The Potential for Using Transit Infrastructure for Air Freight Movement: A Case Study in the San Francisco Bay Area

Phase I, Year 2 Report

Project Sponsored by Caltrans CT #65A0329

Authors

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UCB-ITS-PRR-2010-38

March 31, 2010

First Revision on Feb 20, 2012

Second Revision on April 30, 2013
Abstract

This report examines the impact and feasibility of using an urban railway system for freight movement, in particular, the Bay Area Rapid Transit (BART) system for FedEx Express air cargo movement. Based on the framework constructed in the study’s last phase, social impact (externalities), reliability, and infrastructure feasibility are considered here. The social cost related to emission, energy consumption/efficiency, the impact on road traffic and land use is also considered. Reliability issues are examined from two aspects: transportation delays and emergency situation handling. Infrastructure feasibility is analyzed based on the proximity and accessibility of BART yards/shops/stations and FedEx collection/distribution centers, air freight container size, and the conceptual designs of dedicated BART freight car and trans-shipment equipment.
Acknowledgements

This work was performed as part of the California PATH Program of the University of California in cooperation with the State of California Business, the Transportation and Housing Agency, and the Department of Transportation (CT #65A0329). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This paper does not constitute a standard, specification, or regulation.

Active Participants of the Project include: BART engineers Richard Lu and Stephen Peery; Faisal Zaman, Run Zhou, and Michael Graham of FedEx; Caltrans DRISI project manager Matt Hanson.

The strong support of Tom Messer and Michele Fell of Caltrans Goods Movement, and Colette Armao of Caltrans Aeronautics, is gratefully acknowledged.
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Executive Summary

The San Francisco Bay Area has one of the most highly developed and heavily congested metropolitan corridors in the nation with an ever increasing demand for both passenger and freight transport. It is also a main entry point into the United States for the huge Asian market, and thus is a critical factor for maintaining the United States as a leader in the global economy. On the one hand, traffic in the Bay Area’s main corridors is severely congested and becoming worse with the rapid rise in population and the developing local economy. These corridors are already significantly impacted by truck-related activities, including a growing market for air freight (dominated by companies such as Federal Express and UPS).

On the other hand, the San Francisco Bay Area Rapid Transit District (BART) runs a regional environmentally-green transit system that operates with excess capacity during non-commute periods, as well as during commute periods on those lines that run the reverse-commute direction. On average, BART uses only 30 percent of its capacity for daily passenger movement. The remaining 70 percent remains unused. Here the calculated capacity is based on current full operation with 15 minutes headway using a 10-car train. If, however, the BART system were to adopt modern technologies in its sensor, communications, and control system, the operational headway could be greatly reduced and the capacity could be doubled or even tripled. BART is completely grade-separated from general traffic, making its service free of cross-traffic delays and accidents, and its travel time can be competitive with cars during congested periods. It operates a system that places a high regard for safety. And it is electrically powered, thus emitting no air pollution.

If BART were to be used by air-freight delivery service providers, it could, in theory, provide reliable service to integrated freight carriers to meet their limited time window requirements. This could lead to increased revenue generation for BART. Using BART for air freight movement as a model for combined goods and passenger movement can be generalized to other critical corridors nationwide to effectively relieve corridor congestion problems. Improving traffic movement through these critical metropolitan corridors could yield significant benefits in terms of reduced travel time, delays, increased reliability, and predictability of freight movement, as well as increased utilization of the heavily invested (through public-private partnerships).
existing transportation infrastructure.

This work is a continuation of the preceding phase of the project sponsored by UCTC and Caltrans. Based on the planned transportation network and schedule, this report focuses on the reliability, social cost, and feasibility of using BART for freight movement from/to Oakland International Airport (OAK). We started with air freight because it has safety and security standards that are similar to those used for passenger movement. However, other products, such as high-tech manufacturing and agricultural products, could also be easily made to satisfy those standards.

The proposal is examined both quantitatively and qualitatively, including the benefits and costs to FedEx (the carrier), BART (the urban railway), and the public. Service reliability is of predominant interest to the integrated air freight carriers. This, together with the social benefits that can be attained, are the main concern of this phase of our study.

The reliability issue is examined from two aspects: transportation delays and emergency handling. Although there is no quantitative assessment for reliability levels, it has been shown that the BART system maintains one of the highest levels of on-time reliability.

During the last phase of the project, the social cost (externalities) is presented in a preliminary way. There, more emphasis has been put on social impact analysis, which is demonstrated from three points of view: road traffic congestion (delay, safety, and land use), energy efficiency, and the environment. The monetary cost of emissions is calculated, showing significant cost by emission.

The infrastructure feasibility is analyzed based on the proximity of stations, the feasibility of the containers, and transshipment feasibility. Potential approaches are presented and discussed in partnership with their estimated cost. The overall budget of infrastructure modification has proven to be manageable.

The analysis presents significant improvement in transport reliability when using BART, the high social costs incurred using the current mode of operation, and an operable implementation scheme. In future studies, the analysis and implementation schemes will be refined. With increasing demand, the social benefits could become even more significant.
Chapter 1. Introduction

The rapid increase in traffic congestion in the contemporary world results in an even more rapid rise in social costs. Road traffic congestion is the direct cause of many other problems, such as traffic accidents, environmental pollution, global warming, and pavement wear. Freight moved by trucks is the single most significant contributor to these problems. The densely populated Bay Area is in a particularly critical position to face these problems due to its high level of traffic, container movement through the seaport (Port of Oakland), and air freight movement through the three local international airports (OAK, SFO, and SJC).

Freight movement is a critical factor to the Bay Area economy. Beside the role of importing/exporting from/to international markets through seaport and airports, more than 37 percent of the Bay Area’s economic output is in manufacturing, freight transportation, and warehouse and distribution businesses. Trucking is the most frequently adopted mode in freight movement in those activities. As a consequence, congestion and pollution seems inevitable. Heavy duty diesel vehicles alone contributed 30 percent of nitrogen oxide emission in 2005 (Metropolitan Transportation Commission, 2004; 2008a, 2008b). To mitigate these problems, it is urgent to find alternative transportation modes with less pollutant potential, reduced road traffic impact, and beneficial characteristics--such as safety and reliability--to accommodate the high demand for transportation from economic activities and daily life without sacrificing the interests of the Bay Area community.

Maximizing the underused capacity of the BART system favors all these interests. In addition, the introduction of freight movement to BART offers opportunities to improve the service and performance of the system itself. This is because 1) only 30 percent of BART’s mainline is being used, leaving the remaining 70 percent wasted. As BART adopts more highly developed technology, the current headway of 15 minutes can be greatly reduced, doubling or even tripling capacity; (2) it is completely grade-separated from other modes of traffic and hence not involved in traffic delays. During peak congestion hours, its travel times is especially competitive with cars; (3) it’s on-time reliability is over 95 percent, and its operating frequency is higher than other transit systems; (4) the system places a high regard on its safety record and is not affected
by road accidents; (5) it is electrically powered and emits no air pollution, and reduces road traffic load without generating induced demand. We start off with air freight because its safety and security standards are similar to those of passenger movement. However, other products, such as high-tech manufacturer products and agricultural products, can be easily made to satisfy those standards.

Traditionally, railway systems are considered less effective in terms of efficiency and cost when compared with trucking. However, with increasing concerns over labor costs and rights, as well as accelerating increasing social costs, trucking is rapidly losing its advantage. If the ideas presented in this paper can be extended and practiced on other urban rail lines, it could offer solutions for many existing urban transportation problems. However, there is a surprising lack of exploration in this direction. We hope that this work spurs future action in this regard.

The report is structured as follows: Chapter 2 is for a relevant literature review; Chapter 3 examines reliability issues associated with truck and rail and lays out the comparison between the two; Chapter 4 reviews the work of the previous phase, especially the structure of the transportation network; Chapter 5 explores the concerns of externality generated from trucking. The monetary value of emissions is calculated, offering a more detailed idea of the costs associated with pollution; Chapter 6 discusses infrastructure feasibility issues and proposed operating schemes. Investment and time costs are estimated; Chapter 7 presents some final thoughts and future plans.
Chapter 2. Literature Review

There is very little literature available on urban rail networks for combined passenger and freight movement. The literature on the three aspects we will be investigating—urban intermodal transportation, road pricing (related to future truck operational costs), reliability, social impact, and infrastructure—have been reviewed and presented below in some detail for our upcoming analysis.

In the recent year, there has been a growing consideration about using rail networks for freight movement, most especially in Europe. Existing literature, which shows a rise in this interest, is correlated to congestion in urban areas, environmental issues, and loss of accessibility.

Maes and Vsnelslander (2009) analyzed the feasibility of utilizing rail transport as part of the supply chain in an urban logistic context in Western Europe. They examined the case of Monoprix—an innovative French company—and achieved positive results from the test. Although the current cost-benefit balance for Monoprix is negative, taking into account the possibility of improving efficiency and a possible road-charging scheme in France, the company could become profitable.

In the study of Nozzolo et al (2007), a methodology is presented for metropolitan freight distribution by railway in Italy. The work presents the methodology for the technical and economic feasibility analysis. Using the freight demand modeling system, the study shows that the new distribution system meets demand requirements, but needs public authority intervention to cover the additional costs incurred by the operator. The study by Nuzzolo et al (2007) is different from our study in several aspects. The first difference is the commodity portion: this study is focused on the integrated air freight movement between airports, sorting centers, collection and distribution centers, instead of the last miles which the good distribution mainly need to consider. The second difference is that integrated carriers usually have containerized products, while general goods movement for distribution usually does not use containers. The third difference is in the product value and deliver time window: the products from integrated air freight carriers are usually low weight with high value, and the deliver time window are serious limited. Missing the deliver window will incur compensation to the customer. For other
commercial products distribution, they are relatively lower in value and the delivery time window is not very restrictive in most cases. The fourth difference is the network system: BART system is a trunk line in Bay Area, which does not have direct connection for distribution, which needs to be connected by other mode such as Electric Vehicles (EV). The passenger rail system considered by Nuzzolo et al has a better network connection. However, this does not mean that the BART system could not be used for distribution. In fact, it could be used for such purpose in densely populated areas such as downtown areas of Berkeley, San Francisco, Oakland, and Richmond.

In terms of air freight demand data, the study conducted by Wei (2009) identifies the major data resources of California. He discusses the accuracy and consistency of this data, and concludes that the data indicate the important role of air freight in the California economy. Therefore, it is our belief that there should be a higher level of investment in the air cargo industry in California.

In the *Comparative Evaluation of Rail and Truck Efficiency on Competitive Corridors* conducted by Federal Railroad Administration (ICF International, 2009), it is demonstrated that the rail system usually achieves 2 to 5 times the efficiency of trucks. Although there is consistent effort made to improve truck efficiency, rail systems still maintain an unbeatable advantage in terms of lower emission generation.

Work by Bozicnik (2007) studied the Light-combi project in Sweden, Cargo Sprinter in Germany, and the Mobiler system in Switzerland. The analysis proved that success of intermodal transport can be achieved by going through certain barriers, provided that interdisciplinary support is assured. The work also suggests that the ideal freight transport technology for small shipments and/or short and medium distances would be a combination of a truck (high flexibility) on the rail (mass production).

Work in the reliability of rail network by Vromansa, et al (2006) suggests that the reliability of a railway system depends on time headway. The assessment of reliability is quite complicated, involving measurements of homogeneity, heterogeneity, and headway. The degree of reliability increases with homogeneous service and reduced time headway.
Delucchi (2000) suggested in his *Environmental Externalities of Motor Vehicle Use in the U.S.* that the marginal impact is increasing with existing pollutant levels. The perceivable impact includes human illness, visibility reduction, and agricultural losses, among others. Although there remains considerable uncertainty in all stages of modeling the cost of damages, the results support cost-benefit and pricing analyses to a large extent. The estimation of external costs has been used for comparing the social costs of different transport technologies or modes, evaluating the trade-offs between various environmental impacts, and analyzing policies.

Holguin et al (2009a, 2009b) studied road pricing issues and off-hour delivery strategies. It is optimal for transportation system efficiency if more drivers travel during off-hours. But this requires a certain level of incentive for road users. The research highlighted that, for best results, delivery time decisions should be jointly made between carriers and receivers. Maintaining carrier-receiver consistency is also a requirement. Without large amounts of data, the discrete choice model can be calibrated and utilized for planning purposes. However, with sufficient data, evaluation using microscopic behavioral simulation may lead to successful operation. The approximation model clearly indicates that, for a given probability of product reaching receivers during off-hours, the joint market share will be primarily determined by the proportion of “short” tours. This, since the probability of all receivers agreeing to off-hour deliveries geometrically decreases with delivery tour length increases. On the other hand, increasing vehicle size will increase the cost, pollution, and congestion per trip, and also decrease vehicle dispatching frequency, which will decrease the overall cost, pollution, and congestion levels. The papers of Holguin (2009a, 2009b) deal with the analytical approach to searching for tradeoffs between the positive and negative impact of increased vehicle size. By converting all those factors into monetary values, the results are clearly comparable. Generally, with increasing travel demand, larger vehicles appear to be optimal.

A study by Paaswell (2009) focuses on the elaboration of the potential benefit of transporting freight with rail, aiming to convince the government and stake-holders of the importance of this mode conversion. At the same time, a site for the intermodal facility has been chosen. But it should be noticed that while choosing the site, other negative impacts could arise, such as adverse environmental impacts, including possible effects on local residents and ill or elderly
populations. Environmental justice issues and limitations on space for developing expanded warehouse capacity could also arise. We want to also emphasize that any negative impacts that a transfer yard might produce - especially regarding traffic - would be more than balanced by the negative impacts associated with any new or local development. The problem is especially severe in the case of the long, narrow, densely populated entire Long Island, NY. The outcomes seem to be left in question.

The report of MTC on regional airport study (MTC, 2011) presented the results from extensive study conducted on Bay Area regional airports. The main objective of the projects was to redistribute the demand of the three major airports (SFO, OAK, SJC) through policy to balance with their capacity for maximum use of the airport facility in air traffic management. Currently, regional air cargo shipments (based on 2009 operating statistics)percentage for the three major airports are: SFO serves 43%, OAK serves 52%, and SJC serves 6%.

It also forecasted the demand for each airports up to 2035 to fit the requirement of MTC’s long term planning. Air cargo is forecasted under the base, low and high scenarios are shown in Figure 2.1 and Figure 2.1. They were developed by MTC through consulting with a range of recent long-term forecasts from various industry experts, with adjustments to reflect current economic conditions. SFO’s share of Bay Area air cargo demand would grow to 51%, which is largely due to the projected increase in international air cargo, while OAK’s share would drop to 43%. This forecast implies that more ground access to SFO will be required. With the increasing traffic congestion on Bay Bridge and Highway 101, some alternative for airport ground access to handle the demand would be necessary. This is also a great opportunities for shipping those products with BART system. Now, people begin to think about modifying BART system for some direct service with higher operating frequency as we suggested before (Sivakumaran, 2009b), which has been recognized as the highest benefit-to-cost ratio and thus the highest priority transportation projects in Bay Area. The approach will definitely reduce BART travel time for those direct service lines and further increase BART’s capacity for passenger movement. The further increased capacity and reduced travel time would be more favorable for air freight movement.
Since last year, several other State DOTs including Texas have begun thinking about using regional rail system for combined passenger and freight movement. Most recently, *Freight on Transit Delphi Study* is started in the University of Toronto. Urban freight movement activities
there generate over 20% of road traffic in the Greater Toronto and Hamilton Area and result in pavement damage, congestion, pollution and noise. In order to reduce these effects, alternative strategies must be explored through using lower impact modes such as walking, cycling and public transit. Understanding those impacts requires a collaboration across a range of fields including public transit, logistics, and planning and other stakeholders. The goals of the projects are to guide future research, design possible implementation strategies, and identify key challenges and opportunities related to freight and transit integration.
Chapter 3. Review of Economic Study

The last phase of the project focused on an economic analysis based on some assumptions made for the BART system infrastructure (Figure 3-1). Four alternatives, A1, A2, B1, and B2, were proposed and compared to the status quo of truck-only transport (Lu et al, 2007; Sivakumaran, 2008, 2009a, 2009b).

Alternatives A1 and A2 considered only minor capital investment, while Alternatives B1 and B2 assumed far greater capital investment, including a jointly operated BART/FedEx facility at another local distribution center in Oakland. However, Alternatives A1 and B1 make use of FedEx long-haul trucks for all goods movement, while Alternatives A2 and B2 utilize electric FedEx delivery trucks for local transshipments. Truck VMT, FedEx operating costs, BART operating costs, and CO2 emissions are determined for the status quo and each alternative.

Analysis shows not only that significant truck VMT savings can be accrued from mixed-goods service, but that upon passing a critical demand threshold, such service can be both...
profitable for passenger rail systems and cost-effective for air cargo carriers. If freight demand for a rail alternative is high enough, this may even lead to cross-subsidization, where in fact freight movement could help subsidize the movement of passengers. This would lead to a decrease in BART’s financial dependence on public subsidies, making the agency much more economically viable. Profits could potentially be used to improve connectivity to the BART system for increased ridership, for example, which would lead to improvements in both passenger and freight services for BART.

The following Table 3-1 is the preliminary estimation of FedEx demand between some ODs (Origin Destinations). However, this does not represent the total demand, since demand between SFO, OAK and SJC Airports are not included.

<table>
<thead>
<tr>
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<th>1a: RHV</th>
<th>2a: HWD</th>
<th>3a: LVK</th>
<th>5a: CCR</th>
<th>6a: SFO</th>
<th>7a: SQL</th>
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<tr>
<td>4a: From OAK</td>
<td>36,600</td>
<td>27,600</td>
<td>25,800</td>
<td>26,400</td>
<td>51,000</td>
<td>31,800</td>
</tr>
<tr>
<td>4a: To OAK</td>
<td>120,000</td>
<td>43,800</td>
<td>198,000</td>
<td>102,000</td>
<td>153,000</td>
<td>72,000</td>
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Table 3-1 Origin-Destination Demand Matrix (lbs.)
Table 3-2 Summary of the Scenarios Considered

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<tr>
<td>Little capital investment</td>
<td>Little capital investment</td>
<td>Electric trucks for local transshipments;</td>
</tr>
<tr>
<td>CTV5 Trucks for local transshipments;</td>
<td>Electric trucks for local transshipments;</td>
<td>Existing BART yards, stations and maintenance areas for access point;</td>
</tr>
<tr>
<td>Existing BART yards and maintenance areas for access point;</td>
<td>Existing BART yards, stations and maintenance areas for access point;</td>
<td>Dedicated freight train</td>
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<td>Dedicated freight train</td>
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<tr>
<th>B</th>
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<tbody>
<tr>
<td>CTV5 Trucks for local transshipments;</td>
<td>Electric trucks for local transshipments;</td>
<td>BART connection between OAK and Coliseum Station;</td>
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<tr>
<td>BART connection between OAK and Coliseum Station;</td>
<td>BART connection between OAK and Coliseum Station;</td>
<td>Certain capital investment for retrofitting of existing BART stations for goods movement;</td>
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<tr>
<td>Certain capital investment for retrofitting of existing BART stations for goods movement;</td>
<td>Certain capital investment for retrofitting of existing BART stations for goods movement;</td>
<td>Dedicated freight train</td>
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<td>Dedicated freight train</td>
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The BART system network, its stations, yards, tail-track, shops, and their schematic relationship to FedEx collection/distribution centers are depicted in Figure 3-2 for scenarios A1 and A2, and in Figure 3-3 for scenarios B1 and B2
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<th>San Jose</th>
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<tr>
<td>H</td>
<td>Hayward</td>
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<tr>
<td>O</td>
<td>Oakland Airport Hub</td>
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<tr>
<td>S</td>
<td>Near SFO airport</td>
</tr>
<tr>
<td>S</td>
<td>South San Francisco</td>
</tr>
<tr>
<td>C</td>
<td>Concord</td>
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<td>L</td>
<td>Dublin</td>
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Figure 3-2. Mixed-goods BART network in Alternatives A1 and A2

Figure 3-3. Mixed-goods BART network in Alternatives B1 and B2
The main results are plotted in Figure 3-4 ~ Figure 3-12, corresponding to the Status Quo, Alternative A, and Alternative B. The level of subsidy required will simply be the difference between the total cost of a given alternative and the total cost of the status quo. Any years which indicate a negative level of subsidy indicate that no subsidies are required; rather, opportunities arise for BART profits and FedEx savings.

For Alternative A, which requires minimal capital investment, some subsidy is required throughout the timeline, roughly $3M each year. However, tremendous savings in truck VMT can be achieved. The cumulative truck VMT savings over the analysis period amount to nearly 60 million VMT. This translates to more than 60,000 tons of CO₂ emission savings.

For Alternative B, which requires more significant capital investment but eliminates one of the transshipments required in Alternative A, even greater savings in truck VMT are achieved. The cumulative VMT savings amount to more than 100 million VMT, which translates to more than 110,000 tons of CO₂ emission savings. Perhaps most interestingly, no subsidy is ever required for Alternative B. Thus, if container demand is sufficient, BART mixed-goods service can both be profitable for BART and beneficial for FedEx solely from a fiscal perspective. The exact levels of profit for BART and savings for FedEx will simply depend on a mutually agreed-upon price for transported containers. Assuming a discount rate of 5 percent, the accumulated amount of total cost savings compared to the status quo amounts to roughly $100M. These savings can be channeled towards recovering the initial capital investment, as well as towards improvements in passenger service, which can further incentivize transit ridership.

However, note that other social benefits exist that are not included here, such as reduced congestion, noise, particulate matter reduction, and increasingly economical land use. Government agencies must weigh all of these benefits against any required subsidies or start-up costs in order to determine whether or not mixed-goods service is worthy of pursuit.
Figure 3-4 Truck VMT (Vehicle Miles Travelled) for Different Alternatives; the VMT Reduction can be Inferred

Figure 3-5 CO2 Emission for Different Alternatives; Emission Reduction Can be Inferred Accordingly
Figure 3-6 FedEx Cost for Different Alternatives

Figure 3-7 BART Cost for Different Alternatives
Figure 3-8 Total Cost for BART and FedEx using Different Alternatives

Figure 3-9 Minimum Subsidy Required for Different Alternatives
(Negative Subsidy Indicating Net Revenue Gained)
**Figure 3-10** Comparison of the Numbers of Accidents for Truck Operations for Different Operation Alternatives of FedEx

**Figure 3-11** Comparison of Accident Costs for Different Truck Operation Alternatives of FedEx
Figure 3-12 Maintenance Cost to FedEx using Different Alternatives
Chapter 4. Reliability for Air Freight Movement

The reliability of service is critical to integrated freight carriers, particularly for fixed time-window-delivery express services. The loss of reliability is very expensive to those carriers. The reliability could be quantified as percentages of services that can meet the limited or fixed time-window-delivery requirement. The integrated freight carriers can, in principle, develop good operational logistics for delivering or shipping products such as arranging for night flights instead of peak-hour flights. However, the main problem lies in the interaction with the customer on the roadways. In the Greater Bay Area traffic network, the critical links are the cross-bay bridges and the Highway 24 Caldecott Tunnel. In case of an incident/accident, traffic will be blocked and delayed. Those links were all in the list of significant congested corridors as reported in Eisele et al (2011).

The Bay Bridge carries 270,000 vehicles per day, and can be closed due to a serious incident or maintenance/construction. During a closure, trucks need to re-route all the way down to the San Mateo Bridge in order to move goods between San Francisco and Oakland. Obviously, this adds significant labor, fuel, and time overhead.

As discussed with FedEx engineers on February 22, 2010, there some major changes to FedEx’s operational scheme will take place in April 2010. These will include:

- A new FedEx flight from OAK to Tokyo, which involves overnight delivery from SFO to OAK. It will require adding at least 3 trucks per night in addition to the original 7-8, 3 nights per week. Freight can leave SFO after 11 p.m. and arrive in OAK before 3:30 a.m. The flight to Tokyo departs OAK at 4:30 a.m., leaving one hour for container handling at SFO Airport.

- At least 6 additional trucks will travel from SFO to OAK daily making more than 3 deliveries during peak hours, beginning at 5 p.m.

The modification can potentially provide an additional demand source for the proposed BART service, as well as present an opportunity for a small-scale demo/operation. BART ‘s Millbrae Tail Track (to SFO) and the Coliseum Station (to OAK) would be the preferred access
BART can be used to avoid time or financial or both losses due to unreliable traffic congestion or other factors, such as incidents/accidents. In this chapter we consider transportation delays and emergencies.

4.1 Transportation Delays

The BART system is well coordinated electronically and free from congestion, and therefore maintains a high level of on-time arrivals and departures. Truck travel time, however, has much higher variability. Despite the good performance of trucks during light traffic, on-time delivery is the most critical issue for a mail service business. Travel time reliability is determined by worst case scenarios -- delays during traffic congestion. Scheduled travel time for trucks is usually calculated as follows:

\[
\text{Scheduled Travel Time} = \text{Expected Travel Time} \times \text{Flexibility Factor}
\]

The expected travel time for trucks is time specific. For example, longer travel time is expected during peak hours around 5 p.m. BART travel time is fixed. Under regular traffic conditions, similar expected travel time is required for both modes. During peak hours, time required on BART is comparatively less.

In the case of off-peak operations, we have been discussing the probability of using BART for freight movement during non-passenger hours, such as between 4-5 a.m. In this case, non-stop transport can be expected, reinforcing BART’s travel time advantage.

In addition, truck transport assumes a high variability in travel time. FedEx is adopting a flexibility factor of about 1.35 times the expected travel time to accommodate unexpected delays, which is to say, a 50-minute expected travel time will require scheduling for 67.5 minutes to incorporate the flexibility factor.

The flexibility factor does not apply to BART. The BART schedule is usually accurate, especially on weekdays. The not-on-schedule rate is less than 5 percent, a large percentage of which is weekend operations and irrelevant to our case. Compared with the unpredictability of
road traffic conditions, BART’s delays are usually pre-scheduled and therefore adjustable. Most of the time, the delay is 10-20 minutes, about one headway. As a result, departing one headway before schedule is sufficient for the flexibility requirement.

4.2 Emergency Situation Handling

Closing the Bay Bridge adds cost and inconvenience, as discussed before. An abrupt closure has a more serious impact, as the schedule and rerouting cannot be adjusted before departure. The freight may miss its flight or its promised delivery date, which is one of the most unfavorable situations for a mail service company.

Serious as the consequences are, the frequency of Bay Bridge closures is higher than expected. On October 28, 2009, three pieces of Snapped-Cable which had been used during an emergency repair to the Bay Bridge’s cantilever section, (fabricated over the previous Labor Day weekend), snapped and crashed onto the deck of the span, striking three vehicles and forcing closure of the region’s busiest bridge. The closure lasted six days, and still faced another closure for more permanent repairs.

On the other hand, the BART system does not face the problem of occasional shut downs. In fact, it has maintained relatively low accident rates, with occurrences only once in 5 to 10 years, thereby saving the majority of emergency response efforts for road travel.

Although there is no quantitative assessment for reliability levels, it has been shown through many years operation that the BART system maintains one of the highest levels of on-time reliability. Switching to the BART system will save the cost of rerouting, as well as cutting losses due to unsatisfactory service.
Chapter 5. Preliminary Social Impact Analysis

With the onset of the 21st century, the social costs associated with increasingly congested traffic flow have become a significant social problem carrying increasingly negative impacts that require immediate solutions. The social costs are usually referred to as externalities. Negative impact on three aspects are discussed: road traffic congestion (delay, safety and land use), energy efficiency, and environmental pollution concerns. The monetary cost of emissions is calculated. Strictly speaking, energy consumption and efficiency are closely related to environmental issues, which has gradually garnered more and more attention in transportation planning. The most recent study on environmental impact, which focused on emission pollution and energy efficiency, will be discussed separately.

5.1 Road Traffic Impact

In the Bay Area, road traffic is the main mode of travel. Therefore, improving road traffic performance is a major incentive for promoting an alternate mode of transportation. Relieved traffic load allows for improved traffic efficiency, and also solves long-existing land use problems.

5.1.1 Road Traffic Relief

Converting truck transportation into railway transportation will contribute to major road traffic relief, especially on highways. This directly leads to reductions in transportation time and improvements in efficiency for the entire community.

A high percentage of improvement usually can be achieved by a relatively reduced traffic load, especially during peak hours. The marginal cost of public transportation is increasing rapidly as the roadways approach full capacity, which is to say, when traffic flow is high (i.e., during peak hours), transportation speed is highly sensitive to even minor additional traffic load. As a result, the improvement in transportation efficiency is much better (up to 5 to 6 times better) than what is forecast simply by the percentage of reduced traffic load. A 2004 study of delay versus VMT during weekday p.m. peak hours throughout the state of California, found an 8 percent VMT increase, resulting in a 66 percent delay.
Therefore, the traffic relief resulting from switching freight movement onto the BART system can significantly benefit the entire society.

Switching transportation modes is one of the most cost-effective ways to reduce freeway congestion, especially when compared to a freeway expansion option, which not only carries a high price tag, but involves potential-induced demand. The expansion issue also raises the issue of limited land resources.

5.1.2 Land Use

Reducing road traffic load provides an alternative solution to today’s currently inadequate freeway capacity and reduces the need for expensive freeway expansion.

It should be noted that there are two problems freeway expansion faces. First and most obviously is that the necessary land resources are insufficient. Freeways are usually surrounded by residential, commercial or municipal buildings, and farmland, which cannot be eliminated. Studies based in the greater Lansing area in Michigan show that a loss of $300 million in farmland can be expected by the year 2010. The indirect negative impact makes plans for freeway expansion an eternally controversial issue and difficult to implement.

Secondly, expanding a freeway system seldom improves traffic conditions. This is due to the induced traffic load, which is to say, with the expansion of a freeway, a greater number of vehicles will tend to use it. The improvement is not efficient, and in some cases, has the opposite effect.

Therefore, a change in traffic modes using, in this case, the BART system, is the optimal solution. It will contribute to improvements in both transportation and land use efficiency.

5.1.3 Traffic Safety

When comparing these transportation modes terms of community security, accident risk is a concern. The accident rate for trucks has been discussed previously and is also presented in the appendix. It is approximately $1.6 \times 10^{-6}$, while with large numbers of trucks, the actual number of accidents is significantly high. The number of truck crashes in 2006 was 368,000. The accident rate of the BART system is significantly lower -- about 1 in 5 years.
The community security discussed here covers drivers as well as pedestrians. Not only is driver security directly related to accident rates, the benefits of pedestrian safety for improved transportation security can be applied to a much larger scale that includes almost everyone in the community. It is important to realize that accidents can be fatal, so the true cost cannot be expressed solely in monetary terms. Improvements in crash prevention are, by all means, desirable. This is believed to be a great contribution to overall social security.

5.2 Energy Efficiency

As introduced in the previous section, a comparison of energy type and amount by the two transportation modes is illustrated below. As mentioned before, BART is powered by electricity, while trucks are usually powered by fuel combustion. However, the electricity BART system uses is not completely green as shown in Table 5-1.

\[
\text{Total Fuel Used: BART/TRUCK} = \frac{\text{Percentage of Fuel concerned in BART}}{\text{Energy efficiency of BART}} \times \frac{\text{Percentage of Fuel concerned in truck}}{\text{Energy efficiency of truck}}
\]

In the Table 5.2, we traced back the resources of electricity in the S.F. Bay Area, and broke them up into renewable resources (wind, nuclear, etc.) and fossil fuels (fossil fuels take up to 47 percent, with a declining trend). The energy efficiency of trucks is usually 30 percent more than that of trains, the result of friction. Therefore, the fossil fuel used to generate the same momentum for the BART is about 14 percent less than that of truck, without considering route difference. In practice, BART routes are shorter than truck routes because BART is operated underground and along direct routes between stations.
Table 5-1. California Electric Energy Resources and Emission for 1997 - 2008

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<tr>
<th></th>
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<td>California Generation plus Net Imports:</td>
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<td></td>
<td></td>
<td></td>
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<td>Hydroelectric</td>
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<td>275,803</td>
<td>280,496</td>
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<td>279,252</td>
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<td>288,681</td>
<td>294,916</td>
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<td>Nuclear</td>
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<td>41,627</td>
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<td>43,533</td>
<td>34,353</td>
<td>35,943</td>
<td>30,241</td>
<td>36,155</td>
<td>32,036</td>
<td>35,692</td>
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<td>3,602</td>
<td>3,183</td>
<td>3,881</td>
<td>4,133</td>
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<td>4,283</td>
<td>4,209</td>
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<td>Oil</td>
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<td>123</td>
<td>55</td>
<td>449</td>
<td>379</td>
<td>81</td>
<td>103</td>
<td>127</td>
<td>148</td>
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<td>Gas</td>
<td>74,341</td>
<td>82,052</td>
<td>84,703</td>
<td>106,878</td>
<td>115,447</td>
<td>92,346</td>
<td>94,135</td>
<td>104,707</td>
<td>96,478</td>
<td>107,468</td>
<td>118,413</td>
<td>122,594</td>
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<tr>
<td>Geothermal</td>
<td>11,950</td>
<td>12,554</td>
<td>13,251</td>
<td>13,456</td>
<td>13,525</td>
<td>13,396</td>
<td>13,329</td>
<td>13,494</td>
<td>13,868</td>
<td>12,982</td>
<td>12,999</td>
<td>12,907</td>
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<tr>
<td>Biomass</td>
<td>5,701</td>
<td>5,266</td>
<td>5,663</td>
<td>6,086</td>
<td>5,701</td>
<td>6,192</td>
<td>6,060</td>
<td>6,076</td>
<td>6,072</td>
<td>5,691</td>
<td>5,575</td>
<td>5,728</td>
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<td>3,604</td>
<td>3,242</td>
<td>3,546</td>
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<td>4,084</td>
<td>4,420</td>
<td>5,723</td>
<td>5,724</td>
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<td>Solar</td>
<td>810</td>
<td>839</td>
<td>838</td>
<td>860</td>
<td>836</td>
<td>851</td>
<td>759</td>
<td>741</td>
<td>660</td>
<td>616</td>
<td>668</td>
<td>724</td>
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<tr>
<td>Other</td>
<td>896</td>
<td>230</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
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<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>25</td>
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<tr>
<td>Specified Coal Imports</td>
<td>24,838</td>
<td>31,836</td>
<td>32,726</td>
<td>33,620</td>
<td>32,608</td>
<td>32,543</td>
<td>32,675</td>
<td>34,097</td>
<td>33,612</td>
<td>27,713</td>
<td>27,977</td>
<td>21,969</td>
</tr>
<tr>
<td>Other Imports</td>
<td>52,720</td>
<td>47,563</td>
<td>49,487</td>
<td>26,774</td>
<td>32,325</td>
<td>55,051</td>
<td>52,726</td>
<td>57,192</td>
<td>53,469</td>
<td>52,001</td>
<td>64,240</td>
<td>76,089</td>
</tr>
</tbody>
</table>

|                      |       |       |       |       |       |       |       |       |       |       |       |       |
| Hydroelectric        | 16%    | 18%    | 15%    | 15%    | 9%     | 11%    | 13%    | 13%    | 12%    | 14%    | 16%    | 9%     |
| Nuclear              | 15%    | 15%    | 15%    | 16%    | 13%    | 13%    | 13%    | 10%    | 13%    | 11%    | 12%    | 11%    |
| In-state Coal        | 1%     | 1%     | 1%     | 1%     | 1%     | 2%     | 2%     | 1%     | 1%     | 1%     | 1%     | 1%     |
| Oil                  | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     |
| Gas                  | 29%    | 30%    | 31%    | 38%    | 43%    | 34%    | 34%    | 36%    | 33%    | 36%    | 39%    | 40%    |
| Geothermal           | 5%     | 5%     | 5%     | 5%     | 5%     | 5%     | 5%     | 5%     | 4%     | 4%     | 4%     | 4%     |
| Biomass              | 2%     | 2%     | 2%     | 2%     | 2%     | 2%     | 2%     | 2%     | 2%     | 2%     | 2%     | 2%     |
| Wind                 | 1%     | 1%     | 1%     | 1%     | 1%     | 1%     | 1%     | 1%     | 1%     | 1%     | 2%     | 2%     |
| Solar                | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     |
| Other                | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     | 0%     |
| Specified Coal Imports | 10%    | 12%    | 12%    | 12%    | 12%    | 12%    | 12%    | 12%    | 9%     | 9%     | 7%     |        |
| Other Imports        | 21%    | 17%    | 18%    | 10%    | 12%    | 20%    | 19%    | 20%    | 19%    | 18%    | 21%    | 25%    |

|                      | 60%    | 58%    | 96%    | 49%    | 43%    | 53%    | 53%    | 51%    | 53%    | 53%    | 50%    | 52%    |
| Emission             | 40%    | 42%    | 44%    | 51%    | 57%    | 47%    | 47%    | 49%    | 47%    | 47%    | 50%    | 48%    |
Table 5-2. Energy Resources and Efficiency Factors

<table>
<thead>
<tr>
<th>Energy Resource</th>
<th>BART</th>
<th>Truck</th>
<th>Total Fuel Used: BART/TRUCK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electricity</td>
<td>Fuel Combustion</td>
<td></td>
</tr>
<tr>
<td>Renewable Resource</td>
<td>53%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Fossil Fuel</td>
<td>47%</td>
<td>100%</td>
<td>0.141</td>
</tr>
<tr>
<td>Energy Efficiency</td>
<td>1</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Source: Existing Energy Resources in the Bay Area (The California energy Commission, 2007, 2009);

It can be observed that an impressive improvement of energy efficiency can be achieved by switching transportation modes. In addition, a majority of BART’s energy resources are renewable, important since energy resources, especially fossil fuels, are increasingly problematic resources.

The percentage of renewable energy is increasing for both transportation modes. If a longer period of time is considered, it could be that within 10 years the percentage of renewable energy used in electricity generation will increase significantly. The trend can be observed over the past 10 years, due to maturing technology and resource shortages. On the other hand, the energy switch by the trucking industry will be a longer more gradual process. This is largely because the technology has to further mature before it’s used on a large scale. At the same time, the shift in energy resources will lead to the replacement of cars. But considering the large amount of car ownership, the switchover will be slow and difficult.

Furthermore, taking into account the energy use efficiencies for the BART train and trucks as shown in Table 5-2, the predicted fuel saving and energy saving comparison for the four scenarios in the considered time horizon are shown in Figure 5-1 and Figure 5-2.
Figure 5-1. Predicted annual Gas (Gal) saving vs. Status Quo for the 4 alternatives

It can be observed that an impressive improvement of energy efficiency can be achieved by switching the transportation modes. In addition, a major part of energy resource of BART is renewable, which fits well into the current running out of energy resources, especially fossil fuels, problem.

The percentage of renewable energy is increasing for both the transportation modes. If a longer period of time is considered, it should be predicted that in recent 20, or maybe up to 50 year, the percentage of renewable energy used in electricity generation can increase significantly. The trend can be observed in the past 10 years, due to the maturing technology and the shortage of resources as impetus. On the other hand, the switch of energy resource of trucks will take a longer and slower process. This is largely because the technology has much room to be improved to put into large scale use. At the same time, the shift of energy resource leads to the replacement of cars. Considering the large amount of car ownership, the replacement is also a slow and difficult process.
As a result, changing traffic modes is a good solution to the current energy situation. The best time to do it is now.

5.3 Environmental Impact

The environmental issues considered here include noise and emission pollution--the most harmful factors to human life.

5.3.1 Noise

Noise pollution affects quality of life, as well as work efficiency. Road transportation is responsible for most noise in urban areas, especially during peak hours, due to vehicle’s engine, friction, and other factors. On the other hand, most of the BART system is underground or in relatively remote areas where the noise effect is minimal. At this point, the BART system generates almost no noise pollution.

5.3.2 Greenhouse Gas (GHG) emission

The concepts of direct GHG emission and indirect GHG emission are adopted here. Because we are trying to consider the entire picture, it is more convincing to consider emission output due not only to operation, but also to those emissions that occur during the energy generation process. This part of our work is a further refinement and improvement of...
previous work (Sivakumaran, 2009b).

GHG emissions due to fuel combustion are considered direct emissions. In this study, we are considering the direct GHG emissions to be CO$_2$ truck emissions. However, because the energy resources used to generate electricity and operate the BART system, the process could also involve fuel combustion and this portion of the emissions discussion will be considered as indirect CO$_2$ emissions.

By simple analysis, a relationship can be obtained below.

$$Total \, GHG = GHG \, Generating \, Rate \times \frac{Fossil \, Fuel \, Combusted}{Energy \, Required \times \frac{Percentage \, of \, Energy \, by \, Fossil \, Fuel}{Energy \, Efficiency}}$$

From existing data, the energy efficiency of trains is about 70 percent higher than that of trucks; the percentage of fossil fuel used to generate electricity is about 45 percent lower. Therefore, GHG emissions from BART are about 13.5 percent that of trucks. Emission reduction (refer to appendix), is on the scale of $10^6$ lbs., and $10^7$ lbs over 20 years.

Details assessing emissions will be presented later. It should be noted that environmental pollution is usually irreversible. Currently, an increased negative impact of social significance is emerging, which is alarming to the community. Emissions should be prevented from increasing at the current rapid rate. Measures must be taken as early as possible.

5.3.3 Particulate Matter (PM) Caused by Tire Friction

In addition to GHG, the rubber particles released by truck tires is due to friction and is a significant source of PM in air pollution. The amount of PM due to friction is even larger than that due to diesel combustion emissions. PM effects health (asthma, lung cancer, etc.) and the ozone layer. A switch in transportation modes from trucks to rail would eliminate the friction process, generating a zero level of PM emission. This could be a large step in reducing the negative environmental impact of transportation.

5.3.4 Quantification of Environmental Impact

This section will focus on the environmental impact of vehicle emissions. Different scenarios will be analyzed and compared. For comparison purposes, emissions will be
converted into monetary value. The respective converting rate will reflect the social impact.

**Methodology**

The methodology in this section is similar to that of the analysis of carbon dioxide emissions in the previous section. While CO₂ is not a pollutant, its respective social cost is also calculated here. The discussion of each emission substance is also based on direct and indirect emission, of which the emission factors are the same as that adopted in the previous section. This is because the indirect emission factor is calculated through energy efficiency, which is the same for all the substances.

**Types of Emissions Considered**

Substances discussed in this section include:

- carbon dioxide (CO₂), as mentioned before, although carbon dioxide is not a pollutant per se; it is a greenhouse gas, which plays a role in global warming;
- Nitrogen oxide (NOₓ): a precursor of smog and acid rain;
- Carbon monoxide (CO): reduces the blood's ability to carry oxygen and is poisonous and dangerous to people with heart disease.
- Particulate matter (PM₁₀): causes respiratory disease in humans and animals;
- Sulphur oxide (SOₓ): also a precursor of smog and acid rain;
- Volatile organic compound (VOC): similar atmospheric and health effects.

**Emission Factors**

From existing documents, the emission factors adopted in this project are as follows:

**Table 5-3: Pollutant Emission Factors (Source: Oxford Economic Research Associates, 1999; Matches, 2009)**

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>PM10</th>
<th>SO2</th>
<th>Nox</th>
<th>VOC</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission Factors</td>
<td>0.0022</td>
<td>0.00205</td>
<td>0.031</td>
<td>0.002514</td>
<td>0.00668</td>
</tr>
</tbody>
</table>

**Social and Environmental Cost Factors**

A study was conducted to analyze the cost induced per unit weight of emission. The impact of emissions is not linear with respect to emissions quantity, as it is obvious that the cost per unit extra amount of emission is increasing. As a result, the cost can be a complicated function with respect to environmental pollution at the time under discussion.
(the analysis of which may even involve programming). However, the overall environmental situation is not clear for the future, considering the commitment by almost every country in the globe to reduce emissions. Despite that commitment, industrialization is increasing at an alarming pace. The social and environmental costs are calculated separately for low and high pollution levels. Representative social and environmental costs discussed here include:

**Table 5-4: Emission Unit Cost Factors (Source: Delucchi, 2000)**

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<tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
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<td>CO</td>
<td>CO</td>
<td>0.00</td>
<td>0.04</td>
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<td>NOx</td>
<td>Nitrate</td>
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<td>PM10</td>
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<td></td>
<td>NO2</td>
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<td>Total for NOx</td>
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<td>SOx</td>
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<tr>
<td>VOC</td>
<td>Organic</td>
<td>0.00</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PM10</td>
<td></td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>VOC+Nox</td>
<td>Ozone</td>
<td></td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>CO2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Health costs:** derived from the value of lost work days, restricted activity, tolerating certain symptoms, and so on;

**Reduced Visibility:** derived from the diminishing enjoyment of scenic vistas and increased danger of traveling in smoggy areas; reduced visibility also leads to the increased danger of traveling;

**Crop Loss:** impact of air pollution on agricultural production.

There are other costs, such as material damage and forest damage, which are not calculated here.

**Analysis Result**

These calculations are based on the VMT (Vehicle Miles Travelled) during truck activities.
using various alternatives: A1, A2, B1 and B2 (Sivakumaran et al, 2008, 2009a, 2009b), as reviewed in the previous section.

The figures are only representative, as some other costs carrying a negative impact are not included. Some of them are difficult to quantify. The results can be used to qualitatively indicate the following:

(a) The cost of social well-being and community life due to pollution. The difference between low and high pollutant status indicates the high risk associated with a worsening environment;

(b) The cost is non-cumulative, i.e., the rate of the cost due to emissions per year is increasing (accelerating essentially, see Figure 5-3) at the scale of a million dollars, which reveals the disturbing fact that we may be losing tens of millions of dollars per year without even noticing.

The results shown in Figure 5-3 should be compared with those of CO₂ only in Figure 3-5.

The accelerating growth of factors with a negative impact implies that, sometime in the future, the negative impact could be out of control. Therefore, before that moment, we should do everything we can to prevent it from happening. The best time to start is now. Serious emission-reduction procedures must be implemented by all means. They are absolutely necessary and the timing is urgent.
5.4 Further Remarks

All that was discussed above is only the direct or nearly direct effect on the environment. However, the combined effect in the long run may have even more significant social consequences. This cannot be assessed at this stage.

On the one hand, once the freight-on-BART system is implemented, this transportation mode is not only applicable to FedEx, but also relevant to the products of some manufacturers, which are light in weight but high in value. There is a large customer demand with these products, such as computer parts and medical or pharmaceutical supplies. These companies could benefit from the new mode, and BART revenues could increase as well.

On the other hand, with the economic benefits taken into consideration and with the accumulation of revenue, the BART system could improve its customer service to become more competitive in customer transport. There is a clear trend that with the improvement of customer service, more people could switch off the roadways and onto the rails. Hopefully, in the end, BART will move beyond of its negative revenue problems ➔ decreased service level ➔ losing customers ➔ negative revenue circle.
Furthermore, with increased revenue, the BART system can be modified to improve its working efficiency, such as:

- Improving the capacity of the BART system: adding by-passing track near critical stations;
- Adopting new control and communications systems and control logistics;

All the above would benefit BART and will, in turn, magnify the social benefit of rail systems.

As a result, once the initial investment is made, the social and economic benefits will follow. It is believed that the system will be moving into an optimal direction with increasing demand and operational scale in amount and regional area.
Chapter 6. Infrastructure Feasibility

For practical operations, the feasibility of infrastructure and equipment has to be justified. In the following section, feasibility plans regarding this issue will be proposed, and the corresponding budget, benefits, and disadvantages will be discussed.

The main point here is to share track for both passenger and freight movement. This is very popular in Europe but not yet in the US. As high as the development level of this model is in Europe, freight movement in the European system is in an even more advantageous business position.

The main factors for infrastructure feasibility include:

- Compatibility between BART cars and the containers subjected to the constraints of the BART system operation, safety, and security requirements;
- The BART system’s access points – yards, tail-track, and stations;
- Proximity of BART access points and the source of demand, in this case, FedEx collection/distribution centers;
- Transshipment between FedEx centers and BART access points.

We will discuss some preliminary considerations about these issues.

6.1 Proximity of BART Access Points and FedEx Distribution Centers

To achieve a convenient access point is crucial for the FedEx loading and unloading process. Firstly and most importantly is to consider the proximity between BART stations/yards/shops and FedEx collection/distribution centers. Since the FedEx Western Regional Hub at Oakland Airport is the center of all the spikes, its closest access point to the BART system would be the most critical one.

A general access point can be described as a location which has the following characteristics:

- Ground vehicle accessibility from public roads;
- Proximity of the ground vehicle to the rail for loading and unloading;
- Safety and security - isolated from public access;
- Adequate rail for BART car loading/unloading and operation (to move in the expected direction – ideally, in two directions);
• FedEx collection/distribution centers at the proximity of BART shops and tail tracks, where BART’s dedicated freight cars could be loaded/unloaded; current demand might be low but with this needs to be considered in a long-term scenario that could change as the “goods-movement-on-rail business” develops.

Secondly, to put the issue into realistic circumstances, it is necessary to discuss the possibility of constructing an extra segment of rail (approximately 100 to 150 meters in length), at the point of access in order to realize future loading and unloading needs.

Furthermore, as an extension to the project, in the future, it could be beneficial to build a bypass rail and accommodate direct transit service in order to increase the overall efficiency of the system.

Figure 6-1. BART stations, shops, tail track, and FedEx Collection/Distribution Centers

6.2 BART Cars for Dedicated Freight Movement

For non-containerized products or the those products of USPS Express Service, which use smaller containers with wheels (Figure 6-2), the freight could be directly loaded into
current BART cars, as long as they don’t have seats installed with restraints used to fix the containers to the car floor while traveling.

![USPS Containers used by FedEx are small enough to fit in BART cars](image)

**Figure 6-2.** USPS Containers used by FedEx are small enough to fit in BART cars

However, if we are going to use other FedEx containers (to be discussed later), we need to find alternative solutions for BART cars, either modifying them from retired BART cars or building new ones. The following is the approximate size of BART car:

\[ 70\text{[ft]} \times 10.5\text{[ft]} \times 7\text{[ft]} \]

Flat-bed cars, such as those used on trains for freight movement, would be ideal for container loading and unloading, and they are easy to obtain. However, BART’s operation staff needs to be able to move freely from the head to the tail of the car in case of fire or any other incident threatening safety within the closed passageway.

### 6.2.1 Suggested Modification Approach

The modification approach refers to the potential for modifying existing, but retired BART cars. Procedures may involve:

- removing the seats from the car;
- modifying the door to accommodate some (not all) larger containers without major modification of the enclosure;
- rebuilding the car (both the wall and the bed) to accommodate all standard
containers for air freight movement.

Cost for Modification

The cost for car modification is relatively small when compared to other options. The BART yard is capable of accommodating car modification work, such as occur at yards located in Richmond and Concord.

It is noted that the BART car renewal (retiring) rate will be 8 cars per month, beginning in the year 2016. Those retired BART cars could potentially be modified and used for freight movement. They all have air conditioning, which could keep for shipping exported agricultural products, such as fresh fruit, vegetables, and meat, to airports.

Expected Quantity of Retired Cars

BART is scheduling a car renewal plan in which it is projected that 700 new cars will be put into use by the year 2024.

In the schedule:

(1) The first batch of 10 pilot cars will be tested between January 2014 to June 2016;

(2) During Phase I, production is following a base contract, which includes 200 cars per year, up to the year 2017;

(3) During Phase II, an additional 500 cars will be modified. This work is to be finished in 2024.

Comparing the scheduled renewal and the cars demanded by FedEx freight, the following comparison is made in Figure 6-3:

Using this data, the retired cars can fulfill the FedEx demand beginning in 2017 forward. Even if only the base contract is considered, the FedEx demand can be fulfilled up to the year 2036. Therefore, within a 20-twenty year horizon, the modification approach suffices even if only the base contract quantity is considered. However, this is only for the short term and without considering other potential freight demands. This leads us to considering the purchase of new BART cars that are specifically designed for moving freight.
Figure 6-3

6.2.2 Purchasing Approach

Although currently the modification approach is optimal, considering its minimal cost and reutilization of existing materials, the design and purchase of new cars is still something we are considering. This is especially true when we look at the longer term. There are a series of reasons to consider this:

This case study focuses only on the air freight demand from FedEx. However, our final objective is not limited to this scenario. Once the system is adopted, potentially large markets could exist in manufacturing and agricultural arenas. The supply capacity of the existing cars will be inadequate once the service is expanded;

Although the modification cost may be lower, the cars are still subject to the wear and tear of aging, and thus maintenance costs will increase over time. Sometime later, the cars might become so costly to maintain that purchasing new cars becomes a more viable solution.

The expense for BART car modification could be taken from profits gleaned from freight movement. Once the system is operational, the facility development can be conducted progressively, according to need.
6.2.3 Standard Air Freight Movement Containers

Equipment feasibility is the part of the facility problem that is concerned with container size and equipment for transshipment--loading and unloading containerized and non-containerized products.

FedEx currently utilizes the following container types to transport their items: USPS, LD3, AYY, SAA, AMJ (Figure 6-4), and AMJ pallets. Their respective dimensions are outlined in Table 6-1.

Note that all these container types, including USPS containers, as in Figure 6-2, are moved throughout the FedEx transport chain using ball bearings; that is, items are not lifted onto pallets in order to be loaded onto trucks. Rather, containers are simply slid across platforms and aboard trucks via the casters mounted throughout the surface of the loading platforms.

Figure 6-4: FedEx Standard Air Freight Movement Containers
Table 6-1. FedEx Standard Air Freight Containers (Source: Presentation by Michael Graham of FedEx Express in June 2006)

<table>
<thead>
<tr>
<th>Container</th>
<th>Length (in.)</th>
<th>Width (in.)</th>
<th>Height (in.)</th>
<th>Dry Weight (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USPS</td>
<td>69</td>
<td>42</td>
<td>60</td>
<td>550</td>
</tr>
<tr>
<td>LD-3</td>
<td>64</td>
<td>60.4</td>
<td>79</td>
<td>970</td>
</tr>
<tr>
<td>AYY</td>
<td>62</td>
<td>88</td>
<td>79</td>
<td>1270</td>
</tr>
<tr>
<td>SAA</td>
<td>125</td>
<td>88</td>
<td>79</td>
<td>2700</td>
</tr>
<tr>
<td>AMJ</td>
<td>125</td>
<td>96</td>
<td>96</td>
<td>3700</td>
</tr>
<tr>
<td>AMJ Pallet</td>
<td>125</td>
<td>96</td>
<td>variable</td>
<td>variable</td>
</tr>
</tbody>
</table>

6.3 Transshipment

The station accessibility problem, also called the transshipment problem, is a major obstacle in the operation. The difficulty comes from two aspects: monetary cost due to reconstruction, and time cost due to operation delays.

Several factors need considering at terminals to allow for freight movement access. These include:

- Loading/unloading equipment
- BART access points
- Inventory space
- Security for closed operations

A critical factor in the ease of freight movement within terminals is the availability of access points – areas where freight trucks have access for container loading/unloading. Possible access points in the BART system include: yards, tail-tracks, shops and stations. BART yards usually have multiple tracks for consist operations, including turning around, storing cars, and building required consist. Maintenance is usually performed in shops. Yard accessibility has been discussed in more detail in the report on an earlier phase of the project (Sivakumaran, 2009b). The tail-tracks are also good candidates for access, such as the one in Millbrae. It could be used for truck access, parking, and for transshipment of containers between trucks and BART cars, if appropriate equipment is available. However, some minor modifications might be necessary for such purposes.
6.3.1. Accessing BART Stations

In the case of a BART station, the freight container should have accessibility to the platform. As a result, additional platform modification is required to meet the requirements of freight movement.

However, most BART stations have limited loading space available for freight trucks, due to their location within urban areas. For example, there would be little room for a 53 ft.-long FedEx truck to park at BART’s Embarcadero Station in downtown San Francisco. For underground and aerial stations, dedicated freight elevators will be indispensable. The former might be more expensive, since there’s the labor required to dig into the ground, as well as the need for seismic considerations, which can be cost prohibitive. The cost of an elevator for an aerial station varies with lifting distance and loading capacity. An estimation of the costs are shown in the following table.

Table 6-2. Cost (in $) of dedicated freight lifts for accessing BART aerial station(s)

<table>
<thead>
<tr>
<th>Height (feet)</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,000 lb.</td>
<td>55,900</td>
<td>61,300</td>
<td>65,900</td>
<td>69,800</td>
<td>73,400</td>
<td>76,600</td>
<td>79,500</td>
<td>82,200</td>
</tr>
<tr>
<td>5,000 lb.</td>
<td>61,900</td>
<td>67,900</td>
<td>72,900</td>
<td>77,300</td>
<td>81,200</td>
<td>84,700</td>
<td>88,000</td>
<td>91,000</td>
</tr>
<tr>
<td>10,000 lb.</td>
<td>82,500</td>
<td>90,500</td>
<td>97,200</td>
<td>103,000</td>
<td>108,200</td>
<td>112,900</td>
<td>117,300</td>
<td>121,300</td>
</tr>
</tbody>
</table>

At the same time, all these loading/unloading points (i.e., annex shop, BART yard, BART station) may require pallets or ball bearings (Figure 6-5), such that the freight containers can be moved over some area of the platform which are accessed by passengers.

Table 6-3: Required Modifications

<table>
<thead>
<tr>
<th></th>
<th>Pallets or bearings</th>
<th>Elevator</th>
<th>Modifications on platforms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annex Shop</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BART yard</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BART station</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
To achieve higher transshipment efficiency, one crane will be introduced at each transshipment point. Rolling pads are readily available from FedEx, so only modification costs need to be considered.

Based on all the above assumptions, the cost of establishing a transshipment facility is:

**Table 6-4. Transshipment Capital Cost**

<table>
<thead>
<tr>
<th></th>
<th>Cost ($)</th>
<th>Quantity</th>
<th>Sum ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annex Shop</td>
<td>15,000</td>
<td>1</td>
<td>15,000</td>
</tr>
<tr>
<td>BART Yard</td>
<td>15,000</td>
<td>3</td>
<td>45,000</td>
</tr>
<tr>
<td>BART Station</td>
<td>100,000</td>
<td>2</td>
<td>200,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>260,000</strong></td>
</tr>
</tbody>
</table>

The time required for transshipment per container is estimated as follows:
Table 6-5. Transshipment Time

<table>
<thead>
<tr>
<th></th>
<th>Time Consumed (min/truck operation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annex Shop</td>
<td>1.50</td>
</tr>
<tr>
<td>BART Yard</td>
<td>1.50</td>
</tr>
<tr>
<td>BART Station</td>
<td>2.50</td>
</tr>
</tbody>
</table>

6.3.2 Transshipment between BART Cars and Trucks

Transshipments could be conducted in several possible ways:

- Between trucks and BART trains, which could be flat-beds, flat-beds on one side, or even closed on top, such as those modified from retired BART cars.
- Between trucks, solid platforms, and BART Freight Trains

The work of Bozicnik (2007) provides some possible alternatives for the consist-containers and transshipment solutions directly between BART trains and trucks. This idea could also be applied to cases for transshipment between truck, solid platforms, and BART Freight Trains. The idea has been adopted, and preliminarily modified for our purposes. Basically, two ways exist that can be used for moving containers between BART cars and trucks: (a) pushing over and using a roll-mat or a ball bearing floor; or (b) using a flexible hydraulic crane. These two proposed solutions will be technically discussed below.

![Figure 6-6. Truck-train Transshipment Solution 1: Directly pushing, if the roller-mat or ball-bearing (see Figure 6-5) is installed on both the BART car and truck; (a) without a platform in between; (b) with a platform in between the truck and BART car](image)
Solution 1. As shown in Figure 6-6, if the roller-mat is installed on both the truck and flat-bed BART car, the container could be directly pushed (as is done at the FedEx Sorting Center at OAK) by the operation staff, provided the truck can be parked very close to the train and that the two are the same height. If not, an intermediate platform needs to be built to link the BART car and truck. This is suitable even if the transshipment truck is closed on top and on two sides, in which case the back of the truck would be used.

Solution 2. Using a Flexible Hydraulic Crane

A Flexible Hydraulic Crane, as designed in Figure 6-7, is longitudinally movable along a rail on the platform. Besides, it is flexible in yaw motion, i.e., turning around between the truck and the BART car. It picks up the container from the train, turns 180° and puts the container on the truck to finish the transshipment of one container. Then it moves longitudinally for one container length for the next operation. Such a process is completely reversible from the truck to the train.

![Figure 6-7. Side Loading Using Flexible Crane Mounted on Rail on the Platform](image)

It is also possible to build a vehicle-mounted crane, which could move longitudinally between the truck and the BART car (Figure 6-8). The concept of operation would be the same as above. In this case, the platform in between the truck and the BART car would not be necessary.
6.4 Summary

The main factors for infrastructure feasibility include:

- Compatibility between the BART cars and the containers subjected to the constraints of BART's system operation requirements;
- BART system access points;
- Proximity of BART access points and the source of demand, in this case, the FedEx collection/distribution centers;
- Transshipment between FedEx centers and BART access points.

Transshipment includes the following two main procedures: the truck carries the container between the FedEx center(s) and the access point; and moving a container between a BART car and a truck. For BART yard, shop, and tail-track, a truck can directly access the BART car. The transshipment can be accomplished by: (a) pushing over on a roll-mat and ball bearing; or (b) being lifted with a flexible hydraulic crane. It has already been shown that transportation on BART, as well as transshipment between a truck and BART, is operationally feasible. Most of the necessary equipment, such as cars and rolling pads, are already available for modification and installation. In addition, additional infrastructure and equipment cost is manageable. However, refining the efficiency of the transshipment process needs further experimentation. Transshipment time is another critical factor for the success of the concept. It is expected that with better technology, reduced transshipment time can be achieved.
Chapter 7. Further Thoughts for Next Steps

The presented analysis shows that the BART system can be adopted as a reliable, social, and environmentally friendly mode of freight movement with an operationally feasible plan at an acceptable investment.

Since FedEx service is extremely time sensitive, improved efficiency, which allows for consistently reliable and predictable travel time, benefits FedEx. Through transporting on BART, FedEx can save the effort of rerouting during unexpected events -- such as Bay Bridge closures -- and avoid the risk of delays and traffic congestion.

The social impact analysis, especially the environmental impact aspect of that analysis, demonstrates the significant detrimental effects contributed by current transportation modes for FedEx’s low priority goods. And this, just in the Bay Area alone. It is also a clear indicator of the potential of our proposed modifications and the improvements they could bring. The scale of improvement increases with demand. Considering current environmental degradation, these improvements offer value that increases over time.

Our proposed modifications could also encourage people to make the switch to the public transit mode, hence improving freeway transportation efficiency with alternative solutions to freeway congestion. It could do this without having to resort to freeway expansion.

From the infrastructure point of view, a feasible scheme is readily operable using a system-wide investment of about $260,000. Most of the necessary equipment involved, such as BART cars and rolling pads already exist, and the additional costs would only be needed for BART car modifications. However, modified retired cars alone will not be sufficient to meet future demands, which are expected to be considerably higher. We need to consider the design of new cars at this point. The low cost flat cars for freight movement could be an optimal design.

There are several future extensions to this study which will be pursued. In addition to refining the economic analysis. One critical issue is the potential demand in the manufacturing and agricultural sectors. For example, there are agricultural products from the California Central Valley that are now transported through the Los Angeles airport due to the high inventory and operational expense of using SFPO. If this portion of the demand utilizes BART’s services, the inventory cost could be significantly reduced. Another potential market lies in the expansion of BART.
BART is already planning to extend service to San Jose by 2018. Considering the current high level of congestion on Highways 880 and I80, the route through BART is highly competitive in terms of travel time and level of service. In addition, FedEx is going through some modifications in the Bay Area in April 2010. These involve more trucking input and more service frequency from SFO to OAK. The demand figured into our analysis will increase, therefore, so will the benefits it generates.

As identified in the previous study (Sivakumaran, 2009a, 2009b), the major factors for the success of using BART for freight movement, subjected to the limits and funding for subsidy are: (a) adequate demand; (b) convenient access points in the BART system for freight carriers; and (c) the efficiency of transshipment. Of the three, the demand is most critical and will eventually determine the business case for BART. It is necessary to further investigate those three aspects in the next phase of the project for a demonstration of the operational concept and/or for small-scale operation.

**Potential Demand for BART & Freight Movement**

Potential demand for using BART for freight movement will not be restricted to air freight. Other industrial and agricultural products flowing through the Greater Bay Area, such as those from high-tech manufacturers that could BART’s safety and security standards, are also potential future freight products. This could include products from the electrical, electronics, biological, and medical industries. The point is that, once it has been practically proven that the BART system is capable of moving goods through the Greater Bay Area, other products will follow.

As indicated in O'Connell and Mason (2007) and in a recent discussion with the first author, California continues to export more than one half-billion dollars in agricultural and other food products by air each year, primarily to destinations in the Far East. Looking ahead, worldwide demand for high value-added food products of the sort produced in California is forecast to expand dramatically, especially in such fast-growing economies as China and India, where the ranks of upper middle-class consumers are rapidly expanding and where multinational food retailers are rapidly establishing a major market presence and influencing the practices of indigenous food vendors. The report identified the problem for airport ground access: In California, virtually all of the state’s airborne foreign trade passes through just two gateways, Los Angeles International Airport (LAX) and San Francisco International Airport (SFO). The two airports have long maintained an effective monopoly over the state’s foreign airborne trade.
In 2006, for example, LAX and SFO together handled no less than 97.5 percent of all airborne international trade entering or leaving the state. The products are usually shipped first to the warehouse in the vicinity of SFO and stored there to wait for a call if flights are available. Since warehouse rent has been getting more expensive in recent years, many such exported agricultural air-cargo shipping has shifted from SFO to LAX. Mr. O'Connell, the author of this report and a consultant based in Sacramento, is interested in the concept of using the BART system to move product to Pittsburg and/or Walnut Creek. Those BART stations or tail-track have direct lines to SFO and could possibly be used for exported agricultural products shipment. Renting warehouses in those locations could be significantly less expensive. Further extension plan of BART in the Bay Area has been laid down in MTC San Francisco Bar Area Regional Rail Planning as shown in Figure 7.1. BART extension to San Jose has already been approved and will be executed in next few years. The future BART extension to Central Valley will be on the agenda.

![Figure 7-1 Source: MTC San Francisco Bay Area Regional Rail Planning, 2007](image)

BART is a closed-operational system and meets FAA's security consolidation requirements. It could be advantageous to be a consolidated security company using BART to bring products into the airport. And FedEx already has some shipping interests in internationally exported agricultural products. In the long run, FedEx can also act as the consolidated agency to take the
products from BART into the airport for their own flight or other air cargo flights. And they are experienced enough to do so.

**BART Access Points**

For the Greater Bay Area, collection and distribution of air freight products of both FedEx and UPS to access BART at the closest proximity OAK is critical. It is necessary to investigate the accessibility of BART’s shop and spur track in Oakland near Coliseum station, as well the Oakland Coliseum BART station. Site visits to those points by the project panel were conducted for this purpose. However, how to access the mainline from the spur track needs rigorous logistics consideration as a next step.

In addition to BART access points for local collection and distribution, there is a significant demand between the three international airports: SFO, OAK and SJC. As indicated by FedEx, the freight movement between the three airports is an important part of their business, due to air flight arrangement and products from/to other air cargo carriers. FedEx has a strong interest in a BART link to San Jose, since this could be a potential mode for moving products between the airports instead of using trucks on congested freeway corridors, such as Highway 101 and I-880.

**Practical Equipment for Demo and Small Scale Operations**

The transshipment equipment needs to be practically identified for demo and small scale operations. Due to the new FedEx flight, from OAK to Tokyo, it will require overnight delivery from SFO to OAK, which could start as early as April 2010. As indicated by one FedEx manager, this could provide a chance for demo or small scale operations. However, it is necessary to identify practical equipment for transshipment and convenient access points to the BART system. On the SFO side, BART’s Millbrae Station or the redundant platform at SFO international terminal, are both possible alternatives.

**Improve Economic Analysis of Previous Report**

It is still necessary to improve the economic analysis in the report’s previous phase. The following are some suggestions from FedEx:

- Find load capacity per sq. foot for BART floors, since all the weight of FedEx USPS containers will be on wheels, which is important in BART’s car specifications for container movement;

- Add the Emeryville Distribution Center to the list of possible FedEx sites connected to BART. It was missed in the previous analysis;
• Include low-emission-heavy-duty trucks or electric vehicles (EV) in our analysis; Ongoing projects are being carried on to develop larger EV trucks, which can provide transshipment alternatives for our project. FedEx is also interested in using “green” low-emissions trucks for transshipments.

These results should be of particular interest to other urban areas across the U.S, including Los Angeles, Washington D.C., New York and Chicago, where passenger rail systems exist in close proximity to major air cargo terminals. Some of these systems may possess particular characteristics that favor mixed-goods movement, such as intermodal transfer stations, containers that interface between multiple modes, and standard gauge rails.
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