Electrification of the Freight Train Network from the Ports of Los Angeles and Long Beach to the Inland Empire

The William and Barbara Leonard UTC CSUSB

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Abstract

The goal of this project was to evaluate the benefits of electrifying the freight railroads connecting the Ports of Los Angeles and Long Beach with the Inland Empire. These benefits include significant reduction in air pollution, and improvements in energy efficiency. The project also developed a scope of work for a much more detailed study, along with identifying potential funding sources for such a study.

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Introduction

Much of the freight leaving the Ports of Los Angeles and Long Beach is transported by diesel-powered trains. This rail traffic is expected to expand substantially in the coming decades as the Ports expand and as truck traffic is shifted to rail. The existing main line rail network is served by the two class 1 railroad companies: Burlington Norton Santa Fe (BNSF) and Union Pacific (UP) (see Figure 1).

The existing rail network consists of three rail lines from the Alameda Corridor East. It connects the northern end of the Alameda Corridor from Redondo Junction to the Colton Crossing in San Bernardino County. The BNSF line runs through northern Orange County, while the UP lines run through the San Gabriel Valley before intersecting with the BNSF line at Colton Crossing.

Unfortunately, diesel locomotives are a major source of air pollution, so this expansion of rail traffic could have a substantial impact on air quality in Southern California.

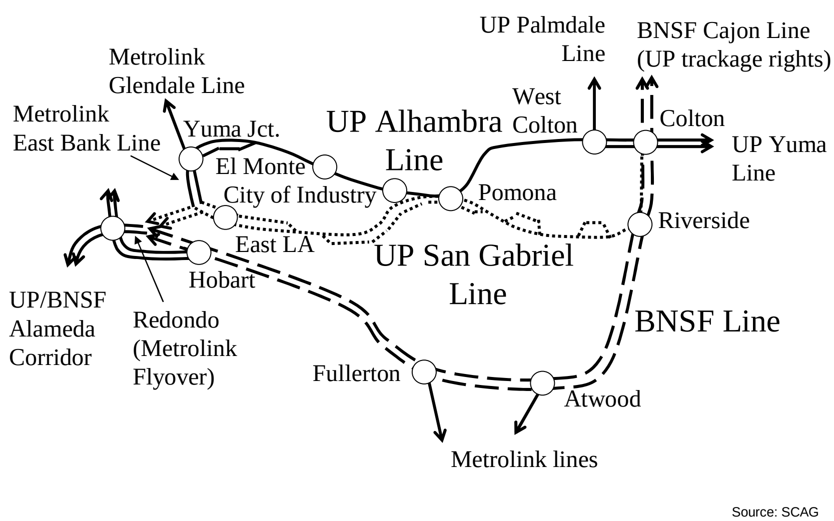

Figure 1. Existing Main Line Railroad Network

The South Coast Air Quality Management District (AQMD) notes that locomotives in Southern California emit about 33 tons per day of smog- and particulate-forming nitrogen oxides (NOx) – as much as the combined total emitted by the 350 largest factories and facilities in the region. Locomotives also are a significant source of noise, odors and toxic diesel particulate emissions [Government News, 2006]. Leachman and his colleagues have conducted an environmental evaluation study on the existing Inland

Expire railroad main line network [Leachman, 2005]. They found that Year 2000 emissions from trains that operate along the BNSF, UP and passenger routes are shown in Tables 1 and 2.

Table 1. Year 2000 Main Line Rail Network Emissions from BNSF, UP, Passenger Trains
(Emissions Expressed in tons)

Year 2000	ROG	CO	NOx	PM10	SOx
BNSF	238.06	325.76	7235.67	162.88	448.55
UP	253.72	347.20	7711.83	173.60	478.07
Passenger	6.65	48.33	476.60	11.08	31.74
Sum	**498.43**	**721.29**	**15424.10**	**347.56**	**958.36**

[Source: Leachman, 2005]

Table 2. Year 2000 Main Line Rail Network Emssions from Traffic Delay
(Emissions Expressed in tons)

Year	ROG	CO	NOx	PM10	SOx
2000	**9.65**	**100.46**	**13.85**	**0.54**	**0.09**

[Source: Leachman, 2005]

Emissions from these rail trains are one of the major mobile sources that make Southern California designated as a severe non-attainment area." These emissions create significant health hazards to the public. Figure 2 shows spatial distribution of the Multiple Air Toxics Exposure Study III (MATES III) model estimated carcinogenic risk within the Southern California due to air pollutions (SCAQMD, 2007).

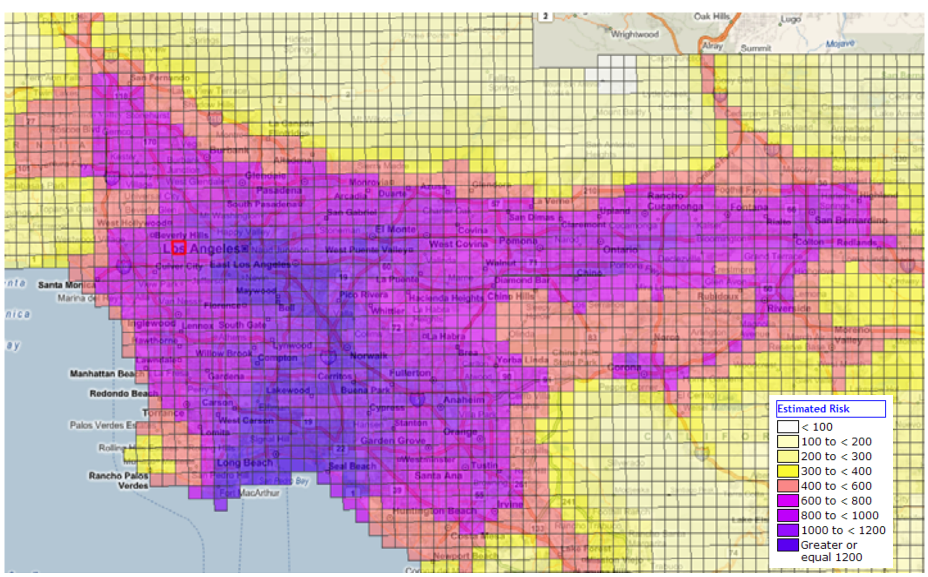

Figure 2. Map of Carcinogenic Risk in Southern California

There are several emission control strategies that have been used to control the air pollution and reduce the toxic exposure risk in Southern California. First, all transportation projects (including rail projects) listed in the Transportation Improvement Programs (TIP) or Capital Improvement Programs (CIP) need to conform with air quality goals. Second, stricter controls have been imposed on diesel powered train engines. Stringent emission standards and requirements for cleaner burning diesel fuels have been implemented for freight transportation.

Electrifying the freight railroads from the Ports to the Inland Empire is another control strategy that has been considered for reducing air pollution in Southern California (SCAG, 2007). Electric locomotives obtain their power from overhead wires, and thus produce virtually no air pollution. Switching from diesel to electric locomotives also conserves energy and helps mitigate global warming. Of course, the power must be generated elsewhere, but power plants are substantially cleaner and more efficient than locomotives. In addition, electric locomotives can use regenerative braking to return power to the overhead wire, and do not consume power when idling, thus further improving their efficiency. Other benefits of electrifying the freight train network will include reduced dependency on oil imports and relieve traffic congestion with the addition of inland ports.

Railroad electrification is a mature, well established and reliable technology. For example:

- Japan and Europe have electrified almost all their railroads.
- Russia has electrified the Trans-Siberian railroad (Moscow to Vladivostok), the longest in the world, as well as many other lines. In 1990, over 60 percent of Russian railway freight was being hauled by electric locomotives.
- China has a large array of electric freight trains and they are constructing more. Their present budget is approximately $42.3 billion for infrastructure, locomotives, and rolling stock. Chinese Railways (CR) Railway is the major rail company in China.

Project Objectives

Electrification of the railroad network from the ports to Inland Empire would be a major project that would require a very extensive feasibility study. Comprehensive financial, engineering and environmental evaluations would be necessary. Thus, this project proposal is merely intended to be a first step in this process. The scope of this project is as follows:

1. Conduct a literature review of electrified freight railroads elsewhere in the world.
2. Assess the temporal and spatial patterns of rail traffic from the ports to Inland Empire, and identify candidate routes for electrification.

3. Conduct a preliminary evaluation of the benefits of electrifying these railroads, and identify the major financial, technical, and environmental concerns and constraints.
4. Identify potential funding sources for a more detailed study. In addition to the University Transportation Center (UTC), these might include the port authorities, railroad companies, Southern California Edison, Air Quality Management District (AQMD), Southern California Association of Governments (SCAG), and others.
5. Develop a scope of work for a more detailed feasibility study.

Project Outcomes

Literature Review of Electric Freight Trains

The research team has conducted a literature review on electric freight trains in various countries. The first successful electric trains were built and put into service in 1888. These trains were considerably low tech compared to the modern electric trains such as the one being designed by the Italian engineering company Ansaldo Breda's rail subsidiary Finmeccanica that will travel at 300 km/h (107 mph) and will comply with the European interoperability standards [Ibrahim 2008]. Europe's most heavily traveled railway is the Channel Tunnel which handles some 100 million tones per year. Some of the major railway design companies are shown in Table 3.

Netherlands has the densest rail network in the world which includes both passenger and a major freight rail linking the port of Rotterdam with Germany. Many of the railways were developed by Alstom of France. Alstom has major facilities in most European countries. Its latest passenger train is the AGV Alstom that travels at 360 km/h. Each buggy has its own motor. Alstom is presently designing a high speed electric train for Argentina which will link Buenos Aires and Cordova. Alstom's high speed V150 electric train set the world high-speed record at 574.8 km/h (359 mph) on April 3, 2007 in France in partnership with SNCF – Société Nationale des Chemins de fer Français (See Figure 3). This train has a power plant rated at 20 MW [Alstom 6]. The old record was set in 1990 at 515 km/h. For non-conventional trains, the world record is 581 km/hr set on December 2, 2003 by J-R Maglev in Yamanashi, Japan. However, this train is not operating on a passenger basis and has only operated on a unique test track.

The Swiss Federal Railway system is almost all electric. It is operated by SBB Cargo, a subsidiary of Swiss Federal Railway (see Figure 4). They use dual-systems on non-electrified lines. Their Cargo Train and Cargo Rail are customized whole-trains offering shipments of large volumes of freight [Cargo 2008], [SBB 2006].

Table 3. Major European/Asian railway companies and railway systems

Company	Country	Comments
Deutsche Bahn AG	Berlin Germany	www.bahn.de.com
Alstom	Levallois-Perret Cedex, France	www.transport.alstrom.com
Swiss Federal Railway (SBB); SBB Cargo	Basel, Switzerland	http://www.sbbcargo.com/en/index.htm
French Development Agency	Paris, France	The French National Railway Company (SNCF – Société Nationale des Chemins de fer Français)
Atkins	North West, United Kingdom	Expertise in rail planning, signaling, telecommunications and other engineering.
Bombardier	Switzerland	Train manufacturer that supplies the French National Railways
WSP	Sweden	Expertise in rail planning, signaling, telecommunications and other engineering.
BMT Rail	Britain	
Enesto Sekko	Finland	Overhead electrification equipment
Central Japan Railway Company	Japan	
Russian Railways	Russia	http://eng.rzd.ru/wps/portal/rzdeng/fp
China Railway	China	http://www.eebf.cn/english/

Dynamic simulation calculations and practical experience have shown that train speeds of 200km/h are possible with the use of 100[mm.sup.2] CuAg contact wire at 13kN tension and a 50[mm.sup.2] Bz messenger wire at 11kN tension. The maximum contact wire uplift in this case is 80mm, and can additionally be blocked at the point of attachment of the steady arm [Nordic 2008]. It's not very likely that electric trains will be traveling at this speed in the Inland Empire. Technical developments such as this are commonly presented at conferences such as the Nordic Rail Infrastructure being held in Copenhagen, Denmark, June 2008.

Figure 3. Alstom's high speed V150 electric train
(Source: Wikipedia/commons/d/d0/TGV-V150)

Figure 4 Swiss Federal Railways overhead lines

(Source: http://en.wikipedia.org/wiki/Image:Overhead_lines%2C_Puidoux.jpg)

The French National Railway Company (SNCF) has over 9026 miles of electrified railways.

Russian Railways operates over 53,000 miles of railway in Russia as shown in Figure 5. See also the Russian, CIS and Baltic railway map at http://www.parovoz.com/maps/supermap/index-e.html. They are constructing 520 km of electric railway from Al Zabirah to King Khalif International Airport for a cost of approximately $2.5 million per mile [RIA 2008]. This cost is about 1/16 the cost of constructing a rail system in Southern California. Presently over 70% of Russia's freight is carried on electric freight trains. This amount is over 80% of all rail freight in the US. The US electrified rail system is very poor and antiquated compared to the rest of the world.

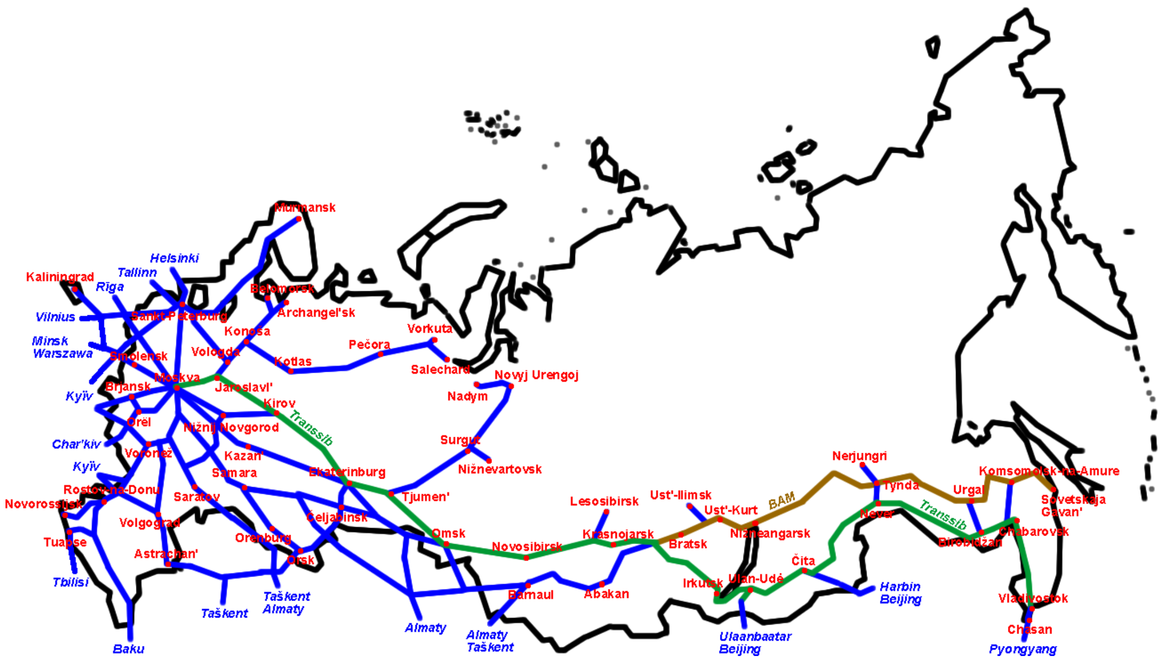

Figure 5. Simplified Russian Railway System, Source: http://en.wikipedia.org/wiki/Russian_Railways

Indian Railways in India is conducting pre-feasibility studies for five (5) new electric railway corridors [Kahleej 2008]. They are presently soliciting global tenders for engaging a consultant for the studies. Also, India and Pakistan are going to link several of their railways. This is part of a $2 billion pledge by the World Bank to Pakistan for improvements to its rails systems and ports [Khaleej 2005].

The first electrified railway in China was built to connect Baoji to Fengzhou in 1958-1960. Since then, electrification of railway lines has continued. By the end of 2003, the total length of electrified railway of China had reached 20,000km. [China Railway Ministry, 2006]

The Saudi Landbridge Expansion Plan will include to passenger and freight train expansion at a cost of about $1.7 billion. The expansion would be at Jeddah Islamic Port, King Abdul Aziz Port and Riyadh Dry Port. The rail system would be over 600 miles long [Khaleej 2005].

In summary, there are numerous efforts in Denmark, Finland, Norway, and Sweden to upgrade their railway systems to be competitive in the transport sector. This includes investments in rolling stock, telecommunications, and signaling systems. Japanese and

Europeans have electrified almost all their railroads. Russia has the Trans-Siberian railroad (Moscow to Vladivostok), the longest in the world already. More recently they electrified it to the arctic. By 1990, over 60% of the railway freight was being hauled by electric freight trains in Russia. This is about 30% of the freight hauled by all railroads in the world and about 80% of rail freight in the US. Russia has one the largest oil reserves in the world and their approach to electrification of their railroads must make us to rethink our current situation.

Rail Traffic Patterns – Temporal and Spatial

Freight movement is a core component of the Southern California economy. It is a major gateway to international commerce. In 2005, over 70% of imports through the Ports of Los Angeles and Long Beach are transported by BNSF and UP trains through rail main lines in Inland Empire region to their destinations outside Southern California [SCAG, 2007].

Southern California also has an intensive network of warehousing and distribution centers to serve its enormous local market. Local freight flows between the centers and the ports are the critical driving forces that support the economy in Southern California. Figure 6 shows the existing spatial distribution of warehouses and distribution centers in the Inland Empire region. It is expected that more distribution centers will be added in the Inland Empire region since people are moving towards to San Bernardino and Riverside counties due to high house prices in Los Angeles County.

Growth in population and trade continues to change the number of distribution centers and shape the spatial and temporal patterns of freight movement in Southern California, particularly in the Inland Empire region. In 2002, the California Department of Finance projected that population in Southern California will reach to 21.5 millions in 2020. The growing population will lead to greater demand of freight volumes between the ports and the distribution centers in Inland Empire area. Also the Los Angeles County Economic Development Corporation (LAEDC) estimated that the future international trade for Southern California and the rest part of the United States will increase to 30.34 million TEU (Twenty Foot Equivalent Units) in 2025 [LAEDC, 2002].

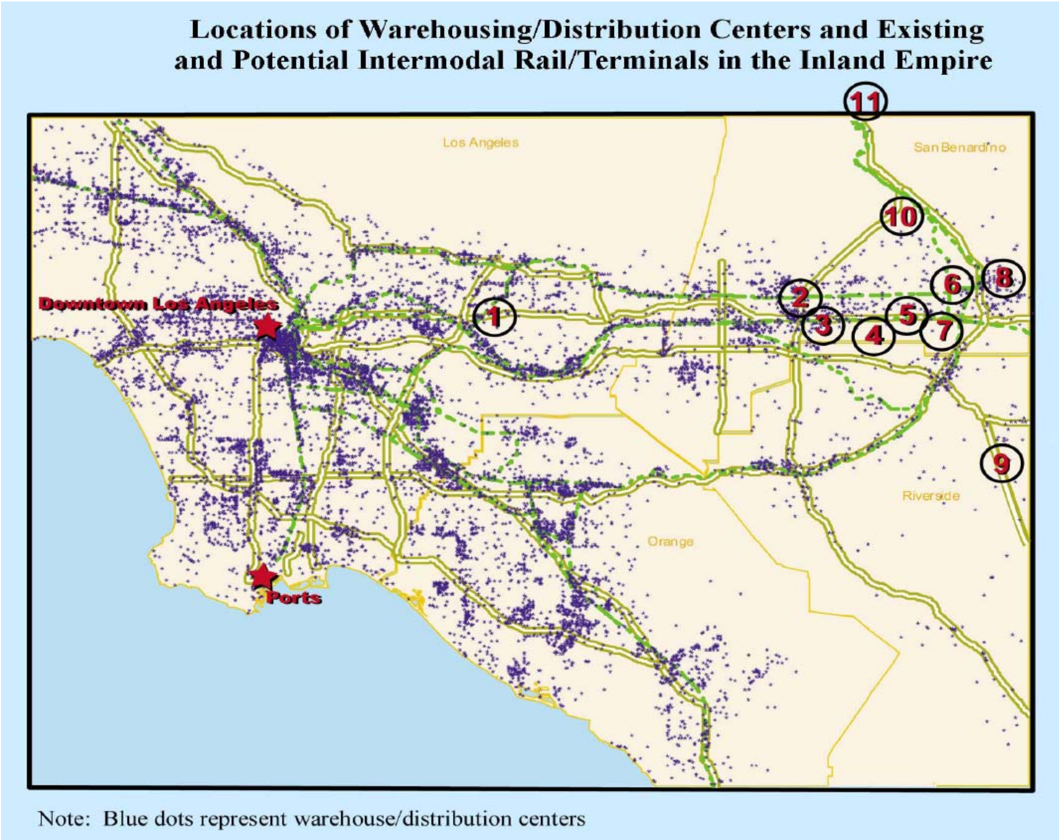

Figure 6. Warehouse and Distribution Center
[LACMTA, 2002]

Considering the projected population and trade, the LAEDC estimated the 2010 and 2025 daily train forecast on the BNSF and UP rail lines. Table 4 shows the BNSF train peak-day traffic on segments of Hobart-Fullerton, Fullerton-Atwood, Atwood-Riverside, and Riverside-Colton. The total number of trains in peak days in 2025 is 218, 144, 183, and 18 at the Hobart-Fullerton, Fullerton-Atwood, Atwood-Riverside, and Riverside-Colton segments, respectively.

Tables 5 and 6 show the UP train peak-day train traffic on the Sub Line and the Alhambra line. In 2025, the peak-day train traffic is forecast to be 161 through Pomona and 176 through Colton.

Table 4. BNSF Peak-Day Train Traffic Pattern (Number of Trains)

BNSF Peak-Day Trains	Hobart - Fullerton	Fullerton - Atwood	Atwood - Riverside	Riverside - Colton
Year 2000 Total	96	52	74	103
BNSF Through freight	50	50	57	57
Passenger	46	2	17	11
UP through freight	-	-	-	35
Year 2010 Total	150	94	120	120
BNSF Through freight	74	74	82	82
Passenger	76	20	38	24
UP through freight	-	-	-	14
Year 2025 Total	218	144	183	174
BNSF Through freight	112	112	121	121
Passenger	106	32	62	36
UP through freight	-	-	-	17

(Source: LAEDC, 2002)

Table 5. UP LA Sub Line Peak-Day Train Traffic Pattern (Number of Trains)

UP Peak-Day Trains	East LA - Pomona	Pomona – Mira Loma	Mira Loma - Riverside	Riverside - Colton
Year 2000 Total	43	43	47	103
UP Through freight	31	31	35	35
Passenger	12	12	12	11
BNSF through freight	-	-	-	57
Year 2010 Total	150	94	120	120
BNSF Through freight	74	74	82	82
Passenger	76	20	38	24
UP through freight	-	-	-	14
Year 2025 Total	218	144	183	174
BNSF Through freight	112	112	121	121
Passenger	106	32	62	36
UP through freight	-	-	-	17

(Source: LAEDC, 2002)

Table 6. UP Alhambra Line Peak-Day Train Traffic Pattern (Number of Trains)

UP Peak-Day Trains	East Bank Line	LATC – Pomona	Pomona – West Colton	West Colton - Colton
Year 2000 Total	31	26	26	31
UP Through freight	19	24	24	29
Passenger	12	2	2	2
Year 2010 Total		**Through Pomona**		**Through Colton**
UP Through freight		78		89
Passenger		26		26
Total		104		115
Year 2025 Total		**Through Pomona**		**Through Colton**
UP Through freight		117		132
Passenger		44		44
Total		161		176

(Source: LAEDC, 2002)

Candidate Routes for Electrification

Preserving the quality of life and economic competitiveness in the Southern California requires meeting the above train freight challenges in the areas of congestion, the environment, safety, and security. The completion of the Alameda Corridor Project in 2002 marked the starting step in a significant upgrade of Southern California's rail infrastructure network. Other possible upgrades considered by SCAG in addressing congestion and emission reduction are 1) rail network expansion with the concept of inland ports and rail shuttles, and 2) electrification of rail network.

SCAG conducted an inland feasibility study in 2006, provided a comprehensive overview of national and international inland ports, and identified possible sites of inland ports in the Inland Empire region (SCAG, 2006). These possible sites could eventually be linked to the existing rail network.

SCAG also developed a conceptual plan on electrifying the existing rail network (SCAG, 2008). The plan outlined three phases for the rail electrification:

Phase 1: Electrify the major east freight rail corridor from the ports to Colton and San Bernardino. This phase would electrify 250 miles, 360 locomotives at a cost of 3.4 billions.

Phase 2: Conduct an electrification extension from San Bernardino to Barstow, from Colton to Indio, and from West Colton to Cajon Submit. This phase would have an estimated cost of 2.5 billion for electrifying 170 miles with 360 locomotives.

Phase 3: Conduct an electrification extension from the Chatsworth and the San Fernando Valley. This phase have an estimated cost of 0.53 billion for 40 miles and 55 locomotives.

The above estimated costs for electrification included the infrastructure cost as well as purchase of a dedicated fleet of electric locomotives for the corridor activity. Because of lack of information, SCAG did not estimate costs associated with any changes in operation and maintenance for the railroads. Nevertheless, the plan provided a feasible concept of using rail electrification as a tool to improve air quality. It established a solid foundation for further engineering and environmental studies on this major investment.

Requirements for Electrifying Rail Lines

Rail electrification system is a system that transmits and feeds traction power from power generation plants to rail trains. It consists of three basic factors: voltage, current and contact system. Contact line systems are the dominating systems that provide voltage and current to rail trains through overhead contact power lines. Design of an electrified system typically involves the geometric arrangement of contact lines, cantilevers, poles, traction power feeder lines, return current conductors, and rail bonds.

Considering the uniqueness of rail electrification in Inland Empire area, this project has identified a set of preliminary engineering and environmental requirements that should be considered in a later major investment study (MIS). These requirements are:

1) Engineering Requirements

Electrical Considerations Rail electrification should consider the type of current and nominal voltage used for train traction. To increase the operational performance of electrified trains, sufficient current-carrying capacity should be provided through overhead contact lines to train engines. Contact lines should be installed to provide short-circuit current capacity (SIMENS, 2001). American Railway Engineering and Maintenance-of-Way Association (AREMA) has provided a set of recommended nominal operating voltage (AREMA, 2007)

Rail Tracks Overhead contact lines should be designed to be compatible with rail track design, gauge clearance, and geometric alignments (horizontal and vertical alignments). Maximum train length and train operating speed affect the length of platforms, spans of overhead contact lines, locations of signals, etc.

When new rail lines are built to connect to Inland ports, the design speed of trains governs all the geometric design including radii and superelevation right from the outset. It also controls the geometric layout of overhead contact lines for the electrified system. On existing rail tracks where radii and superelevation are small and might not be up to current design standards, an analysis should be conducted to ensure contact line design can support the existing tracks. Otherwise, the existing tracks need to be upgraded and reconstructed before contact lines are built.

Rail Lateral Clearance (or Gauge Clearance) Rail lateral clearance is critical to the contact line design for rail electrification because no components of any kinds can be allowed to be inside this area.

Rail Vertical Clearance Rail electrification needs to consider vertical clearance requirements when overhead contact lines are designed and built. As double-deck containers are transported on the existing rail lines, the design of electrified system needs to consider the vertical requirements of double-deck containers. When overhead contact lines have to pass below structures, the vertical clearance must be maintained for freight and passenger trains.

Seismic Considerations Sothern California is prone to major earthquakes. The design of electrified system (including overhead contact lines, poles, etc) should meet the updated building codes.

Power Switchover Rail electrification should select appropriate power switch over sites to allow electrified train engines need to be replaced by diesel engines.

2) Environmental Requirements

Land Use Vast linear acreages are required for electrifying the rail network. The amount of the land required will depend on the length and cross section design of rail lines (existing and new lines to link to inland ports). Normally the land needed for new double-track rail lines is about 36% of that for a four-lane highway (SIEMENS, 2001).

Since desirable areas for the new rail lines for inland ports are also in demand for other purposes, land costs are high, and real estate can be expected to appreciate with the planning and development of the inland ports and rail extension to these ports.

Hazard Due to Birds. Contact lines used for the electrified network are often the rest and landing places for various species of birds. This may cause potential dangers to birds and operations of the overhead contact line installation (including the collision of contact line equipment). In areas where bird habitats or natural preserves and feeding grounds are found, the installation of bird protection devices can reduce the potential hazard significantly.

Context-Sensitive Considerations Engineering design of the electrified network should consider context-sensitive factors such as the local landscapes surrounding the contact lines. The layout of the electrified rail lines should consider the existing terrain characteristics; the height of the overhead contact line poles needs to consider the horizontal and vertical clearance available on the rail lines; the design of cantilevers, overhead contact line, equipment, reinforcing feeders and return lines needs to consider compatibility with local aesthetic landscape.

Electric and Magnetic Field Analysis Rail electrification produces significant electric and magnetic fields that may influence existing electrical devices or systems in the vicinity of the rail lines.

Atmospheric Conditions Rail electrification should consider the impacts of temperatures to the contact lines. Contact lines and posts should not suffer irreversible damage to the change of temperatures. Also, the design of overhead contact lines should consider wind velocities in the areas where high wind speeds are observed.

Aggressive dusts and active gases and airborne substances can cause contamination of insulators and damage of components in overhead contact lines. When existing rail network is extended to link to Inland ports, the new rail lines should be aligned to avoid the areas (normally manufacturing sites) where such dusts and substances are found.

Lighting hits can cause power flashovers at the insulation and lead to severe damage to contact line systems and rail trains. Rail electrification system design should consider lighting voltage surges and devices to protect overvoltage.

Preliminary Evaluation of Electrification Benefits

Electric freight trains have some major advantages over diesel powered trains as follows:

- Faster acceleration and more starting torque available to the wheels. Modern electric trains can use individually powered buggies with individual motors on each wheel. This greatly increases the available acceleration torque just as 4-wheel drive vehicles have more traction than 2-wheel drive vehicles.
- Regenerative breaking incorporated into electric trains will able to recover some the energy that is normally lost during breaking. Some trains such as Maglev system use eddy current brakes that have no wearing parts.
- Less maintenance. Electric motors require less maintenance than diesel engines since the only parts subject to wear are the armature bearings. The power electronics is continually being improved in capabilities and reliability.

- Pollution from power generation is located at a single source, enhancing the efficiency of pollution control devices compared to having control devices on each engine. It is much easier to reduce CO_2 emissions at a stationary source than in a mobile source. CO_2 emissions are a world wide concern and all major developed countries are seeking methods of reducing their emissions. Underground storage is a primary area of present research. There is no way to incorporate this type of emission control in a diesel locomotive.
- Electric motors are considerably more efficient than diesel engines. Nationally the trucking industry carries about 75% of the freight and railways only10%. Switching to railways should reduce costs considerably. A well designed electric traction motor can have an efficiency greater than 95%. An ideal diesel engine cannot have an efficiency greater than its theoretical maximum efficiency of 56%.
- No idling is required when the train is stopped. All diesels required a warm-up period before they are loaded. As such many diesel locomotives are left idling in switch yards when they are not moving cars. This same pollution source is being investigated by Southern California Edison as it relates to cargo ships in the harbor. The goal is to provide an electrical power source to the cargo ships so they do not have to idle their diesel engines while in port.
- Signals and communications can be transmitted over the electric supply system. Modern control systems for electric trains permit a large amount of data to be transmitted over the electric power grid. Each control room for a railway system monitors everything that is occurring on or near a train. Enormous data banks store the collected data for use in analysis of various types.
- Reduced dependence on oil. Electrical power can be generated by many methods that are not dependent on oil.
- Reduced dependence on truck usage and the resultant reduction of truck traffic on highways. The availability of inexpensive diesel fuel and many highways led to the proliferation of the trucking industry without regards to their environmental impact on pollution, traffic congestion, and accelerated wear of highways.

Some of the technical issues and past reports that will need to be considered with the electrification of the present diesel railway system are as follows:

- Southern California Regional Rail Authority (SCRRA) reports
- Rail Electrification Task Force report
- Cost per mile for electrification. Estimated at $40 million per mile.
- Effects of magnetic fields (are there any adverse effects? Studies have not been conclusive on whether or not electric fields increase the risk of cancer, but that does not alleviate the public's concerns.
- Generating electrical energy using traditional means is certainly not an environmentally friendly approach. The Rancho Seco nuclear generating station which was built by the Sacramento Municipal Utility District (SMUD) was shut down by local voters on June 6, 1989. Obtaining sufficient electrical generating capacity for an electric rail system is going to be a major hurdle for Southern California Edison and the Los Angeles Department of Power.

- What other countries have done and what is the experience? France for example has over 80% of their electrical generating capacity in nuclear fission technology and its nuclear waste disposal problems. On the other hand, if nuclear fission ever becomes possible, then electrical energy will become very inexpensive.
- Difficulty in converting regenerative brake energy back to the grid. Most of the technological problems have been solved and this technology is being incorporated into high speed passenger rail systems. It is much easier to incorporate into a Maglev system.

Funding Sources

"Before funding of a transportation project is pursued the project must be included in the Transportation Corridor studies, better known as *Regionally Significant Transportation Investment Studies (RSTIS)* determine transportation need and evaluate alternatives. SCAG, in cooperation with other stakeholders, approves the initiation and scope of these studies. Each incorporates a "purpose and need" statement, alternatives analysis utilizing a range of performance indicators, record of community involvement, a locally preferred alternative selection and preliminary environmental documentation. Before a project can be included in the RTIP for construction, the project must be one of the alternatives in a completed RSTIS, and must be included in the RTP".[SCAG 2004]

Typically funding for major railway improvement are provided by the railway company's involved and the local government surrounding the railway system. Less than 50% of the funds come from the federal government. For example, the $264 million the rail system in downtown Reno was funded as follows:

- $113 million municipal bond issue
- $73.5 million Transportation Infrastructure Finance (TIFIA) a US Department of Transportation direct loan
- $81.3 million cash, grants or investment income

Another example is the $2.5 billion Alameda Corridor in Los Angeles which was opened on April 15, 2002.. It was funded as follows:

- $1.2 billion in revenue back bonds
- $400 million USDOT loan
- $394 million grant from Ports of Long Beach and Los Angeles
- $347 million from Los Angeles County MTA
- $160 million in interest/ others

This was a design build project for the mid-corridor and a design-bid-build project for the north and south ends. This was on of the largest design-build projects in the United States.

A technique that is being implemented by many agencies is innovative surface transportation finance which is defined as follows:

"Innovative finance" for surface transportation infrastructure is a broadly defined term that encompasses a combination of techniques and specially designed mechanisms to supplement traditional financing sources and methods. Innovative finance for surface transportation includes such measures as follows:

- new or non-traditional sources of revenue;
- new financing mechanisms designed to leverage resources;
- new funds management techniques; and
- new institutional arrangements.

The U.S. Congress has a long history of funding surface transportation infrastructure through grants from the HTF. Innovative finance provides and array of tools and institutional arrangements as alternatives to traditional, grant-based funding strategies. Innovative finance techniques have been designed to enhance the effectiveness of grant management techniques and bridge investment gaps between available resources and infrastructure needs. Several of these techniques may not be new or particularly innovative outside of the transportation sector. It is important to recognize that the benefits associated with these tools are not mutually exclusive and that there is potential synergy in combining tools on a single project.

Innovative finance has evolved at the Federal level as a product of dialogue between policy and administrative officials at the USDOT and partners at the state and local levels. Most of the programs and tools have been enabled by legislative changes to the U.S.C., Title 23. As transportation finance needs evolve, new tools and programs are likely to add to the field of innovative finance" [Innovative 2008].

It will be the responsibility of transportation agencies to find new ways to finance new construction projects. The old method of tax and spend is no longer a viable entity. Bond issues and small taxes on services have been successful with the voters. For example, Measure M in Orange County passed 68.5% for to 31.5 against to retain their extra 1% sales tax for another 30 years for transportation improvements [Sellers 2007]. An example of innovative finance as related to a transportation project is shown in Figure 4.

Government Agencies

In addition to the funding sources, considerable efforts will need to be expended to coordinate the various agencies involved in a project of this magnitude. The political reality is that SCAG with its 79 voting members has responsibility for six counties, 197 cities covering 38,000 square miles which translates into local interests coming first [Petix 2008]. Before any major progress can be made in electrifying the local railway system, the project will have to become part of the $590 billion 20-year Regional Transportation Plan developed by SCAG. The regional agencies that will have to be persuaded that electrification of the railway system is important enough to be included in their development plans and their responsibilities are outlined in Table 7.

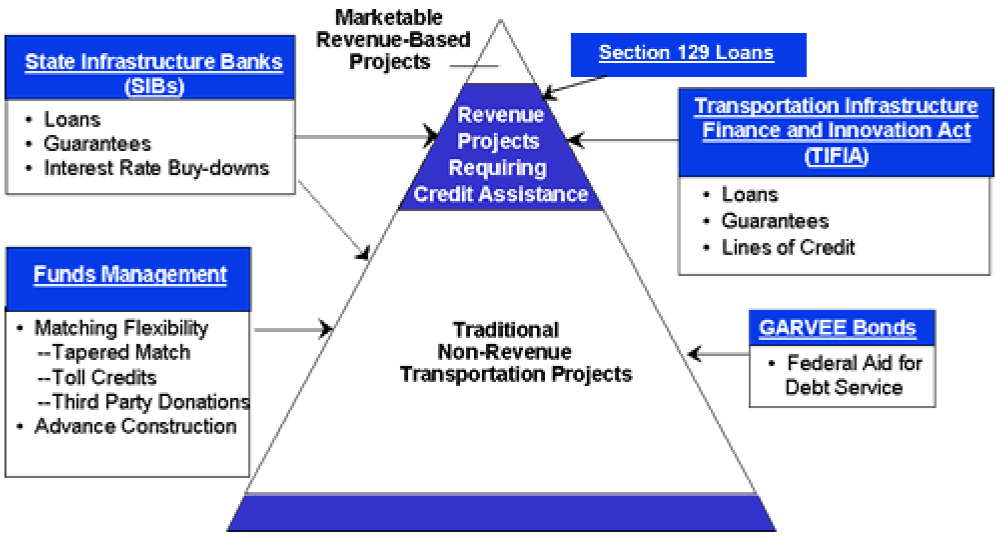

Figure 7. Revenue Pyramid for Transportation Projects. Source:
http://www.innovativefinance.org/defined/ques10.htm

Table 7. Government Agencies and their Role in Inland Valley Development

Name of Agency	Contact Information	Responsibility
California Department of Transportation	www.dot.ca.gov	Statewide transportation issues
UTC San Bernardino	http://leonard.csusb.edu/	Solving Transportation Problems
UTC Long Beach	http://www.metrans.org/	Solving Transportation Problems
Cities along rail route		Responsible for constituents concerns
Counties along rail route		
SCAG	President, Gary Ovitt, San Bernardino County's 4th District supervisor Glen Duncan, Chino Hills Council member	Long-term strategies for six counties Data collection and maps for roads, rail, air quality, and housing
Los Angeles Economic Development Corp.	Jack Kyser	Chief economist
The Port of Los Angeles [Harbor Department]	Governed by a five-member commission appointed by the major.	

The Los Angeles and Long Beach ports are the first and second busiest ports in the United States measured by container units [Sonenshein 2006]. The Los Angeles and

Long Beach harbors jointly supported the construction of the Alameda Corridor project which was funded by federal grants and from the issuance of bonds. The harbors are self-supporting and can issue bonds for construction projects. The Los Angeles port handles over 162 million revenue producing tons of cargo per year.

The Alameda Corridor which opened in 2002 eliminated over 200 at-grade crossings. This was a major improvement to local traffic conditions.

The Southern California Association of Governments (SCAG) Goods Movement Program seeks to optimize the region's transportation system through increases in economic efficiency, congestion mitigation, safety and air quality improvements, and enhancements to system security. In doing so, all modes of freight are being evaluated, ultimately resulting in a series of new recommendations and policies regarding infrastructure improvements. See http://www.scag.ca.gov/.

SCAG's 2004 Regional Transportation Plan identifies transportation needs in corridors and encourages planners and policy-makers to start preparing strategies for preserving corridors now for use in the future. Good planning can prevent losing rights-of-way needed for developing transportation facilities. Thus, rights-of-way preservation is a reasonable objective, particularly in areas where new development may block a long-range corridor. See http://www.scag.ca.gov/

The Plans and Programs Technical Advisory Committee is charged with coordinating and ensuring the technical integrity of the RTP, including the overall technical analysis of the RTP as well as specific assumptions for finance, growth, aviation, freight, and modeling. The committee brings forward recommendations on technical aspects of the RTP to various task forces and policy committees. The committee is comprised of staff from transportation planning (or related) agencies at all levels of government, as well as representatives from community, environmental, business, and other interest groups. See http://www.scag.ca.gov/

Scope of Work for a More Detail Feasibility Study

While the impact and advantages of electrification of freight network from ports of Los Angeles and Long Beach to the Inland Empire is evident, implementing such a massive undertaking requires more detail feasibility study. This section addresses some of the pertinent issues.

<u>Overhead lines</u>

Overhead lines are widely used for transferring electrical energy to freight trains. Tension in overhead lines vary between 9 to 15 kN and they are tensioned generally weights. In the US, overhead catenary system is used to supply electricity to locomotives equipped with a pantograph.

- The height of overhead lines poses serious problems especially at level crossings. In highly populated southern California, with a number of crossings, there the possibilities of road vehicles come in contact are very high.
- Overhead lines used for the electrified network are often the rest and landing places for various species of birds. This may cause potential dangers to birds and operations of the overhead contact line installation.
- Installation of overhead lines can significantly alter the landscape and visually unappealing.
- Overhead lines are prone to weather damage.
- Access for repair and maintenance is hard
- The landscape in of California and its hills necessitate the construction of tunnels which will have limited vertical clearance. This in turn increases the cost of overhead line installation significantly.

Third rail system provides an alternative to overhead lines. Use of third rail system is by no means a new. It has been in use since 1880s but has undergone significant improvements over the years and widely being adopted. For example, Singapore banned the use of overhead lines. The advantages of using third rail system include cheaper construction costs, less restriction on vertical clearance in tunnels, no threat to birds, easy access for repair & maintenance, no visual obstruction and accident prevention in line crossings. Hence a comprehensive feasibility study needs to be conducted for the potential use of third rail.

<u>Regenerative breaking</u>

Electric motors operate as electric generators during regenerative breaking. During breaking, electric power is generated from the kinetic energy of the train. The breaking force is composed of friction breaking force and motor breaking force. Hence the motor breaking force must be calculated and the product of motor breaking force, velocity and regenerative efficiency must be obtained. A paper by Fernandez discusses energy savings in railways operation and efficient regenerative breaking [Fernandez 2007]. However, it must be noted that the high average weights of freight trains and considering that only the locomotive axles are powered. Thus major share of braking power comes from the mechanical breaking in freight cars. Only a small share is added by the locomotive itself. Freight trains are also much longer and heavier and have large mass to be braked by unpowered axles. Hence the potential to increase the share of regenerative braking energy seem to be limited for freight trains. Strategies to increase the share of regenerative breaking need to be developed. A feasibility study must be conducted to estimate the power generated by regenerative breaking.

<u>Self Propelled freight cars</u>

For smaller quantities of cargo the conventional freight train system is expensive and time-consuming due to train formation and freight handling processes. This problem could be solved by making freight trains more truck-like, self-propelled freight cars and eventually leading to driverless operation. Self-propelled freight cars have a propulsion unit on-board. Self-propelled freight cars could be used for a direct point-to-point delivery of small freight quantities. From an economic point of view, this is economically attractive if the operation is driverless. Figure 8 shows how customer needs are met by self propelled freight cars.

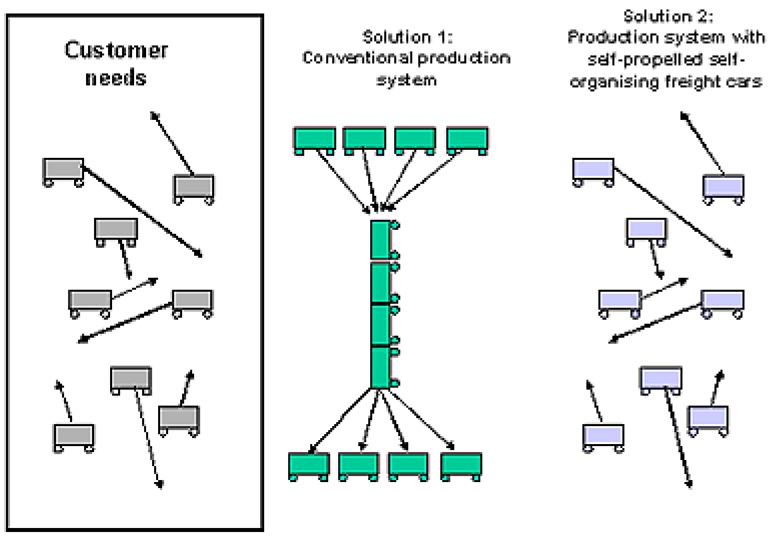

Figure 8. Self-Propelled Freight Cars. Source: http://www.railway-energy.org

No. of Trains and workforce

Electric locomotives have made great strides in terms of performance in acceleration and pulling capacity. An electric freight train can run continuously meaning less trains (or more capacity) and fewer workers needed to run it. A model is necessary for forecasting the need for the number of trains and workforce.

Cost Analysis

The biggest disadvantage of electrification is the cost associated with the development of necessary infrastructure e.g. the construction of overhead power lines. Electrification offers a lower cost per mile of train operation but at a very high initial cost. A model justifying the high initial infrastructure development costs is necessary to create awareness and public policy.

In addition to the required engineering analysis considerable effort will be required to prepare budgetary documents for all of the affected agencies. Preparation of the proper documents will require considerable negotiation with many agencies including the upper management of the various railroads and the House Transportation and Infrastructure Committee and the Federal Railroad Administration in Washington, DC. An investigative effort of this magnitude would require initial funding of approximately $500,000. The total project cost, if approved, to electrify the existing rail system would exceed $2 billion. A second phase investigation would need to be coordinated with the appropriate committees of SCAG and railroad management as shown in table 8.

Table 8. Local Railroad Management.

Amtrak, National Railroad Passenger Corporation	Alex Kummant, CEO, 810 North Alameda Street, 3rd Floor Los Angeles CA 90012 or 60 Massachusetts Avenue, N.E. Washington, D.C. 20002
BNSF, Burlington Northern Santa Fe Corp.	Mathew K. Rose, CEO, P.65, 740 East Carnegie San Bernardino, CA 92408 or P.O. Box 961056 Fort Worth, TX 76161-0058
LA Junction Railway Co.	P.65, 740 East Carnegie San Bernardino, CA 92408
Pacific Harbor Lines Inc.	Andrew C. Fox, President 340 Water Street Wilmington, CA 90744
UPRR, Union Pacific Railroad	James R. Young, CEO 10031 Foothills Blvd. Roseville, CA 95747 or 1400 Douglas Street Omaha, Nebraska 68179

Conclusions

Despite many of the obstacles to electrifying the railway system between the ports and the inland empire a concerted effort should be made to get this transportation project on the SCAG agenda. This is a long committee process and will have to have the backing of the Burlington Norton Santa Fe (BNSF), Union Pacific (UP) and other railway management as a starting point closely followed by both the Long Beach and Los Angeles Port Authorities.

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