,000	$ 303,524,000						
						10.0%	5.0%	0.0%	15.0%	
Vehicles Total Cost ====================================>					$ 800,800,000	$ 80,080,000	$ 40,040,000	$ -	$ 120,120,000	$ 920,920,000
(8) Car Consists	10	each	$ 80,080,000	$ 800,800,000						
						0.0%	0.0%	0.0%	0.0%	
Right of Way ====================================>					$ 339,076,125	$ -	$ -	$ -	$ -	$ 339,076,100
Right of Way	1	LS	$ 339,076,125	$ 339,076,125						
						25.0%	30.0%	3.0%	58.0%	
Roadway Improvements/Utility Relocation/Traffic Control====================================>					$ 162,798,100	$ 40,699,525	$ 48,839,430	$ 4,883,943	$ 94,422,898	$ 257,221,000
Roadway Improvements										
Roadway Improvements w/Drainage	1	LS	$ 45,000,000	$ 45,000,000						
Utility Relocation	1	LS	$ 50,000,000	$ 50,000,000						
Traffic Control During Construction (2.5% of structure+guideway)	1	LS	$ 67,798,100	$ 67,798,100						
					System Subtotal	Estimated Design/Constr. Contingencies	Estimated Program Implementation	Environmental Impact Mitigation	Contingencies, Management, & Mitigation Costs	Estimated Item/System Total Cost
Subtotal ====================================>					$ 5,716,358,453	$ 1,049,281,562	$ 1,412,984,698	$ 137,294,470	$ 2,599,560,730	$ 8,315,919,100
Cost per Mile (Double Track System) ====================================>					$ 97,933,158	$ 17,976,364	$ 24,207,379	$ 2,352,141	$ 44,535,904	$ 142,469,061

Table 3: UPRR Alignment

Item	Quantity	Unit	Unit Cost	Cost	Subtotal	Estimated Design/Constr. Contingencies	Estimated Program Implementation	Environmental Impact Mitigation	Contingencies, Management, & Mitigation Costs	Estimated Item/System Total Cost
Conversion from feet to meters	0.3048									
Conversion from miles to kilometers	1.6093									
Conversion from cubic yards (cu-yd) to cubic meters (cu-m)	0.7646									
Conversion from square feet (sq-ft) to square meters (sq-m)	0.0929									
Length of Alignment (miles)	56.33									
						10.0%	30.0%	3.0%	43.0%	
Guideway ==========>					$ 1,133,878,580	$ 113,387,858	$ 340,163,574	$ 34,016,357	$ 487,567,789	$ 1,621,446,400
Type 1 Guideway	566,560	LF	$ 1,943	$ 1,100,826,080						
Type 3 Guideway	28,250	LF	$ 1,170	$ 33,052,500						
						25.0%	30.0%	3.0%	58.0%	
Structures/Foundations/Tunnels ==========>					$ 1,454,987,650	$ 363,746,913	$ 436,496,295	$ 43,649,630	$ 843,892,837	$ 2,298,880,500
Substructure for Guideway Type 1 and 3	297,410	LF	$ 4,665	$ 1,387,417,650						
Elevated Walkways	20,900	LF	$ 800	$ 16,720,000						
Sound Walls	10,400	LF	$ 1,000	$ 10,400,000						
Tunnel substructure	-	LF	$ 15,000	$ -						
Retaining Walls	1	LS	$ 10,450,000	$ 10,450,000						
Ground Densification	1	each	$ 30,000,000	$ 30,000,000						
						25.0%	30.0%	3.0%	58.0%	
Stations/Maintenance Total Cost ==========>					$ 801,917,376	$ 200,479,344	$ 240,575,213	$ 24,057,521	$ 465,112,078	$ 1,267,029,500
Stations					$ 592,383,376					
Ontario Airport Station (Center Side Platform Mezzanine)	1	LS	$ 80,377,000	$ 80,377,000						
Ontario Airport Station Parking Structure	5927	Spaces	$ 19,173	$ 113,638,371						
Industry Station (Center Platform)	1	LS	$ 42,184,000	$ 42,184,000						
Industry Station Parking Structure	6358	Spaces	$ 19,173	$ 122,083,684						
Union Station (Center Side Platform Mezzanine)	1	LS	$ 80,377,000	$ 80,377,000						
Union Station Parking Structure	3500	Spaces	$ 19,173	$ 67,105,500						
West LA (Center Platform)	1	LS	$ 42,184,000	$ 42,184,000						
West LA Parking Structure	2317	Spaces	$ 19,173	$ 44,423,841						
Maintenance & Operations Facilities					$ 209,534,000					
Central Maintenance Facility & OCC (Building and Non-Maglev Equipment)	1	LS	$ 91,452,000	$ 91,452,000						
Decentral Maintenance Facility (Building and Non-Maglev Equipment)	1	LS	$ 27,332,000	$ 27,332,000						
Maglev Vehicle Equipment	1	LS	$ 70,000,000	$ 70,000,000						
Maglev Maintenance and Inspection Vehicles	1	LS	$ 10,000,000	$ 10,000,000						
Maglev Train Wash Facility	1	LS	$ 7,000,000	$ 7,000,000						
Parking Facility	250	LS	$ 15,000	$ 3,750,000						
						25.0%	30.0%	3.0%	58.0%	
Communications/Signal/Power ==========>					$ 878,696,591	$ 219,674,148	$ 263,608,977	$ 26,360,898	$ 509,644,023	$ 1,388,340,600
Power Substations/Distribution	56.33	Mile	$ 10,400,000	$ 585,797,727						
Operations/Control/Communications	56.33	Mile	$ 5,200,000	$ 292,898,864						
						10.0%	5.0%	0.0%	15.0%	
Vehicles Total Cost ==========>					$ 800,800,000	$ 80,080,000	$ 40,040,000	$ -	$ 120,120,000	$ 920,920,000
(8) Car Consists	10	each	$ 80,080,000	$ 800,800,000						
						0.0%	0.0%	0.0%	0.0%	
Right of Way ==========>					$ 314,461,250	$ -	$ -	$ -	$ -	$ 314,461,300
Right of Way	1	LS	$ 314,461,250	$ 314,461,250						
						25.0%	30.0%	3.0%	58.0%	
Roadway Improvements/Utility Relocation/Traffic Control==========>					$ 161,721,700	$ 40,430,425	$ 48,516,510	$ 4,851,651	$ 93,798,586	$ 255,520,300
Roadway Improvements										
Roadway Improvements w/Drainage	1	LS	$ 47,000,000	$ 47,000,000						
Utility Relocation	1	LS	$ 50,000,000	$ 50,000,000						
Traffic Control During Construction (2.5% of structure+guideway)	1	LS	$ 64,721,700	$ 64,721,700						
					System Subtotal	Estimated Design/Constr. Contingencies	Estimated Program Implementation	Environmental Impact Mitigation	Contingencies, Management, & Mitigation Costs	Estimated Item/System Total Cost
Subtotal ==========>					$ 5,546,463,147	$ 1,017,798,687	$ 1,369,400,569	$ 132,936,057	$ 2,520,135,313	$ 8,066,598,600
Cost per Mile (Double Track System) ==========>					$ 98,469,513	$ 18,069,559	$ 24,311,747	$ 2,360,089	$ 44,741,395	$ 143,210,910

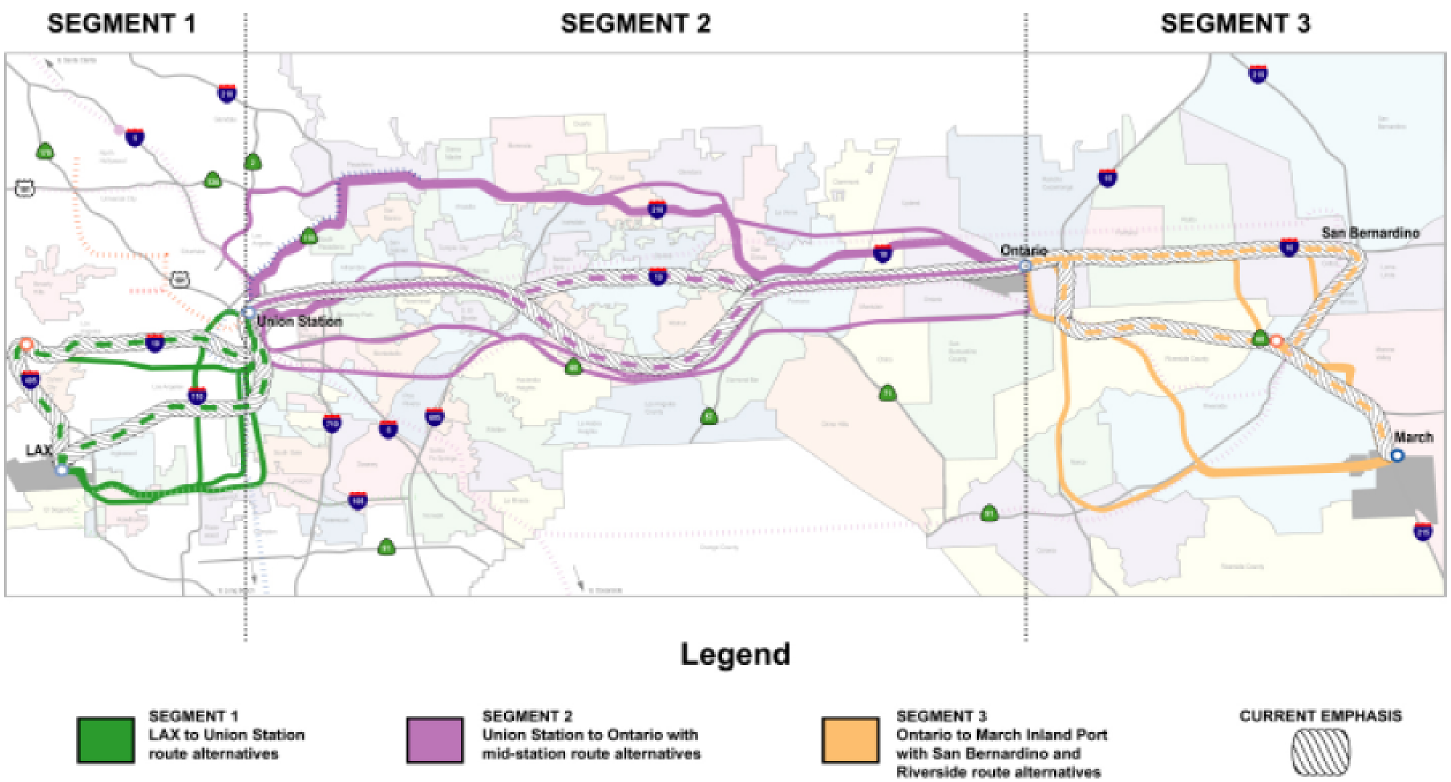
Appendix 1-2: LAX to March

Source

Federal Railroad Administration (FRA 2000, July), California MAGLEV Project, Prepared under a cooperative agreement among the California Business, Transportation & Housing Agency, California High Speed Rail Authority and Southern California Association of Governments; accessed online at: http://www.scag.ca.gov/Maglev/pdf/lax_marchgp.pdf

Figure ES-1

California MAGLEV
Route Variations



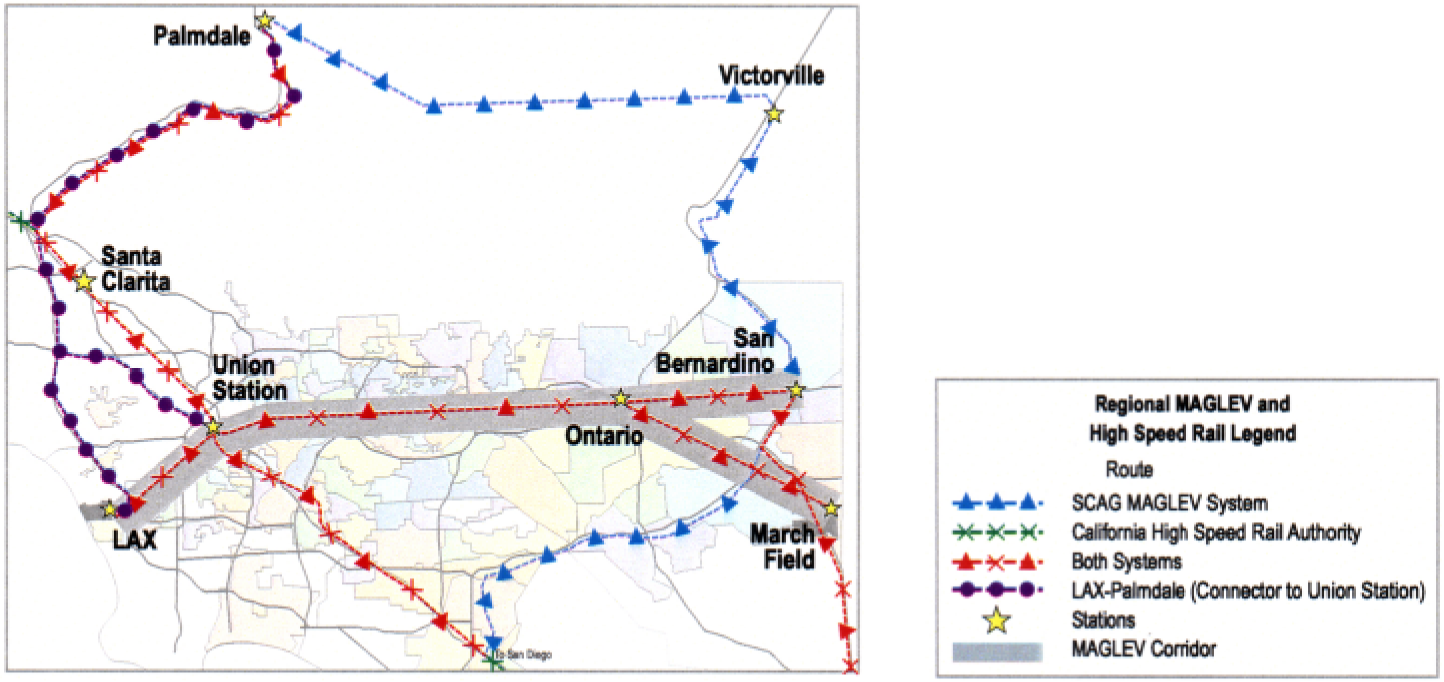
Financial Plan Characteristics

Daily Ridership in Year 2020	Annual Revenue	Ratio (=40x Rev/Capital)	Capital Cost	Annual O &M Costs	Funding Gap	Annual Passenger Miles
75,630	$394 M	3.3	$4.8 B	$81 M	$3,250,000	741 M

The following chart identifies the financial instruments to be used for the project.

Financial Instrument	In Dollars ($)
Par Amt. Of Bonds	$2,840,610,00
TIFIA Loan	1,016,750,000
FRA Grants	950,000,000
Other	3,250,000
Interest Earnings	1,655,565,943
Project Cost	4,800,000,000
Debt Service Reserve Fund	223,760,614
Capitalized Interest	1,331,535,938

Regional High-Speed MAGLEV System



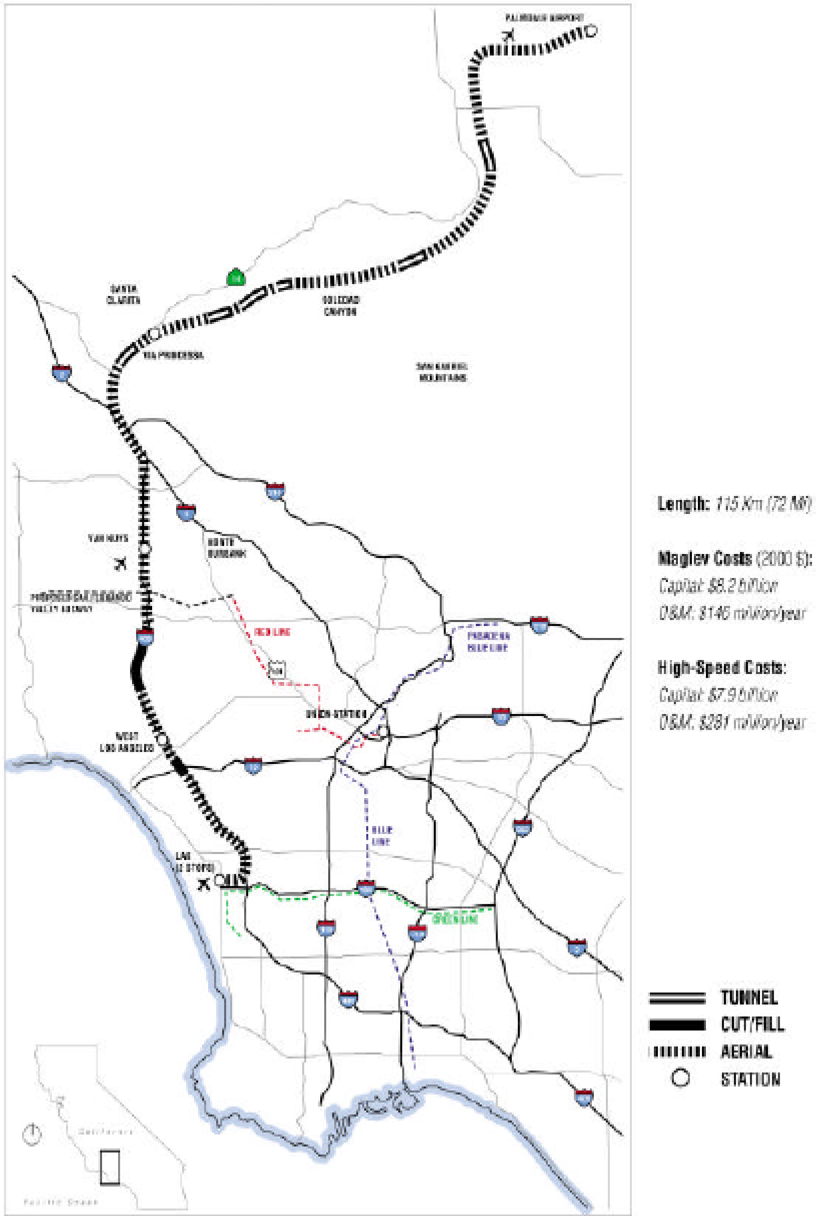
Appendix 1-3: LAX to Palmdale

Source

SCAG, *LAX-Palmdale High Speed Ground Access Study*, Prepared by IBI Group, January 2002; accessed online at:

http://www.scag.ca.gov/Maglev/pdf/lax_palmdale.pdf

AIRPORT CONNECTOR ALTERNATIVE



TRANSIT HUBS ALTERNATIVE

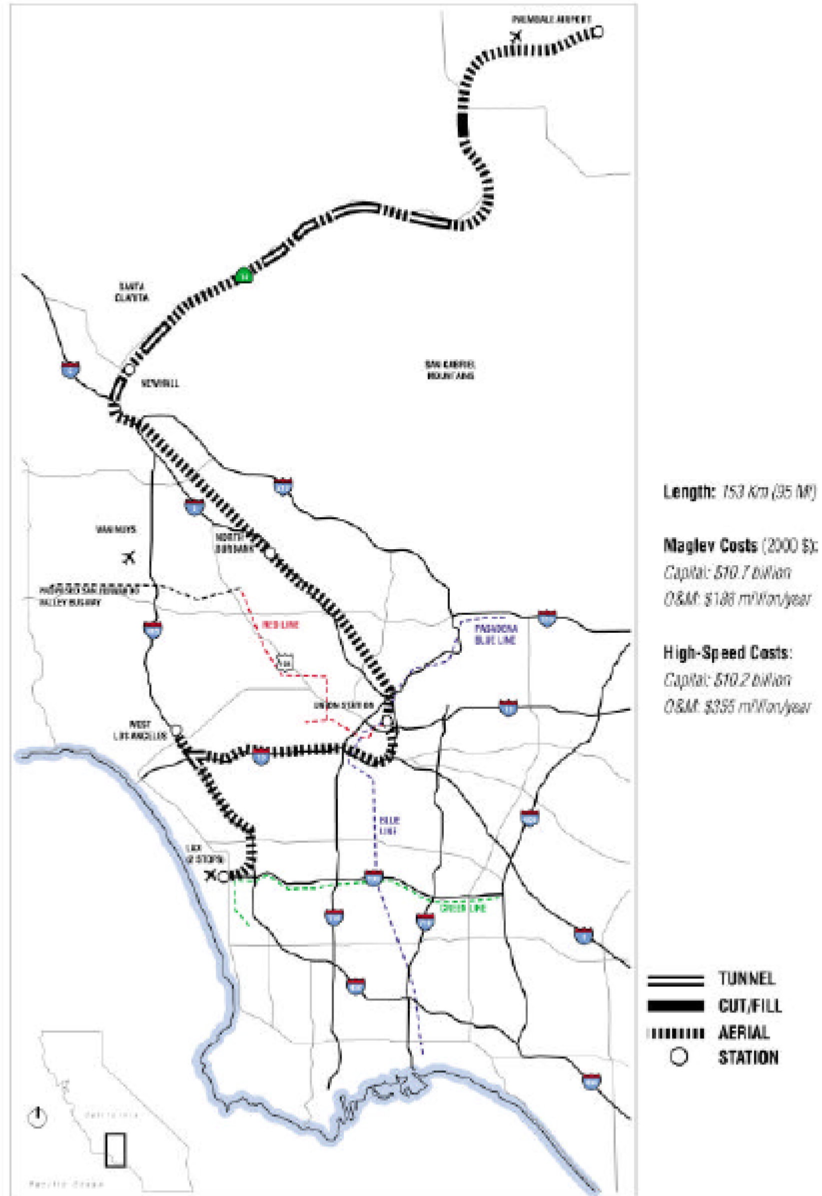
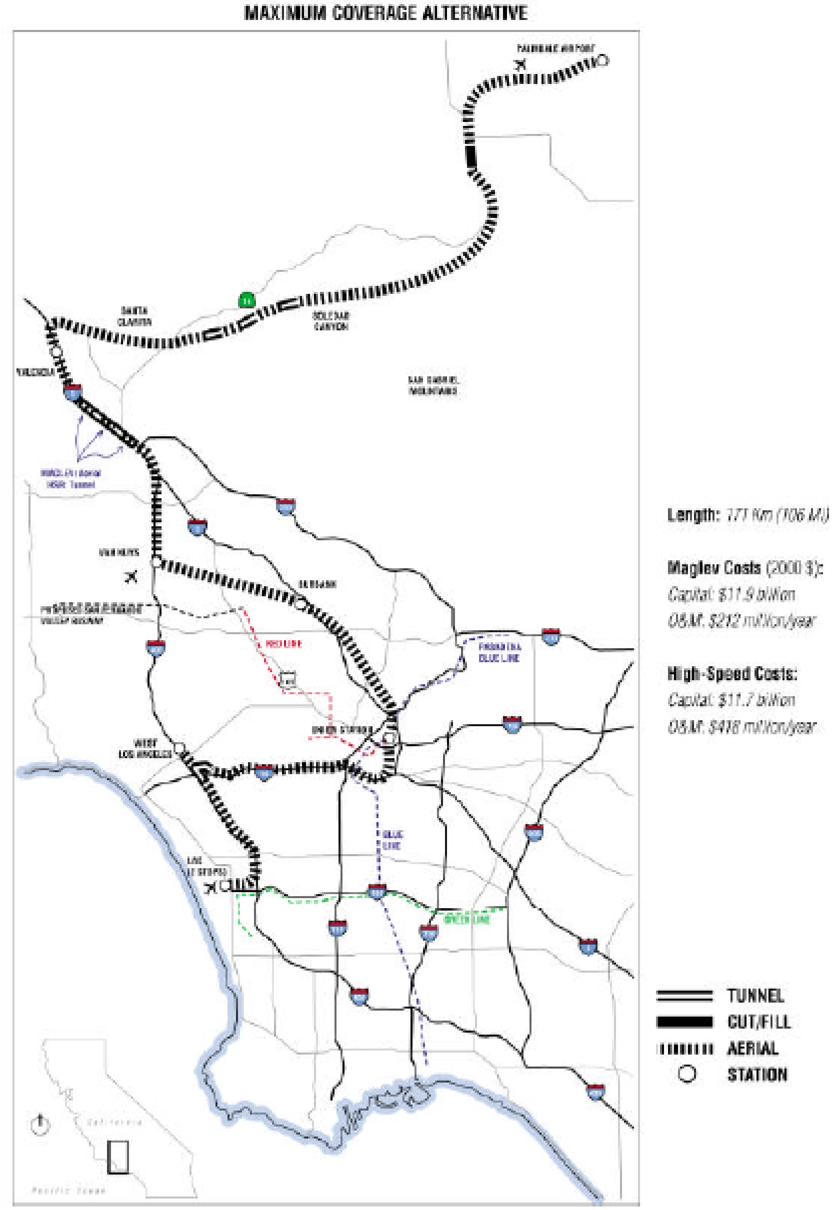


Table 1
LAX-PMD Capital Cost Estimates

Technology	Airport Connector	Transit Hubs	Maximum Coverage
VHSM Standalone	$8.2 Billion	$10.7 Billion	$11.9 Billion
HSR/VHSR (for comparison)	$ 7.9 Billion	$10.2 Billion	$11.7 Billion

Table 2
LAX-PMD Annual Operations & Maintenance Cost Estimates

Technology	Airport Connector	Transit Hubs	Maximum Coverage
VHSM Standalone	$ 184 Million	$ 236 Million	$ 267 Million
HSR/VHSR (for comparison)	$ 281 Million	$ 355 Million	$ 418 Million



Appendix 1-4: Orange Line

Source

SCAG, *Orange Line Feasibility Study*, Prepared by IBI Group, April 2002; accessed online at: http://www.scag.ca.gov/Maglev/pdf/orangeline.pdf

Feasibility of the OrangeLine to Support Corridor Development

In assessing the feasibility of the OrangeLine, a key question is whether or not the system can generate sufficient revenues to cover capital and operating costs. The ability of the OrangeLine to be self-financing alleviates the need to seek public funds from local, state and federal sources. If the project is required to rely on conventional public transportation funding sources, it is unlikely that the OrangeLine could be built within the next 20 years or more. Demand on traditional federal and state transportation funding sources already exceeds the ability of current government funding programs. The OrangeLine can compete against other transportation projects, however transportation agencies have not considered the OrangeLine corridor as a high priority project for public support.

OrangeLine ridership studies and empirical data from existing transit projects in the region (such as the Blue and Green line light rail projects and the Red Line subway) indicate that the OrangeLine would attract a base ridership of over 46,000 riders per day. This does not take into consideration the additional ridership that could be generated by more compact urban development around the station areas.

The estimate of 46,000 daily riders assumes current development trends with a supporting transit feeder network. This ridership will be higher if the cities along the corridor are successful in fostering development around the OrangeLine stations. Preliminary estimates suggest this ridership potential at 5,700 to 7,000 daily riders depending on the alignment and stations.

Under either the conservative ridership scenario or a higher ridership estimate, the OrangeLine would generate sufficient annual operating revenues to cover construction and on-going operating costs. The OrangeLine is projected to cost about $3.6 billion dollars to build[1]. While further analysis may indicate a lower construction cost, the current preliminary estimate is adequate for the purposes of this feasibility study.

Construction costs would be financed through tax-exempt municipal bonds. The low operating cost of maglev technology and the high quality of service the system provides are key to the financing plan and the ability of the OrangeLine to cover capital and operating costs from passenger revenues.

The financial plan assumes that the right-of-way along the former Pacific Electric corridor, currently under ownership of the LACMTA and OCTA, would be made available to the Gateway Cities Council of Governments at no charge. This is believed to be a reasonable assumption, as the right-of-way would be used for the transportation purpose for which it was purchased. Currently, these agencies are studying the corridor and every effort will be made to coordinate the OrangeLine findings with these ongoing studies.

Appendix 2: Characteristics of California High Speed Rail Proposal: Bay Area to Central Valley

Source: CHSRA and FTA, 2008

Table S.8-1. Summary of Characteristics and Impacts for the Network Alternatives

	Altamont Pass											Pacheco Pass						Pacheco Pass with Altamont Pass (local service)			
Characteristic/Impacts	San Francisco & San Jose Termini	Oakland & San Jose Termini	San Francisco, Oakland & San Jose Termini	San Jose Terminus	San Francisco Terminus	Oakland Terminus	Union City Terminus	San Francisco & San Jose — via SF Peninsula	San Francisco, San Jose, Oakland — no Bay Crossing	Oakland & San Francisco — via Transbay Tube	San Jose, Oakland, & San Francisco via Transbay Tube	San Francisco & San Jose Termini	Oakland & San Jose Termini	San Francisco, Oakland, & San Jose Termini	San Jose Terminus	San Jose, San Francisco & Oakland- via Transbay Tube	San Jose, Oakland & San Francisco- via Transbay Tube	San Francisco & San Jose Termini	Oakland & San Jose Termini	SF, Oak, & SJ Termini (without Dumbarton Bridge)	San Jose Terminus
Figure # (see Chapter 7 of the Program EIR/EIS)	*7.2-1*	*7.2-2*	*7.2-3*	*7.2-4*	*7.2-5*	*7.2-6*	*7.2-7*	*7.2-8*	*7.2-9*	*7.2-10*	*7.2-11*	*7.2-12*	*7.2-13*	*7.2-14*	*7.2-15*	*7.2-16*	*7.2-17*	*7.2-18*	*7.2-19*	*7.2-20*	*7.2-21*
Length (miles)	203.34	182.16	241.16	160.18	191.56	170.86	157.93	213.30	244.70	179.64	199.11	267.53	256.87	309.60	213.15	276.31	265.66	339.16	318.45	360.90	286.04
Number of stations	9	8	11	6	8	7	5	9	11	8	9	7	7	10	4	8	8	10	9	12	7
Capital costs (billions $)	$12.7	$10.0	$15.1	$7.7	$11.0	$8.2	$6.0	$12.6	$14.5	$12.9	$14.8	$12.4	$11.6	$16.0	$8.0	$17.0	$16.3	$18.3	$16.0	$20.4	$13.5
Capital costs/mile of alignment (millions)	$62.5	$54.9	$62.6	$48.1	$57.4	$48.0	$38.0	$59.1	$59.3	$71.8	$74.3	$46.3	$45.2	$51.7	$37.5	$61.5	$61.4	$54.0	$50.2	$56.5	$47.2
Ridership (millions annual)	87.91	88.01	81.13	94.65	93.88	94.39	83.49	90.75	85.22	95.94	89.62	93.33	91.37	85.52	79.69	95.2	92.07	96.15	92.88	87.81	89.79
Revenue (millions annual)	$2,844	$2,881	$2,625	$3,176	$3,127	$3,153	$2,701	$2,743	$2,733	$3,164	$2,884	$3,090	$3,071	$2,782	$2,666	$3,152	$3,038	$2,992	$3,065	$2,897	$2,963
Annual operating costs (millions)	$1,099	$1,085	$1,098	$1,076	$1,124	$1,093	$1,073	$1,115	$1,123	$1,106	$1,093	$1,182	$1,166	$1,174	$1,099	$1,196	$1,179	$1,171	$1,140	$1,179	$1,130
Bridge over bay=B Transbay tube=T	B	—	B	—	B	—	—	B	—	T	T	—	—	—	—	T	T	B	—	—	—
SF, Oakland, San Jose - # served	2	2	3	1	1	1	0	2	3	1	3	2	2	3	1	3	3	2	2	3	1
International airports	SFO/SJC	OAK/SJC	SFO/OAK/SJC	SJC	SFO	OAK	—	SFO/SJC	SFO/OAK/SJC	OAK	SFO/OAK/SJC	SFO/SJC	OAK/SJC	SFO/OAK/SJC	SJC	SFO/OAK/SJC	SFO/OAK/SJC	SFO/SJC	OAK/SJC	SFO/OAK/SJC	SJC
Express Train Travel Times (Hours:Min)																					
San Francisco - Los Angeles	2:36	—	2:36	—	2:36	—	—	2:36	3:17	2:31	2:31	2:38	—	2:38	—	2:38	2:38	2:38	—	2:38	—
Oakland - Los Angeles	—	2:23	2:23	—	—	2:23	—	—	2:23	2:23	2:23	—	2:30	2:30	—	2:46	2:30	—	2:30	2:30	—
San Jose - Los Angeles	2:19	2:19	2:19	2:19	—	—	—	2:37	2:19	—	2:19	2:09	2:09	2:09	2:09	2:09	2:09	2:09	2:09	2:09	2:09
San Francisco - Sacramento	1:06	—	1:06	—	1:06	—	—	1:06	1:39	0:57	0:57	1:47	—	1:47	—	1:47	1:44	1:15	—	1:48	—
Oakland - Sacramento	—	0:53	0:53	—	—	0:53	—	—	0:53	0:53	0:53	—	1:38	1:38	—	1:54	1:38	—	1:00	1:00	—
San Jose - Sacramento	0:49	0:49	0:49	0:49	—	—	—	1:03	0:49	—	0:49	1:18	1:18	1:18	1:18	1:18	1:18	0:56	0:56	0:56	0:56
Union City - Los Angeles	—	—	—	—	—	—	2:13	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Characteristic/Impacts	Altamont Pass											Pacheco Pass						Pacheco Pass with Altamont Pass (local service)			
	San Francisco & San Jose Termini	Oakland & San Jose Termini	San Francisco, Oakland & San Jose Termini	San Jose Terminus	San Francisco Terminus	Oakland Terminus	Union City Terminus	San Francisco & San Jose —via SF Peninsula	San Francisco, San Jose, Oakland – no Bay Crossing	Oakland & San Francisco – via Transbay Tube	San Jose, Oakland, & San Francisco via Transbay Tube	San Francisco & San Jose Termini	Oakland & San Jose Termini	San Francisco, Oakland, & San Jose Termini	San Jose Terminus	San Jose, San Francisco & Oakland-via Transbay Tube	San Jose, Oakland & San Francisco-via Transbay Tube	San Francisco & San Jose Termini	Oakland & San Jose Termini	SF, Oak, & SJ Termini (without Dumbarton Bridge)	San Jose Terminus
Union City - Sacramento	—	—	—	—	—	—	0.43	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Farmland (acres)	764.2	761.9	764.2	761.9	757.8	755.5	755.5	757.8	761.9	755.5	761.9	1,372.3	1,378.7	1,378.7	1,372.3	1,372.3	1,378.7	1,380.0	1,384.1	1,384.1	1,384.1
Prime farmland (acres)	429.1	426.8	429.1	426.8	422.7	420.3	420.3	422.7	426.8	420.3	426.8	663.3	669.7	669.7	663.3	663.3	669.7	760.4	764.5	764.5	764.5
Floodplains (acres) direct impacts (direct/indirect)	308.3/ 969	218.6/ 720	315.3/ 984	211.6/ 706	270.7/ 817	181.1/ 568	177.6/ 561	317.7/ 891	314.5/ 896	181.1/ 568	218.6/ 720	520.8/ 1,633	477.5/ 1,639	573.4/ 1,814	424.9/ 1,458	520.8/ 1,633	477.5/ 1,685	547.1/ 3,411	456.4/ 1,633	552.2/ 1,685	432.2/ 1,479
Floodplains/linear mile of alignment	1.52	1.20	1.31	1.32	1.41	1.06	1.12	1.49	1.29	1.01	1.10	1.95	1.86	1.85	1.99	1.88	1.80	1.61	1.43	1.53	1.51
Streams (linear feet) (direct/indirect)	16,824/ 71,320	17,660/ 76,905	19,814/ 82,951	14,670/ 65,274	15,995/ 67,867	16,831/ 72,451	14,432/ 65,198	17,481/ 70,714	20,273/ 82,171	16,831/ 73,451	17,660/ 76,905	20,276/ 90,572	21,788/ 99,406	24,401/ 104,672	17,663/ 85,306	20,276/ 90,572	30,278/ 137,768	27,130/ 125,490	27,666/ 132,501	30,278/ 137,768	24,197/ 120,049
Waterbodies (lakes + SF bay) (acres) (direct/indirect)	39.6/ 154.9	2.3/ 7.6	39.6/ 154.9	2.3/ 7.6	39.6/ 154.9	2.3/ 7.6	2.3/ 7.6	39.6/ 154.9	2.3/ 11	38.8/ 243.1	38.8/ 243.1	3.8/ 19.7	4.5/ 17.6	4.5/ 21	3.8/ 16.3	40.3/ 255.2	41/ 253.1	41.9/ 164.9	5.3/ 18.92	5.3/ 22.3	4.6/ 17.6
Wetlands (acres) (direct/indirect)	45.9/ 2,526	12.3/ 805	46.3/ 2,594	12.0/ 737	44.4/ 2,259	10.8/ 539	10.7/ 499	44.4/ 2,264	12.4/ 957	33.6/ 1,892	35.1/ 2,158	15.6/ 1,601	17.4/ 1,825	17.5/ 1,977	15.5/ 1,449	38.4/ 2,955	40.2/ 3,179	56.1/ 3,499	25.3/ 2,180	25.4/ 2,332	23.7/ 1,972
Nonwetland waters (linear feet)	16,773	14,032	16,932	13,577	15,947	13,502	13,113	15,947	14,662	13,502	14,032	14,395	14,533	15,123	14,395	14,395	14,553	19,891	17,977	18,556	17,521
Species (special status plants)	56	40	57	39	56	39	38	56	56	40	42	58	49	63	46	59	50	70	67	71	54
Species (special status wildlife)	50	44	50	43	49	44	36	49	50	43	43	53	49	53	38	53	49	57	51	58	50
Cultural resources (number)	151	128	175	93	146	112	88	182	205	114	119	167	106	195	78	108	111	198	133	222	109
Fault Crossings (Active & Potentially Active)	11	7	13	6	9	5	4	10	9	5	7	5	6	8	3	5	6	13	10	12	9
Crosses Active Fault in Tunnel (Calaveras)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	Yes	Yes	Yes	Yes
Immediately Adjacent & Parallel to Active Fault (Hayward)	No	Yes	Yes	No	No	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	No	Yes	Yes	No
4(f)/6(f) Resources (0-150 feet)	32	29	39	22	24	21	18	30	39	22	30	18	21	31	8	19	22	35	36	46	27

Appendix 3: Comparative Capital Costs of Urban Rapid Transit Systems

Source:

National Bus Rapid Transit Institute, Rapid Transit: Elements, Performance, and Benefits, Promotional flyer of NBRTI, assessed online at: http://www.nbrti.org/docs/pdf/BRT_promo_low.pdf

Improved capital cost effectiveness

BRT systems can use less costly or existing infrastructure and reduce fleet requirements with better vehicle utilization. Overall, capital costs are less than other rapid transit modes, such as light rail (LRT) or heavy rail (HRT).

	Mode	Length (Miles)	Capital Cost (Millions of US$) per Mile (2003 dollars)
Las Vegas MAX Las Vegas Blvd., North	BRT (surface)	7.5	$2.70
Boston Silver Line Phase 1 - Washington St	BRT (surface)	2.3	$11.90
Los Angeles - Orange Line	BRT (exclusive ROW)	14.0	$23.07
Bogotá TransMilenio (Phase 1)	BRT (exclusive ROW)	25.6	$13.30
Bogotá TransMilenio (Phase 2)	BRT (exclusive ROW)	25.6	$24.80
Salt Lake North South Corridor	LRT (surface)	15.0	$26.50
Minneapolis Hiawatha Corridor	LRT (surface, 1.5 mile tunnel)	11.6	$52.80
Los Angeles (LACMTA) Red Line	HRT (underground)	16.5	$337.60
Washington (WMATA) Entire Metrorail System	HRT	112.0	$145.50

Source:

Federal Transit Administration (FTA, 2009) Characteristics of Bus Rapid Transit for Decision-Making, Prepared by The National BRT Institute, February, 2009

Exhibit 4-7: Capital Costs for Selected Recently-Implemented U.S. BRT Systems

City	Boston		Eugene	Las Vegas	Los Angeles		Sacramento	San Jose
BRT Line / System	Silver Line Washington St	Silver Line Waterfront	EmX	MAX	Orange Line	Metro Rapid (All Routes)	EBus - Stockton	Rapid 522
Year of Opening	2002	2005	2007	2004	2005	2000-today	2004	2005
Length of Route (mi)	2.4	4.5	4.0	7.5	14.5	229.5	8.0	25.0
Total Capital Cost by Route	$27.29 m	$618 m	$23.5 m	$20.16 m	$318 m		$7.95 m	$3.5 m
Running Way	$8.44 m	$572.2 m	$18 m for all design and construction	$0.04 m	$180 m			$2.7 m
Stations	$5.0 m	included in Running Way		$5.45 m	$40 m	$50,000 per station	$0.80 m	minimal, used existing stops
Vehicles	$13.85 m	$42.2 m	$6.5 m	$12.10 m	$16 m	$350,000 per bus	$3.8 m	$130,000 to wrap existing vehicles
ITS			Included in $18 m	$0.57 m	$10 m	$100,000 per mile	$1.8 m	Included in other VTA projects
Fare Collection				$2.00 m	$6 m			No extra investment needed
Other		$9.60 m			$66 m		$1.55 m	$550k for planning and project management

Exhibit 4-10: Operating Efficiencies in the Wilshire–Whittier Metro Rapid Corridor (as of 2002)

Route	Passengers per Revenue Hour		Subsidy Per Passenger Mile		Subsidy Per Passenger	
	Before Metro Rapid	After Metro Rapid	Before Metro Rapid	After Metro Rapid	Before Metro Rapid	After Metro Rapid
18 / 318*	62	63	$0.17	$0.18	$0.51	$0.46
20 / 21 / 22 / 320* / 322*	43	61	$0.21	$0.15	$1.08	$0.58
Metro Rapid 720		57.2		$0.14		$0.82
Combined	51	59.7	$0.20	$0.15	$0.79	$0.65

** Service eliminated after implementation of Metro Rapid*

Metro Rapid's implementation increased the service productivity from 51 passengers per vehicle revenue hour to 59.7 passengers per vehicle revenue hour. It also reduced corridor subsidies related to both passenger miles and total passengers. Note that the Metro Rapid service increased the combined efficiency of service operated in that combined passengers per revenue hour increased and combined subsidy per passenger and per passenger mile decreased. The benefit of Metro Rapid is that it improved performance measures for the corridor transit service as a whole (Transportation Management & Design, Inc., 2002).

West Busway, Pittsburgh

The West Busway in Pittsburgh demonstrated the following performance measures for operating cost efficiency and cost effectiveness, as illustrated in Exhibit 4-11 and Exhibit 4-12 (U.S. Department of Transportation 2003):

Exhibit 4-11: Performance Measures for Pittsburgh West Busway Operating Cost Efficiency (veh mi per veh hr)

Operating Cost Per:	
Vehicle revenue mile	$6.40
Vehicle revenue hour	$81.90
Passenger mile	$0.65
Unlinked passenger trip	$2.73

Martin Luther King Jr. East Busway, Pittsburgh

The speed of the East Busway allows more vehicle miles of service to be operated with the same number of vehicle hours, which drive major operating costs such as labor costs. This is because operating speeds are higher.

Exhibit 4-12: Performance Measures for Pittsburgh East Busway Operating Efficiency (veh mi per veh hr)

Route Type	Vehicle Miles per Vehicle Hour
New routes	15.8
Routes diverted to East Busway	19.6
Other routes in system	11.5

The comparison of vehicle miles per vehicle hour shows that routes on the East Busway are able to generate between 37 and 70 percent more vehicle miles from each vehicle hour (Pultz and Koffman 1987). An analysis performed by Port Authority Transit (now Port Authority of Allegheny County) assigned operating costs to transit trips and calculated operating cost parameters for different types of routes.

Exhibit 4-13: Operating Cost per Service Unit by Type of Route for Pittsburgh East Busway (1983 $)

Performance Measure	Ridership	New Routes	Diverted Routes	All Other Routes in System
Cost Effectiveness	Per passenger trip	$0.76	$1.95	$1.27
	Per peak passenger trip	$1.32	$3.19	$3.09
	Per passenger mile	$0.15	$0.37	$0.24
	Per peak passenger mile	$0.27	$0.60	$0.58
Cost Efficiency	Per seat mile	$0.06	$0.06	$0.07
	Per peak seat mile	$0.12	$0.09	$0.16
	Per vehicle vile	$3.61	$2.58	$3.26

The analysis shows that new routes and diverted routes on the busway operate with higher operating efficiencies with respect to capacity operated (seat mile and peak seat mile). Diverted routes have lower operating costs per vehicle mile than other non-busway routes. (The higher cost of operating vehicle miles for new routes can be attributed to the fact that those routes are operated with articulated vehicles.) Furthermore, new routes have higher cost effectiveness, with lower costs per unit of service consumed across the board, especially since demand is close to the operated capacity. Diverted routes demonstrate lower cost effectiveness since they tend to generate demand further below capacity than other routes (Barton-Aschman 1982).

Silver Line Washington Street and Waterfront Service, Boston

A comparison of the Silver Line Washington Street service with the previous local bus service in the corridor and MBTA's systemwide bus service demonstrates how BRT's greater ridership intensity can improve operating cost efficiencies even if the costs per vehicle mile are higher.

The Silver Line's costs are higher on a per vehicle mile basis, largely due to the higher cost of CNG over diesel fuel used by the previous local bus service and by the rest of the MBTA fleet. However, the Silver Line has much higher usage than the other local services. As a result, MBTA is providing less of a rider subsidy for the Silver Line service than for its local routes.

Early results for the Silver Line Waterfront service show a higher passenger subsidy rate due to the lower ridership levels than on the Washington Street service. Two of the Waterfront lines operate in corridors not previously served by transit, and the Waterfront area is still in the early stages of a major redevelopment boom. Therefore, current ridership is lower than would be expected when the new developments open.

Exhibit 4-14: Comparison of MBTA Silver Line Washington Street Operating Costs

	Cost per Vehicle Mile	Cost per Vehicle Hour	Passengers per Vehicle Hour	Cost per Passenger	Revenue per Passenger	Differential
Silver Line	$17	$109	117.4	$0.92	$0.42	($0.50)
Rt. 49	$13	$102	99.5	$1.03	$0.48	($0.55)
System	$10	$102	51.2	$1.99	$0.53	($1.46)

Source: 2004 MBTA Service Plan

Exhibit 4-15: MBTA Silver Line Waterfront Operating Costs, Early Results

Cost per Vehicle Mile	Cost per Vehicle Hour	Passengers per Vehicle Hour	Cost per Passenger	Revenue per Passenger	Differential
$11	$142	76	$1.88	$1.15	($0.73)

TRANSIT-SUPPORTIVE LAND DEVELOPMENT

Benefit of Transit-Supportive Land Development

Like other forms of rapid transit, BRT has a potential to promote transit-supportive land development, promoting greater accessibility and employment and economic opportunities by concentrating development, increasing property values, and creating more livable places. BRT corridors serve both existing land use and