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16. ABSTRACT

The Bay Area Rapid Transit (BART) system has 63 percent unused capacity on average in non-peak hours. If BART's service is extended to include air-freight movement, extra revenue can be generated, truck miles travelled on highways will be reduced (potentially leading to a reduced traffic congestion and pollution), and traffic safety could be improved.

The objective of this study is to identify the number of feasible dedicated freight train that can be accommodated by BART lines using its current operational schedule, without creating a negative effect on passenger service. The measurement of time or distance between two successive train-runs at a station, also referred to as the 'headway', for selected lines have been considered to evaluate possible freight train insertions into time-space slots of current passenger services. To qualify this, the headway of the two trains needs to be greater than twice the minimum headway required (based on BART train safety requirements). Furthermore, BART trains should be subjected to the limit on acceleration/deceleration capabilities. The findings are as follows: for peak hours and commute directions, it would be impracticable to add more trains without adjusting the current schedule for lines crossing the San Francisco Bay. For peak hours in non-commute directions, some capacity could exist for mixed freight cars and on empty passenger cars. For non-peak periods such as early mornings and evenings, slots for dedicated freight train insertions are available.

17. KEY WORDS

operational logistics feasibility study, mixed passenger and goods movement, air freight, BART (Bay Area Rapid Transit), urban rail, dedicated freight train

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The Potential for Using Transit Infrastructure for Air Freight Cargo Movement:
Feasibility Analysis of Freight Train Operation Logistics

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Keywords: operational logistics feasibility study, mixed passenger and goods movement, air freight, BART (Bay Area Rapid Transit), urban rail, dedicated freight train

Abstract

The San Francisco Bay Area is considered to be a gateway for international air freight -- receiving and exporting goods to and from many Asian countries. It is also home to several freight generators, like the San Francisco International Airport; the Port of Oakland and Oakland International Airport. Traffic congestion and trucking activities are increasing due to the rapid population growth and the expansion of the local, State, national, and international economy. Because of these conditions, it is imperative to explore transportation alternatives.

The Bay Area Rapid Transit (BART) system has 63 percent unused capacity on average in non-peak hours. If BART's service is extended to include air-freight movement, extra revenue can be generated, truck miles travelled on highways will be reduced (potentially leading to a reduced traffic congestion and pollution), and traffic safety could be improved.

The objective of this study is to identify the number of feasible dedicated freight train that can be accommodated by BART lines using its current operational schedule, without creating a negative effect on passenger service. The measurement of time or distance between two successive train-runs at a station, also referred to as the 'headway', for selected lines have been considered to evaluate possible freight train insertions into time-space slots of current passenger services. To qualify this, the headway of the two trains needs to be greater than twice the minimum headway required (based on BART train safety requirements). Furthermore, BART trains should be subjected to the limit on acceleration/deceleration capabilities. The findings are as follows: for peak hours and commute directions, it would be impracticable to add more trains without adjusting the current schedule for lines crossing the San Francisco Bay. For peak hours in non-commute directions, some capacity could exist for mixed freight cars and on empty passenger cars. For non-peak periods such as early mornings and evenings, slots for dedicated freight train insertions are available.

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Executive Summary

The San Francisco Bay Area is one of the most heavily congested metropolitan traffic corridors in the nation and it is projected that demand for both passenger and freight transportation will continue to increase in the future. The ports (seaports and airports) located on the San Francisco Bay are also gateways for the import and export of goods, providing a critical link between the United States (U.S) and the large, growing Asian markets.

The San Francisco Bay Area Rapid Transit (BART) District runs a regional environmentally-green transit system that operates with excess capacity during non-commute periods, offering a potential route for the movement of goods into its congested cities. On average, BART utilizes about 36 percent of its capacity, for daily passenger movement (2013).

The benefits of using BART for goods movement are derived from that it is grade-separated and won't interrupt traffic flow and that it is electrically powered. Travel times on BART are more reliable than can be achieved by ground vehicles, because the grade separation frees it from the impact of cross-rail traffic delays and accidents. Because BART is powered by electricity, goods movement on BART would reduce emissions of both criteria pollutants and greenhouse gases (GHG) than if had moved by truck or rail since most power consumption of BART comes from green sources (Ref. *4.5 About Energy Consumption* of this document). An added benefit of goods movement on BART is the superior safety that it offers, in comparison to other surface transportation systems. As an example, nationwide average truck crash was 102 per 100 Million VMT (vehicle-miles-travelled) in 2009, but BART car cash was 0 in the same time year due to separation of tracks in direction and from other road vehicles [2].

This report will demonstrate the operational logistics – how to insert dedicated freight cars into the BART system without affecting current passenger services, which is the major task for BART. Furthermore, a complete summary of feasibility studies and recommendations for using the BART system for air freight movement will be provided.

There are two critical issues for inserting dedicated freight trains in the BART system: (a) the access of the Oakland International Airport (OAK) to and from the nearby BART lines, stations and maintenance workshops; and (b) the insertion of a dedicated freight train in the section of the Transbay Tube (an underwater rail tunnel) where four cross-bay lines share the same track and is a major system bottleneck between San Francisco and Oakland because four cross-bay lines share the same track.

The conclusions of this study are as follows: For peak periods and commute directions, it would not be feasible to add more trains without adjusting the current schedule. For peak hours in non-commute directions (from San Francisco to East Bay – including communities within Alameda and Contra Costa counties, in am peak and towards San Francisco in the pm peak), some trains could be used consisting of mixed freight cars and empty passenger cars (for returning). For non-peak periods such as early mornings and evenings, slots for dedicated freight train insertion are available. Air cargo freight trains can and should be scheduled so that the available slots are matched to the appropriate air-freight product in order to maximize air-freight transportation efficiency. However, the above considerations are based on the current BART train control system which is over fifty-years old. If modern train control systems are adopted, the safety headway requirement will decrease significantly, which could greatly increase the capacity of BART. Accordingly, more slots would be available for inserting dedicated freight trains for operation.

Chapter 1. Introduction

Freight flow volumes within the San Francisco Bay Area (Bay) and the United States (U.S.), in general have increased at almost twice the rate of population growth over the past three decades [18, 19]. In the Bay Area a drastic decline in air freight was experienced during the economic downturn of 2007 through 2011. Since 2012, both the regional economy and air freight have rebounded.

Freight movement is a critical factor to the Bay's economy. The ports of San Francisco and Oakland (both the seaports and the airports) provide a critical link between California and international markets. Over 37 percent of the Bay Area's economic output is through the manufacturing, freight transportation, warehouse, and distribution businesses sectors. And, approximately one-third of California's specialty crops are exported, often using air freight. Regional growth in transportation is steady, with the demand being predominately generated for the Bay Area by the Asian and European markets, particularly China [10, 11, 12]. Beside the exported fresh agricultural products, the air freight items are usually smaller packages, high value and time sensitive.

Trucking is the most frequently used mode in freight movement for most activities, and. as a consequence, congestion and pollution are inevitable. Heavy-duty diesel vehicles alone contributed to 30 percent of nitrogen oxide emissions in 2005 (Metropolitan Transportation Commission [17, 18, 19]). Therefore, finding an alternative transportation mode is of paramount importance. For this reason, the focus of this study will be to investigate the feasibility of using BART to accommodate some demand of air freight cargo movement, mainly the collection and distribution of containerized products in the Greater Bay Area where the BART lines can reach. Aside from the economic benefits for BART due to the revenue generated from freight-use charges, the BART system is electrically powered, with a large percentage of electricity generated from green energy causing less air pollution. Shifting goods movement to BART will improve the reliability of the delivery of these goods and it may also have a positive improvement with the travel reliability of the surface roadways potentially improving goods and people movement on key arterials and highways.

Knowledge of the current patterns of air freight activities and decision-making processes is important in the development of modern transportation models, but the very nature of these services provides fundamental challenges to data collection. Freight services, in general, are unregulated and highly competitive.. Freight pickup and delivery is a commodity service where service providers compete on cost, efficiency and reliability. However, there is a strong proprietary element to their business processes, their customer base and the relationships they forge and maintain with their customers. Consequently, comprehensive and reliable data is not readily available. Typically, freight carriers and shippers do not respond to surveys due to institutional issues. These issues include, but are not limited to, the confidentiality of carrier information so that they can retain a competitive position in the regional market. Fortunately, the two largest integrated carriers, FedEx and United Parcel Service (UPS), were supportive partners in this project from its inception and provided the required data for analysis.

This study focused on the feasibility of utilizing existing BART infrastructure to move air cargo for integrated carriers from OAK using the BART system,, thereby reducing truck trips on the Bay's highly congested interregional corridors. To be successful, in practice, feasible schedules and routes for such a seamless handover would need to be negotiated. This handover can be conducted with selected overall system performance, such as minimizing the overall logistics cost for a given transportation task. Once the strategy is implemented, the extra capacity of the BART based on a given schedule will be utilized for overall system optimization.

For the purpose of analysis, the access point of the Oakland Annex Shop (OAS), as shown in Figure 1-1, was assumed. This shop has a spare track connected with BART mainlines, (further details discussed later), which was originally built for BART car servicing.

The access of BART's mainline in two directions from the spare track of OAS has been considered with several factors taken into account: acceleration/deceleration capability of BART cars, minimum time headway for safe train operation, BART line connections and switching (how to move the vehicle from one direction to the opposite direction and to other lines). It is noted that connections between different directions and multiple lines in the BART system were originally built for moving BART cars to and from the shop for repair and maintenance services and for car distribution among different lines. A map of those connections and their locations are detailed later in this document [15].

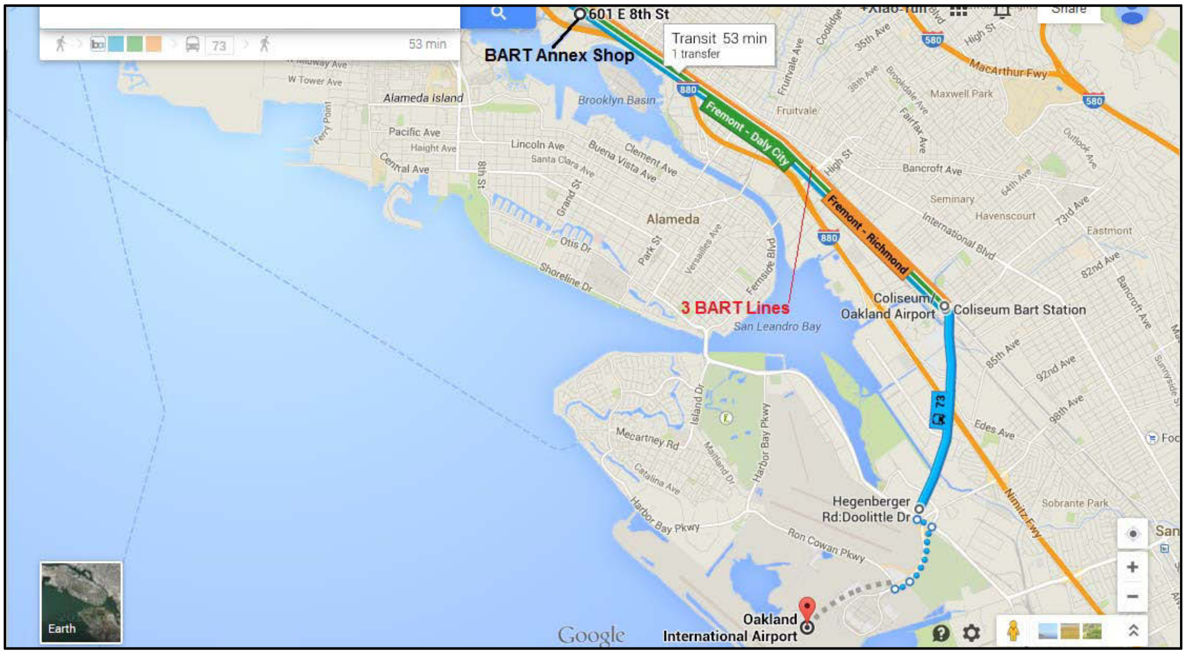


Figure 1-1 Accessing BART lines to and from Oakland International Airport (OAK) (Source: Google Map)

This report is structured as follows: the first part focuses on the logistics feasibility – how to insert a dedicated freight trains into the BART system with the current operation schedule without creating negative impacts to passenger services; followed by the summary of feasibility study results conducted in the previous phase of the project, including: economic analysis, infrastructure feasibility, transshipment, energy consumption and emissions, safety and security, institutional issues, and exploring the feasibility of integrating a similar program with high-speed rail (HSR). Currently, all U.S. HSR is focused only on passenger service; however, freight should be considered for future long distance transport since it could provide a potential revenue source to be used for both passenger and freight movements. Finally, some recommendations, are made including pursuing and conducting a small scale demonstration project.

Chapter 2. Literature Review

The following factors have prevented previous studies on combined passenger freight movement to flourish in the U.S.: (a) both combined passenger and freight movements belong to different stakeholders with different customers; (b) traditionally, in the U.S., larger quantities of goods for long distance are transported by train. High value, low weight products - such as those by integrated air freight carriers FedEx and UPS - are transported by air, and relatively short distance movement are usually transported via truck; (c) while the highway system in the U.S. is considered to be the most advanced in the world, the passenger train system is less developed and is predominantly dependent on investments from federal and state government levels, with funds usually going towards highways first.

Previous studies on urban freight movement have largely ignored the concept of incorporating air freight into a transit system. Instead, they investigated issues such as intermodal transfers, cost and reliability of line-haul, last-mile delivery, and social impacts, etc. These issues are relevant to the current study though, and are outlined later in this chapter. Additionally, some European cities have undertaken pilot programs using streetcars or trams to deliver small packages to central city businesses. While this type of system poses a slightly different problem than the current study, these pilot programs offer some valuable information on transshipment, which could be borrowed for this project.

Arvidsson [1] was among those whose work sheds light on the "last mile problem (delivery to home or final destination)." The author examined the potential for a combination of trams and electric delivery vehicles to lower the social costs of urban freight. The work summarized several case studies from Western Europe and presents logistical, capital, and political barriers to a successful implementation.

Maes and Vanelslander [16] studied the economic, social, and logistical issues of incorporating rail into the urban supply chain. Their domain focused upon the French retail group Monoprix system (intermodal deliver chain); though a unique system, the lessons learned are extendable. The reduction in KMT (kilometer travelled), congestion, GHG emissions, and an increase in supply chain efficiency were shown to be within reach for an urban freight rail system.

Moving up from the city-level, Nozzolo et al. [22] presented both a methodology and the results of using railways to distribute freight throughout a metropolitan region. The case study used was for the region near Naples, Italy which, like the San Francisco Bay Area, presented problems related to freight interference with passenger rail service. The authors found a feasible solution, albeit one that required public subsidy which was justified by the externalities imposed by the status quo.

Bozicnik [6] suggested that intermodal freight service through urban regions was most sustainable in certain niche market segments. These segments included valuable goods (a large portion air freight's raison d'être) and perishable goods (which were vital to exporting through San Francisco Bay Area to Asia market such as China and Japan). Bozicnik also stressed the need for cooperation among stakeholders for successful intermodal regional freight transport.

More specific to the Bay Area, Wei discussed [29] the major air freight data resources available for California. The discussion also leads to an explanation of air cargo importance to the regional economy, and thereby a justification for increased investment in air freight distribution.

Regarding externalities, ICF International [8, 9] and Base Energy Inc. [5] provided important data on rail versus truck comparisons, as well as BART-specific energy use profiles. Additionally, Delucchi [7] offered a more general view of the environmental damage done by automobile including freight trucks usage in the U.S. This study explores justification for more efficient use of rail systems such as BART.

Paaswell discussed [24] the site selection in Long Island, New York and conducted a careful weighing of both the benefits of increased efficiency in intermodal shipping and the costs which accrue from site selection, including construction, traffic, and other effects on the nearby population. The importance of stakeholder buy-in was discussed in the study but was not noted as the single determinant of project success.

Finally, work by Smirti et al. [25] modeled the Logistics of FedEx International Express. Their work examined three operation scenarios: without transshipment, with one transshipment, and with two transshipments, for all air freight moved by FedEx. They presented a method for estimating the effects of network expansion, modification of transshipments, and new technologies. They found out that either raising additional revenue by offsetting costs incurred by transshipment, or simply lowering costs were feasible alternatives.

Chapter 3. Inserting Dedicated Freight Train in Current BART System

The purpose of this project was to identify goods movement opportunities without modifying the BART system operation as it exists today. We examined the current BART schedule of operations to find potential time slots for dedicated freight trains which could also comply with BART train acceleration and deceleration requirements. Since both FedEx and United Parcel Service (UPS) have their sorting center at Oakland International Airport (OAK), it is naturally considered as the origin or destination in the analysis.

After data was gathered and analyzed, two critical issues for inserting dedicated freight trains in the BART system came up. The first was the accessibility of OAK from nearby BART lines and stations. The second was to find a way to use the main point of congestion of the BART system, the Transbay Tube with four lines sharing a single track, to and from San Francisco in morning and afternoon during peak hours. For accessing the BART system from OAK, which is a major distribution site for the regional offices of both FedEx and UPS, we assumed no significant infrastructure change. However, for practical operation, it would be necessary to build an access point near OAK. Although, an automated guideway transit (AGT) system has been built to connect OAK with Coliseum/Oakland Airport BART Station, this system has its own track and smaller cars and would not be suitable for air freight movement.

To insert a dedicated freight train into the BART system without affecting passenger service, it is necessary to identify critical issues that represents the analysis constraints for this study such issues include:

- BART train operation schedule for all lines
- BART line physical structure including transfer connection between service lines and between two opposite directions of the same service line
- Acceleration/deceleration capability of BART cars
- Minimum time headway for safe operation of BART

3.1 Critical Issues for Inserting a Freight Train(s) in the BART System

Although, the access points of the BART system for dedicated freight train could theoretically include all the BART shops, yards, and tail tracks (end of the rail), which could be potentially modified for loading and unloading; this study focused on two points: OAK and San Francisco International Airport (SFO). The reasons for doing this are discussed below.

BART's current operation schedule is based on many years of operation experience and the ridership distribution among all stations and lines. Any changes to the schedule could be impractical and could potentially degrade overall system performance.

The two main integrated air cargo freight carriers (with all the required intermodal transportation capabilities for delivering products), FedEx and UPS, both use the OAK and SFO Airports. FedEx has its Western Regional Hub at OAK, which means that all FedEx products of 11 states in the Western U.S. are shipped to OAK for sorting and redistribution for North American flights. Of course, all products from the Bay Area to all over the world also get sorted from OAK. FedEx also uses SFO for products to and from the Asian market, particularly, China and Japan. Therefore, FedEx needs to move products between OAK and SFO. UPS has a sorting center at OAK and has many cargo flights using SFO. Therefore, UPS has a significant volume of cargo to move between SFO and OAK, too. For this reason, UPS proposed a project several years ago on the use of helicopters for shipments between OAK and SFO. This project did not come into effect partly due to investment costs.

The BART station at the international terminal at SFO has a spare platform which is not being utilized. Some products with small containers could use this platform for loading and unloading. For large quantities of products with larger containers, BART's tail track at Millbrae near the Millbrae Station (about one mile to SFO) could be used for loading and unloading; although some minor modifications of the tail track might be necessary. The gate to the tail track is large enough and easy to access for ground vehicles including large trucks.

The Transbay Tube is the bottleneck of the BART system and passage through it is necessary to move goods between the San Francisco Peninsula and East Bay. The tube itself has only one track in each direction. Currently, four different BART lines pass through the tube, to and from San Francisco, share the track. BART safety standards define a minimum distance between trains traveling on the same track, known as headways, and the unit of measure is time. The combination of traffic, the single available track and the headway requirements creates a bottleneck during peak demand hours in the Transbay Tube. Thus, travel through the tube represents the major capacity constraint of the BART system. If dedicated freight trains could be inserted into the schedule of trains through the tube; travel through any other track of the BART system would be possible.

In summary, there are two critical issues for inserting dedicated freight trains onto the BART system:

- The access of OAK from the three BART lines: Dublin/Pleasanton ⇔ Daly City; Fremont ⇔ Balboa Park; and Fremont⇔ Richmond; and
- the Transbay Tube bottleneck

3.2 Data Collection and Analysis

Data for this analysis was obtained from the BART General Transit Feed Specification (GTFS). Several important factors regarding the overall BART system operation - including service lines, train scheduling, shared-track, the locations of integrated freight carrier sorting center - were analyzed to determine the best locations for inserting dedicated freight trains into the BART system without affecting current passenger services would be. Data was thereafter sorted to classify the trips using different origin and destinations of BART lines. The data includes information about BART train runs which pass through the respective stations at particular times, from the first to the last run of the day. We then focused on weekday trips because air freight carriers, such as FedEx and UPS, usually do not operate on weekends.

In BART's current schedules, there are southbound and northbound trips which had to be categorized and analyzed separately. Schedule timing was based on final destinations of the individual dedicated freight train trips. Two critical sections were identified for all the dedicated freight trains: (a) Access to the OAS; and (b) Downtown San Francisco BART corridor. They are critical (bottleneck) since the shortest time headways for current passenger services have been observed at those locations. Therefore, once the insertion of dedicated freight train is feasible at those locations, they will be feasible at other locations and other scenarios.

The reason for the selection of OAS is as follows: FedEx has its Western Regional Hub (sorting site) at OAK. Recently, FedEx finished its sorting system update – by replacing a previous manually-operated system with a fully automatic sorting system based on barcode recognition. Such an upgrade has significantly increased the sorting capacity at this site. Because of this, more states such as Alaska have been included in this site for sorting and transfer. UPS also has its sorting center at OAK. Although, it has freight flights to and from SFO, their products have to be moved to OAK for sorting and transfer. Therefore, OAK has the largest demand for the products from the two integrated air freight carriers. A direct link with OAK with

BART track could greatly facilitate air freight in the Greater Bay Area movement using BART, or at least, a close access point between the BART system and OAK. Unfortunately, this is not available. The nearest location of the BART system with a spare track which could be used for container loading and unloading is at the OAS. The recommendation, in case the P3 funding plans to invest in creating an access point in BART system for freight operation in the future, is to select a point closest to OAK on the BART system. Also, for the BART link with OAK, full size BART trains is recommend instead of smaller trains to improve the integration of passenger and air cargo movement.

The San Francisco downtown BART corridor is the only path between OAK and SFO. This is critical since both FedEx and UPS have their flights in SFO. As we mentioned before, cargo arriving in SFO will need to be moved to OAK for sorting and transfer. The main source of cargo is related to the booming Asian markets. The goal is to create a convenient link for freight operations without being impacted by road traffic. Moreover, passing through San Francisco-Oakland Bay Bridge is difficult because of the high level of congestion during peak hours. UPS had a project several years ago where they wanted to use helicopters to transfer their products between OAK and SFO; but, it was found to be cost prohibitive and the idea was abandoned. FedEx is doing such transfers now during non-peak hours between SFO and OAK, which might affect the schedules of all the modes in its intermodal transportation chain.

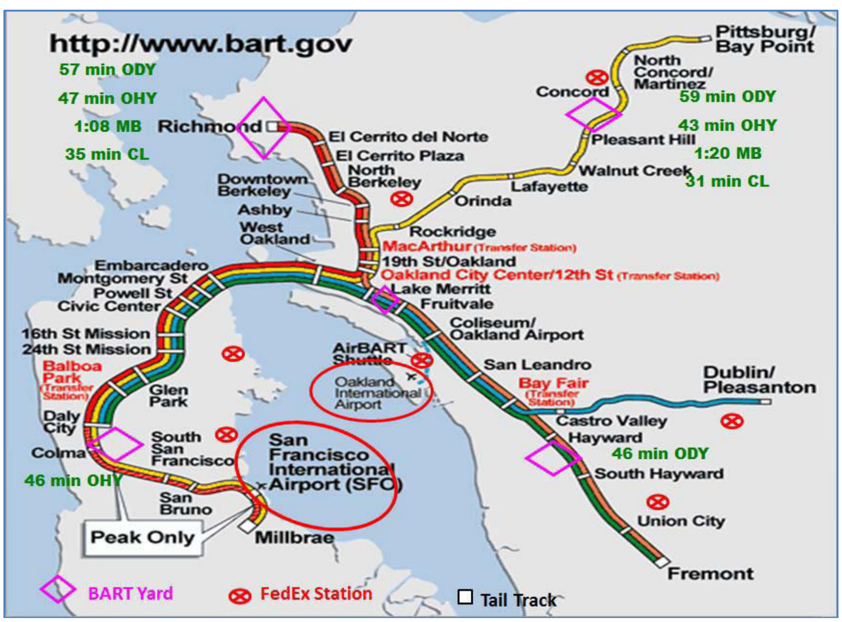


Figure 3-1: BART Access Points (Yards and Shops) and FedEx Collection/Distribution Stations

Figure 3-2: BART Oakland Annex Shop

3.3 Access from Oakland BART to Annex Shop

As shown in Figure 3-2 above, the OAS is located on the west side of the BART tracks. Freight trains northbound from the OAS would have to cross the southbound BART tracks for loading and unloading. The track change locations are set and known. With such track geometry, the deceleration for the access of OAS would create a temporary bottleneck for incoming northbound freight trains. Schedules should therefore be monitored to identify slots with large gaps to ensure a safe and smooth track change for freight trains. Based on the research of BART train schedules for both directions, gaps were identified to allocate the number of possible freight train insertions for the respective directions. Continuing with the previous reasoning, the capacity for freight train allocation must be higher for the southbound direction. For the purpose of this report, we will assume that the critical direction of movement is northbound, which will be the focus of the remainder of this methodology.

Oakland Annex Shop is located between the Fruitvale and Lake Merritt BART stations. BART schedules for these two stations were used to estimate the minimum headways required for a northbound freight train insertion to and from OAS. The times when trains arrived at particular points between Fruitvale and Lake Merritt were obtained using interpolation of the BART train stop times at the two stations. Figure 3-3 below details the distances between the two stations.

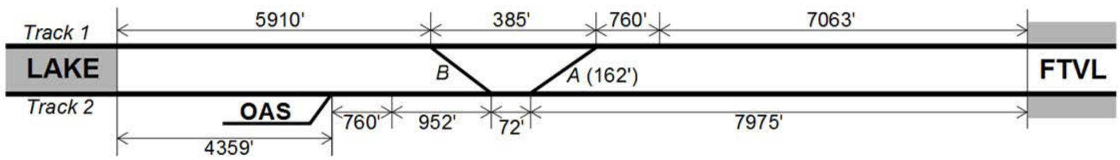


Figure 3-3: Rail Track Geometry at Access Point to Oakland Annex Shop (OAS) for section between Fruitvale (FTVL) and Lake Merritt (LAKE)

Parameters used in the analysis:

- 2 miles per hour (mph)/second acceleration/deceleration
- 20 miles per hour (mph) maximum operating speed while switching tracks
- Maximum operating speed of 80 mph, average 33 mph
- Maximum length of the train is 710 feet or 216.408 meters (assuming ten cars).
- Cross-over switch takes only 3 seconds to operate
- 1.5 mile minimum separation distance between BART trains

3.3.1 Determination of northbound insertion slots at OAS

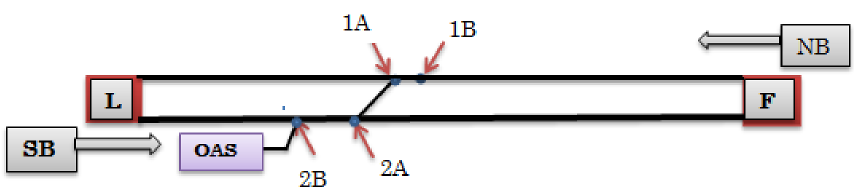


Figure 3-4: Access Main Line Two Directions at Oakland Annex Shop

Figure 3.3.1 description*:*

1A: Indicates the point at which the freight train crosses over from the northbound (NB) track to the southbound (SB).

1B: Indicates the point at which the entire length of the train joins the NB track equivalent to the maximum length of the train; 710 ft from point 1A.

2A: Point at which freight train crosses over to and from the SB track.

2B: Point at which freight train joins or leaves the OAS.

Given the above assumptions, it would require 10 seconds to accelerate from 0 to 20 mph and 40 seconds from 0 to 80 mph. For the two cases, the distance travelled would be 0.055 miles and 0.833 miles respectively.

3.3.2 Determination of available capacity for northbound freight trains heading to OAS

In the following discussions, North Bound (NB) and South Bound (SB) are sued to refer to the section of BARET line from/to Fremont near the OAS. To determine the available capacity for northbound freight trains heading into OAS, the following information is required:

- Minimum headway between two consecutive northbound BART trains
- Minimum headway between two consecutive southbound BART trains
- Minimum headway between northbound BART train at the cross-over point and the next southbound train at point OAS termed as the north-south-lag

Headway between two consecutive NB passenger trains:

Distance between the preceding passenger train and the freight train to be inserted should be maintained above 1.5 miles - the safe distance between the two trains. Assuming maximum speed of 80 mph, the headway between the two trains should be a minimum of 67.5 seconds.

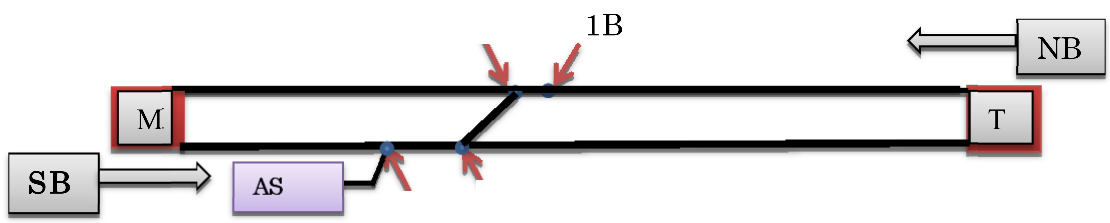


Figure 3-5: Scheme for Accessing Point to Oakland Annex Shop from BART

Interchanges between tracks can be performed at 20 mph. The time required to decelerate to 20 mph, assuming the trains had previously achieved the maximum speed of 80 mph, is 30 seconds. Distance required to decelerate from the speed of 80 mph is 0.333 miles.

For example, the distance that would have been travelled by a freight train in 30 seconds at 80 mph is 0.666 miles or 1,072.9 m. When it slows down to 20 mph in 30 seconds, it travels half of the distance it would have travelled had it not slowed down. An additional separation distance of 0.333 miles will therefore be considered in the analysis.

Total separation distance at the Fruitvale BART station to maintain the minimum 1.5 miles safe distance will be 1.833 ~ 2 miles. Taking a maximum speed of 80 mph, the time headway required is 90 seconds. Therefore, the minimum headway between two consecutive northbound passenger trains should not be less than 158 seconds to allow an insertion of a NB freight train within the schedule.

$$\text{Nbound H} = 90 + 68 = 158 \text{ seconds.}$$

Headway between two consecutive SB trains:

After a SB passenger train passes the cross-over point 2A, the freight train must cross over from the NB tracks to the SB track heading north towards OAS. It has to reach its destination (OAS) (by passing 2A➔ 2B) before the next SB passenger train approaches OAS.

The distance from Lake Merritt to point 2A is 6,143 ft which is equivalent to 1,872 meters (1.163 miles). Assuming an average speed of 40 mph, it will take approximately 105 seconds for the passenger train to travel this distance. Assuming that the freight train will maintain a constant speed of 20 mph from the point it changes its tracks until it reaches OAS, the distance from 2A to OAS, is 2,494 feet ~ 0.29 miles. With a speed of 20 mph, it will take 53 seconds for the freight train to travel this distance.

For the next southbound train, assuming that it travels at an average speed of 40 mph, to travel from Lake Merritt to OAS interchange point (distance of 4,359 ft = 0.8256 mile), it would take 74 seconds.

Total time headway between two SB trains should be $\text{Sbound H} = 105 + 53 = 158$ seconds. Adding a lag time of 60 seconds, the minimum headway between two consecutive trains is 218 seconds.

North-South (NS) lag: Time lag between the northbound (NB) train at 1A and the next SB train at OAS.

The NS lag is the difference between the times at which the NB passenger train approaches the crossover point 1A and when the SB passenger train reaches OAS station. This should be large enough to accommodate a freight train crossing over from the NB side to the OAS without collision with the oncoming SB passenger train.

$$NS_{lag} > \text{Northbound Freight Train (NBFT) lag} + T(\text{1A to OAS})$$

The NBFT is the NB-Freight Train lag time, and T(1A to OAS) is the time required for the freight train to travel from point 1A to OAS at the average speed of 20 mph. The distance from

1A-train to OAS is 2,706 ft ~ 0.318 miles. It takes 58 seconds for the freight train to travel from point 1A-train to OAS.

$$NS_{lag} > 68 + 58 = 126 \text{ seconds}$$

Adding an extra 90 seconds as a safe time lag between the freight train and the SB train:

$$NS_{lag} \geq 68 + 58 + 90 = 216 \text{ seconds} = 3.6 \text{ minutes}$$

Figure 3-6 depicts the northbound insertion of a freight train showing gap allowances for the leading and preceding BART trains.

Description:

- The blue squares symbolize northbound BART trains from Fruitvale to Lake Merritt
- Green rectangles symbolize southbound BART train.
- The red rectangles symbolize a freight train.

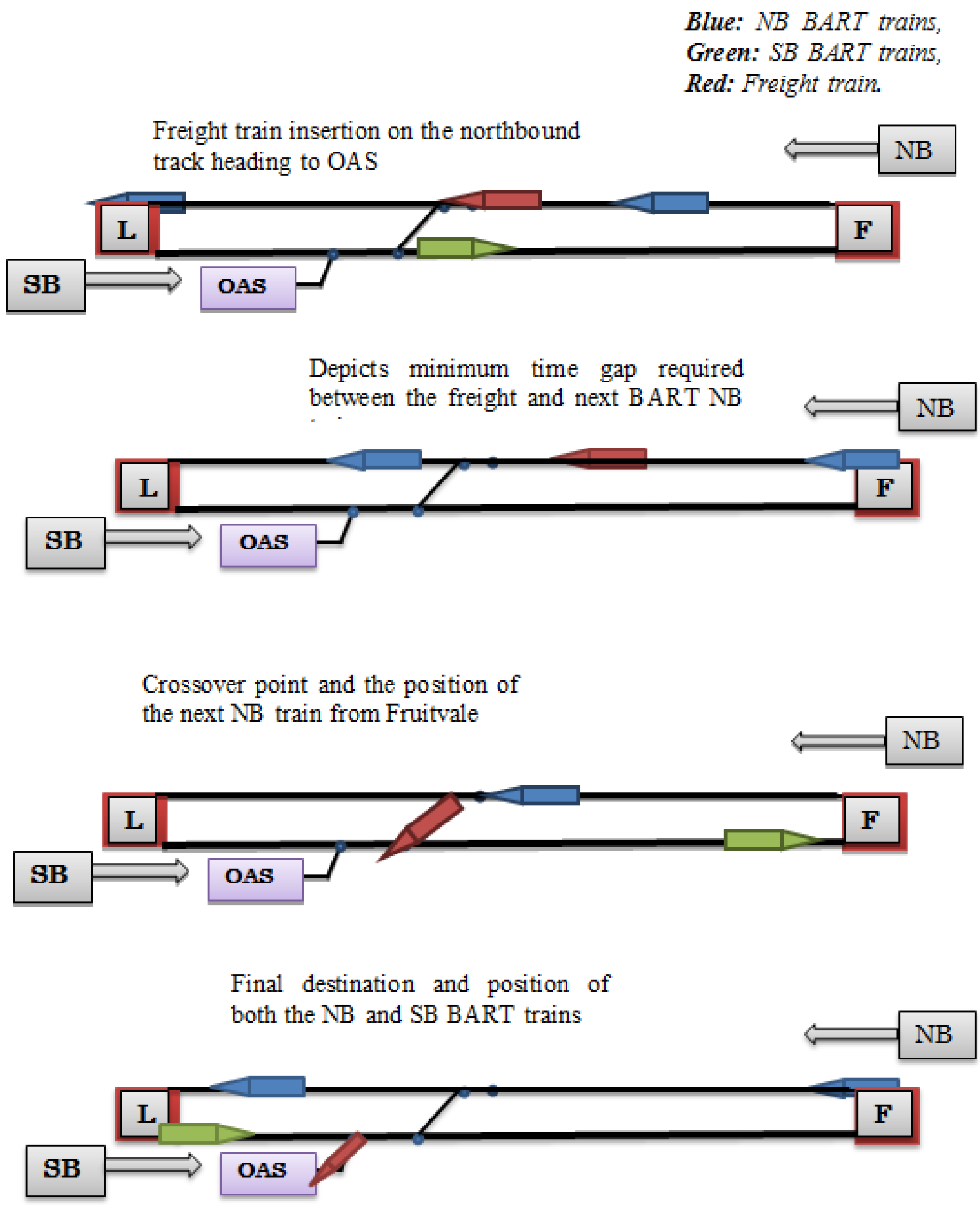


Figure 3-6: Illustration of a NB freight train movement into OAS

3.3.3 Capacity for northbound freight trains originating from OAS

NB freight trains have to cross over (through a linkage track between the two tracks) from the SB track to the NB track given the location of the OAS. Because of the track changes, the capacity in this direction is limited by both the northbound and southbound passenger train movements.

Headway between two consecutive NB passenger trains:

As previously stated, the safe distance between two consecutive trains travelling at the maximum speed of 80 mph is 1.5 miles, which is equivalent to a minimum headway of 68 seconds. Since the freight train is going to follow this already fast train, the minimum allowable headway is reduced by the time the freight train takes to accelerate to a speed of 80 mph.

As the freight train joins the northbound track, its speed reduces to zero due to a direction change. The time and distance required to accelerate to maximum speed is 40 seconds, which is equivalent to 0.444 miles. The distance that would have been travelled in 40 seconds at 80 mph is 0.889 mile. While accelerating from zero to 80 mph, it will travel for approximately half the distance it would have travelled had it been at maximum speed. This creates an extended distance buffer and therefore reduces the safe distance limit for the preceding northbound train but increases that for the next NB train.

Furthermore, the headway between the preceding train and the freight train at the point of entrance into the NB track should be 45 seconds. A safe distance of 1 mile at point 1A must be considered while the time between the freight train and the next northbound train should be 90 seconds. This will allow for a safe distance of 2 miles at point 1A assuming a maximum speed of 80 mph. Minimum headway in the northbound direction, N-bound H, is given as:

$$\text{Nbound H} \geq 40 + 90 = 130 \text{ seconds.}$$

Headway between two consecutive SB trains:

The headway between two consecutive southbound trains shall be constrained to the minimum safe headway between the two trains. Taking, for instance, a southbound train travelling at maximum speed of 80 mph, with a safe distance gap of 1.5 miles, the headway would be 68 seconds. At the same time, there has to be a reasonable gap for the freight train to join the tracks and thereafter cross over before the next passenger southbound train departs from Lake Merritt. In addition, the headway has to be large enough to allow a freight train to merge onto the tracks before the next southbound passenger train departs from Lake Merritt. With 2 mph/sec acceleration, it will take the freight train 10 seconds to achieve a speed of 20 mph. As shown on Figure 3-7, point 2A is 0.482 miles from OAS entrance location. At a speed of 20 mph, it will take 87 seconds to travel this distance, hence approximately 100 seconds for the freight train to cross the SB track to the NB track. Minimum headway between two SB trains should be given as;

$$\text{Sbound H} = 68 + 100 = 168\text{seconds}$$

Adding a lag time of 60 seconds, the **S-bound H = 225 seconds**

South-North (SN) lag: Time lag between the southbound train (at 2B) and next northbound train (at 1B).

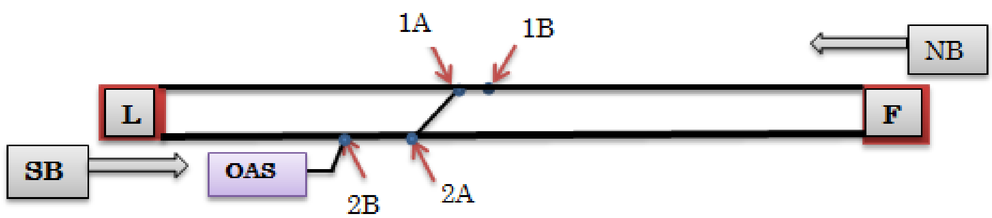


Figure 3-7 Time lag effect to mainline access mainline track

SB lag is critical and ensures that there is adequate time for the freight train to cross over from the SB track to the NB track and then continue towards the NB direction. In order to ensure a safe transition, the time at which the freight train approaches point 1B is a critical factor in determining how far apart the trains on the northbound track should be spaced. An adequate gap is required for the freight train to join the NB track just ahead of the next NB train.

With reference to the Figure 3-7, the times at which the trains pass the marked points were determined. Two time lag scenarios were identified: Period 1 - the time period between the instances at which the freight train departs OAS and arrives at point 1A; Period 2 - the time period between the instances at which the southbound train approaches point 2B and the northbound train arrives to point 1B on their respective tracks. If all goes as planned, Period 1 should be shorter than Period 2, making the scenario feasible.

While travelling at an average speed of 20 mph, it will take a freight train 114 seconds to cover 0.635 miles, the distance from OAS to point 1A on the NB track with a 10 second buffer allowing for deceleration. As stated above, the minimum headway between a freight train and the succeeding NB train and between the freight train and next SB train is 87 [sec] and 30 [sec] respectively. These are all summed up to provide an estimate of the SN-lag.

$$SN_{lag} = 30 + 128 + 87 = 245 \text{ seconds} \cong 4.0 \text{minutes}.$$

The SN_{lag} should therefore be greater than 4 minutes to allow freight train movements from OAS heading northbound. Figure 3-8 illustrates northbound freight train maneuvers.

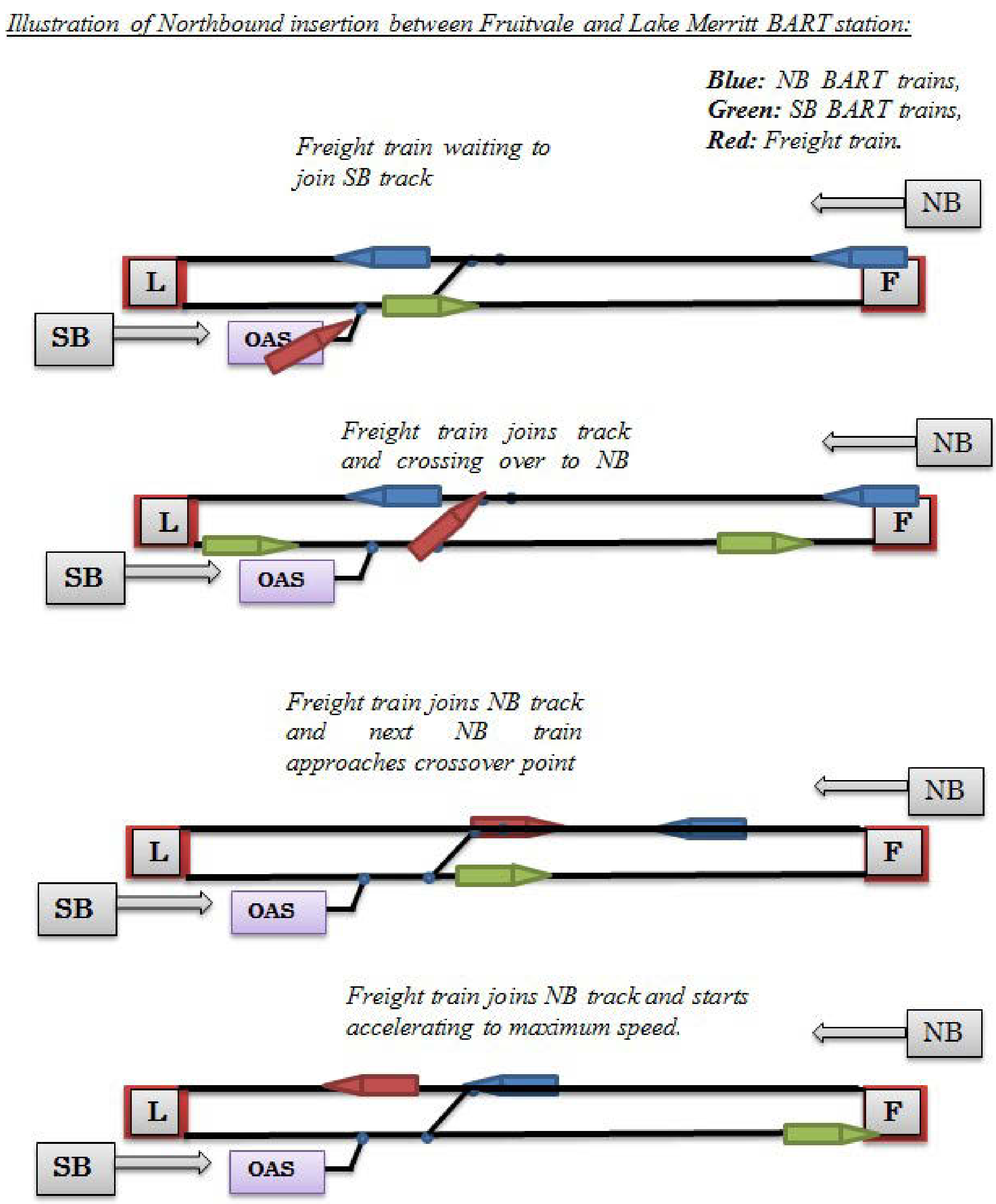


Figure 3-8: Northbound freight train accessing maneuver from OAS

3.3.4 Discussion of Results

The tables below show the findings for the available slots within the current schedule.

Table 3-1: Minimum headways for northbound freight trains heading to OAS

Headway	Time (seconds)	Time (minutes)
Northbound	158	2.6
Southbound	218	3.6
NS lag	216	3.6

Table 3-2: Minimum headways for freight train insertion northbound from OAS

Headway	Time (seconds)	Time (minutes)
Northbound	130	2.2
Southbound	225	3.8
NS lag	245	4.1

Table 3-3: Number of insertions for NB freight trains heading to OAS (Oakland Annex Shop) during weekdays

Period	Insertions
4:00am – 10:00am	22
10:00am – 4:00pm	23
4:00pm – 12:00am	37

Table 3-4: Number of insertions for NB freight trains from OAS during weekdays

Period	Insertions
4:00am – 10:00am	18
10:00am – 4:00pm	4
4:00pm – 12:00am	10
Total	32 per day

From Table 3-4, there are 32 possible northbound freight train insertions per weekday heading to OAS and 82 possible southbound insertions per weekday to OAS.

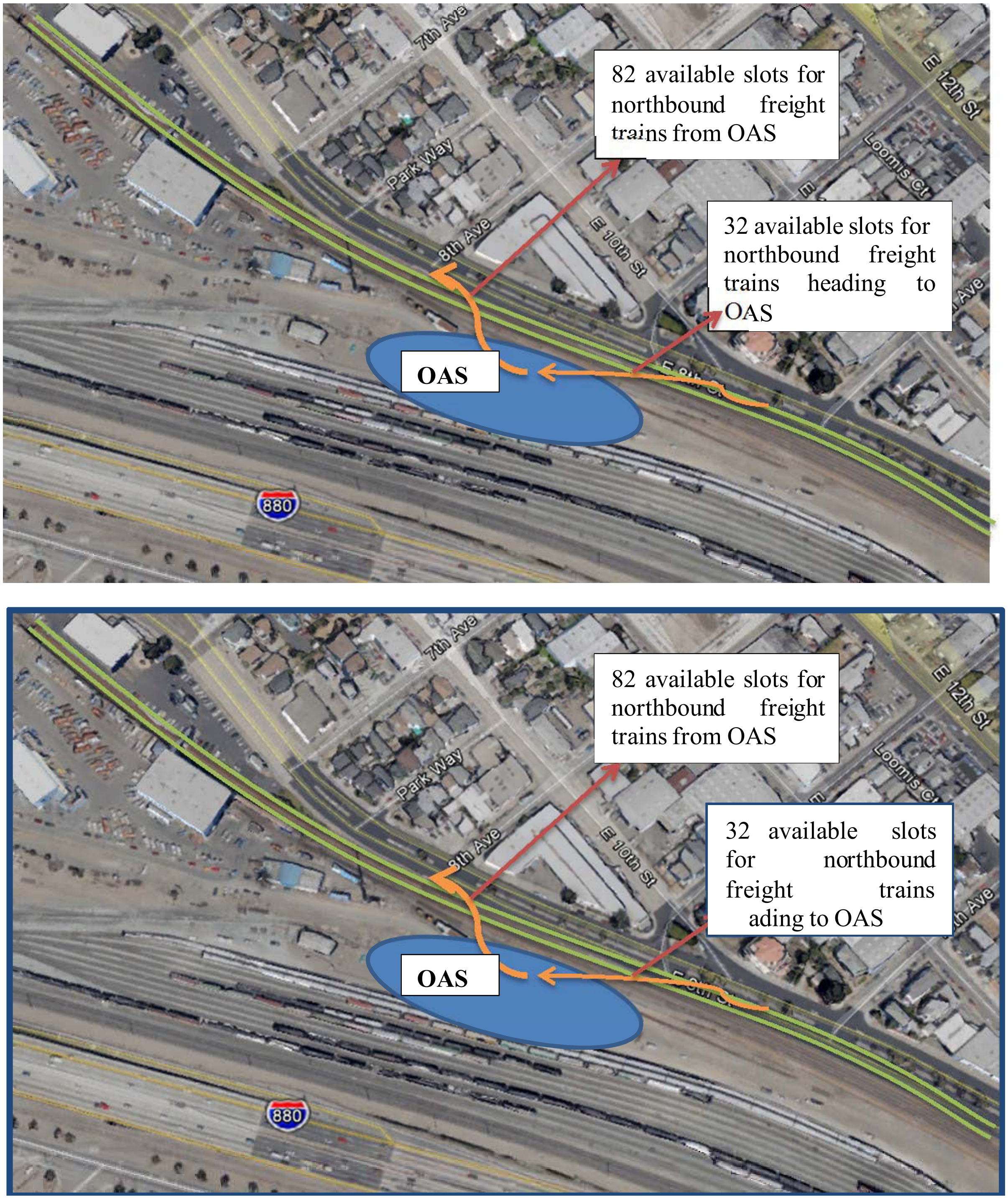


Figure 3-9: Map **-** Northbound freight train maneuvers from/to the OAS

Figure 3-9 above shows freight train movements and the available capacity for the northbound trains to and from OAS. At a minimum, there will be 32 freight trains that will be able to run for a complete loop to and from OAS during weekdays, assuming current BART passenger service schedule. In the case of only FedEx using BART system, there is more room for flexibility to ensure that it utilizes the slots at maximum capacity. In the case of more than one integrated air freight carriers using the system with greater demand, a scheduled system can be devised to distribute the available slots for maximum utilization efficiency.

3.4 San Francisco BART corridor

BART lines that run from San Francisco across the Bay travel through a common corridor running from Daly City to Embarcadero BART stations. This is the corridor with the highest operational frequency of passenger trains in the entire BART system. It is referred to as the *critical corridor* in the description below.

Sorting stop times within the critical corridor have been obtained chronologically, and thereafter sorted per station within the corridor. The headway of trains traveling through the critical corridor was used as a basis to check the availability of slots in the schedule. Headways, which are twice as large as the minimum allowable headway, were considered to be possible freight insertion points.

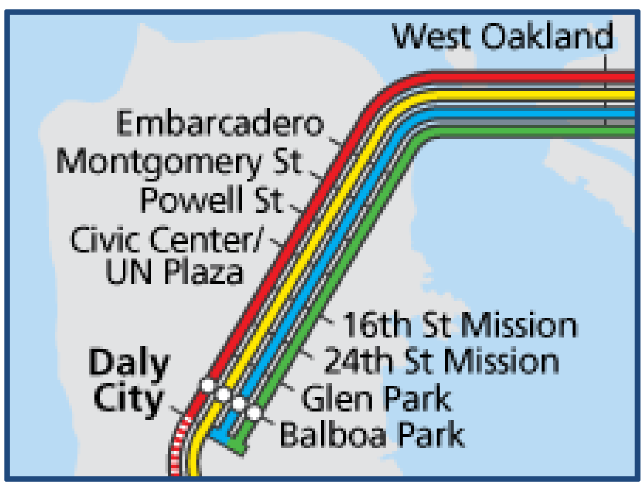


Figure 3-10: BART corridor with highest frequency of trains

Time Space Diagram (TSD) plots can were used to illustrate freight train insertions within the current schedule. Distances between the nine stations in the critical corridor, shown in Figure 3-10, were used to locate their respective positions along the corridor.

3.4.1 Northbound Direction (NB)

The following destinations are northbound.

- Dublin/Pleasanton (Blue line)
- Pittsburg/Bay Point (Yellow line)
- Fremont (Green line)
- Richmond (Red line)

A detailed analysis of headways at the particular stations above was performed. It was observed that the minimum allowable headway for BART trains is two minutes. Headways greater than the minimum headway by a factor of at-least two minutes were noted and analyzed using the two possible scenarios described below.

A. *Optimal Scheduling.*

For this case, the minimum headway between consecutive trains was taken to be 4 minutes to affirm insertion of an extra freight train, hence meeting the allowable minimum headway of 2 minutes. This means that the dedicated freight train should always be on schedule when traversing this corridor.

B. *Conservative Scheduling.*

An extra minute was added to act as slack in case the freight train fluctuated from its current schedule, therefore making the headway between a passenger and the dedicated freight train to be a minimum of 3 minutes. For this case, in-order to count it as an available slot for a freight train, the minimum headway between consecutive passenger trains had to be at least 6 minutes.

Both cases were analyzed using Time Space Diagram system. The results are displayed in Table 3-5.

Table 3-5: Northbound Insertion slots

Possible Insertions	**Case A (2 min. gap)**	**Case B (3 min. gap)**
4:00 am to 6:00am	10	8
6:00am to 7:00pm	39	0
7:00 pm to 8:00 pm	10	5
8:00pm to 10:00pm	12	12
10:00pm to 12:00am	10	10
Total # of Trips	81	35

Figure 3-11 below shows the insertion of dedicated freight trains between BART morning runs within the critical corridor.

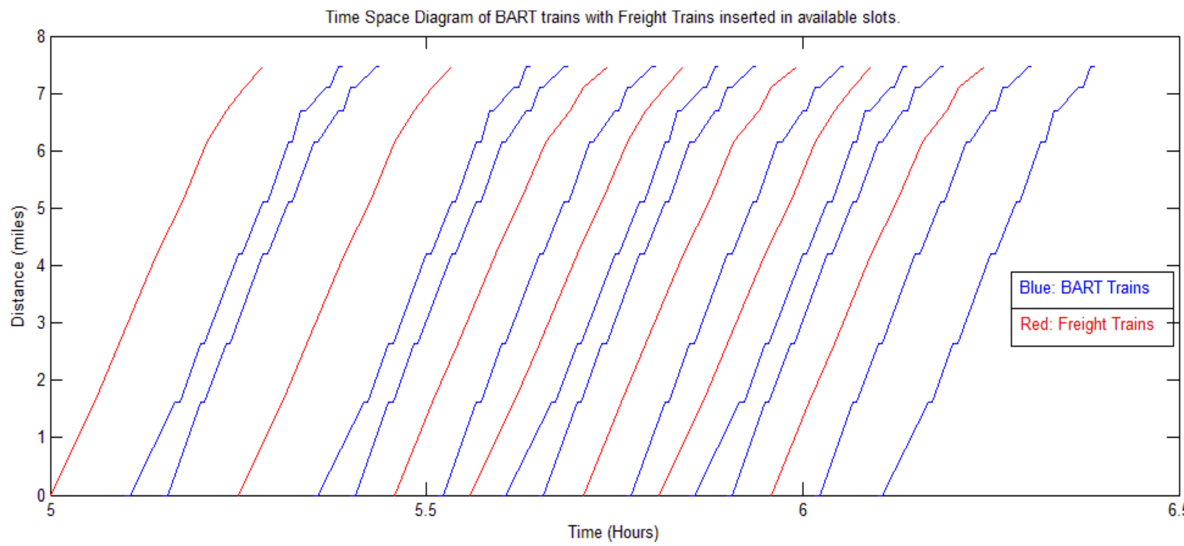


Figure 3-11: Time Space Diagram showing Freight train insertion in the morning slots

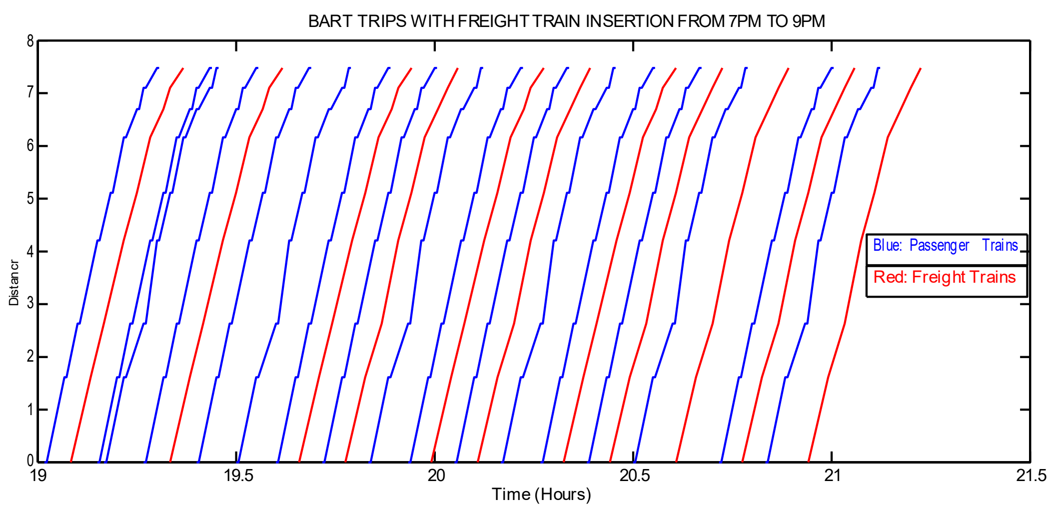


Figure 3-12: Time Space Diagram for Freight train insertion in the evening slots

It's important to note that the passenger trains always stop at stations as depicted by the stepwise motion of the train trajectory. However, the freight trains do not have to stop at any of the stations since dispatch is at the tail track. From Figure 3-12 above, the evening freight trains are able to maintain a uniform speed with slight variations from the start to the end of their destination. Trackers on the freight trains would be able to detect separation distances and vary speeds accordingly.

Figure 3-11 and 3-12 attest to the fact that some slots can accommodate more than one freight train as indicated by large headways between consecutive trains. However, for this study, only one dedicated freight train insertion per slot was considered.

Cumulative plots were made showing possible slots for freight train insertion during the BART operation period for the two cases, as shown in Figure 3-13.

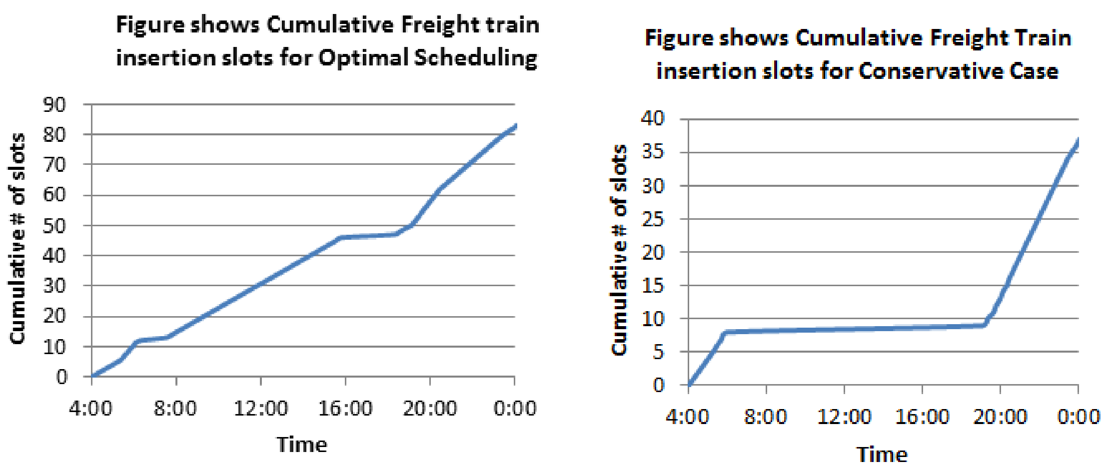


Figure 3-13. Cumulative Freight Train insertion slots (Left), Optimal Scheduling (Right): Conservative case

Observations

In the Optimal scheduling scenario, it was observed that there are available slots for insertion of an extra train, except during the period between 6:30 am and 8:00 am and the three hour period (peak period) between 4:00 pm and 7:00 pm. It can also be observed that there are greater gaps available in the morning before 6:30 am and in the evening after 7:00 pm. The time gaps can accommodate at least one extra train every 10 minutes in the evening with higher frequency after 7:00 pm.

It can be inferred from the above observation that the slots available within the day for the optimal scheduling case can only accommodate one train insertion, and only for such cases whereby the trains are strictly on schedule to maintain the two minute headway requirement between consecutive trains.

For the conservative case, one can detect a large gap between BART schedules for availability of slots. In the cumulative plot from Figure 3-13 above, there is a uniform increment of available slots with time from 4:00 am to around 6:30 am. There are no available slots for freight train insertion from 6:30 am to about 7:00 pm. After 7:00 pm, there is a stable increment of available slots for freight trains.

3.4.2 Southbound Direction (SB)

The following destinations were considered as southbound:

- Montgomery
- Daly City
- San Francisco International Airport
- Millbrae

To determine possible insertion slots for freight trains moving southbound, the optimal and conservative scheduling methods were used again. Analyses for both cases were carried out separately and the findings are displayed in Table 3-6.

Table 3-6: Insertion slots for Freight trains heading SB

Possible Insertions	**Slots Case A (2 min)**	**Slots Case B (3 min)**
4:30 am - 6:00 am	4	4
6:00 am to 7:00 pm	0	0
7:00 am to 8:00pm	4	2
8:00pm to 10:00 pm	12	7
10:00pm to 12:00 am	12	6
Total # of trips	32	19

Figure 3-14 shows the cumulative time slots for insertion of an extra train within the BART schedule.

Figure 3-14: Number of slot insertions in the SB direction

Observations

From Table 3-7, it can be observed that there is no significant difference in the number of available slots for the two cases. Availability of slots follows exactly the same trend until close to 8:00 pm in the evening whereby the curve for optimal scheduling diverges slightly farther away from the conservative case.

In both cases, it is not feasible to insert freight trains during the day from 6:00 am to about 7:00 pm without any adjustment in the current schedule.

Table 3-7: Number of possible insertions for both Optimal and Conservative Case

Period	**Optimal (2 min)**	**Conservative (3 min)**
	NB	SB
Before 6:00 am	10	4
6:00 am – 7:00 pm	39	0
After 7:00 pm	32	28
Total	81	32

3.5 Using Extra Capacity in Non-Commute Direction during Peak Hours

The unused capacities in BART cars are available in the non-commute directions during peak hours: in morning peak hours from San Francisco to the East Bay, and evening peak hours from East Bay towards San Francisco direction. There are two possible ways to use the extra capacity:

- combine passenger and air freight movement by only using an adequate number of passenger cars for passenger movement and the rest are freight cars - in this approach, empty passenger cars will need to be returned to their origins for continuous operations. Demonstrations will need to be conducted in off-peak hours; and
- run dedicated passenger service at lower frequency than the current schedule so that some dedicated freight train consist(s) may be inserted, which may be composed of empty passenger cars. The reason to add empty passenger cars is to return the empty cars to their origin(s) for continuous passenger services.

3.6 Discussion of Results

The feasibility of freight train insertion within the BART schedule has been extensively investigated. It can be shown that there are available slots within the current BART schedule, although limited to particular time periods as detailed above. The question as to how many trains can actually fit into the schedule can now be answered quantitatively in principle, but for practical purposes finding the optimal number to fit into the available slots is beyond the scope of this report. For practical operation, it is necessary to ensure that the dedicated freight trains travel in a complete loop seamlessly for more efficient use of the infrastructure.

The above schedules were obtained based on the assumption that there is just one freight train insertion per time gap; although there are some possibilities of multiple freight train insertions for time slots greater than 6 minutes (for Optimal method) and 9 minutes (for the Conservative method). These findings are important to support the basis of this study.

3.7 Concluding Remarks on Logistics Feasibility Study

In summary, two factors are critical for dedicated freight train operation in the current BART system: (a) the creation of a convenient access point of a BART line to OAK; and (b) collect and observe data from current BART lines that run through the critical corridor of downtown San Francisco to determine safe headways for possible freight train insertion. The critical corridor studied in San Francisco runs from Daly City to Embarcadero BART station. The trends for the NB and SB directions are similar showing many feasible slots in the morning before 6:00 am, and later in the evening after 7:00 pm. However, the SB direction has fewer available slots in both cases analyzed above and therefore becomes the critical direction for further analysis. In the current weekday BART schedule, four possible freight train insertions are possible from 4:30 am to 6:00 am and 28 freight trains after 7:00 pm.

This preliminary study is based on the assumption that the BART system maintains their current status without schedule changes. However, if BART trains are renewed in the next 6 to-10 years, and/or if the control system is updated from the technology currently in place with a modern control system, the minimum headway between BART trains could decrease, and the capacity of BART system could significantly increase. There could be more slots for insertion of dedicated freight trains in BART system. In addition, if another Transbay Tube is built as planned by the Metropolitan Transportation Commission (MTC), then the bottleneck at this location will no longer exist.

Chapter 4. Summary of Feasibility Studies and Recommendations

This chapter briefly summarizes and updates all the research results of feasibility studies previously conducted towards using BART system for potential air freight movement.

Generally speaking, the current BART system has a significant portion of capacities that are not being used. If the upgrade of BART cars and the control system in the next few years do come about as planned, it is expected that the extra capacity could be much higher. However, several issues need to be resolved before the operation of air freight movement: (a) enough demand for practical operation of BART cars for freight movement will be required - the economic analysis conducted before showed that a large demand could bring benefits to all stakeholders (integrated air freight carriers, BART, MTC, Caltrans, and others); and (b) some modifications to the BART tracks with the inclusion of new platforms built for transshipment for loading and unloading will be necessary, specifically near OAK.

4.1 BART Capacity Use

BART is a regional rail transit system that serves approximately 340,000 passenger trips per weekday. This number increased to 390,000 trips per weekday in 2013. Despite BART's excellent track record in moving people, system utilization of its mainline capacity was at 29.3 percent in 2004 [13]. This number increased to 37 percent by 2013 [21]. Here, the system capacity utilization is passenger miles divided by seat miles. But what this study also demonstrates is that BART lines running to and from East Bay to San Francisco reached their capacity and a major bottleneck occurs in the Transbay Tube during commuting peak hours. Although many passengers use BART, they did so during periods of peak demand in certain directions, leaving much unused capacity during off-peak hours and in some reverse-commute directions during peak hours. BART continues to aim for increased usage of the remaining 63 percent of its overall capacity through marketing and other strategies to bring in more riders [13, 21].

In a broader sense, BART's capacity can be looked at from two viewpoints: the primary viewpoint is the capacity of mainline, or track (line capacity [21]), which can be measured by the number of consist (the cars that make up a train) and the maximum number of trains in each consist that can operate. The second viewpoint involves the role of BART yards, vehicle (seating) and station capacity (platform access and egress) for transport but not restricted to passengers only (station access capacity as discussed in [21]), which is related to the dynamics of tail track and storage track capacity. In either case, the total capacity minus the passenger demand produces the *extra capacity*. To understand where and when the extra capacity exists is critical to primary service, revenue service staging and scheduled maintenance procedures. Here, the revenue service staging means other possible services beside the primary passenger service such as air freight including exported agricultural products through airports.

For current BART operation, Transbay lines are the major bottleneck, as shown below in Figure 4-1 (Source: BART Capacity Planning, Board Workshop, Jan 2013, BART Operations Planning [4]).

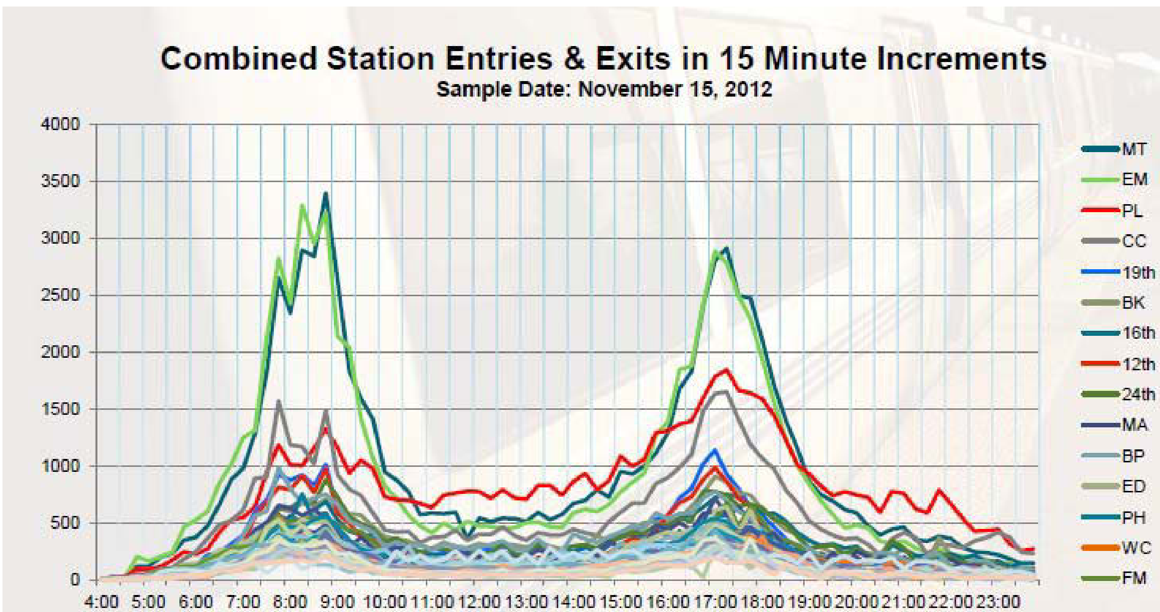


Figure 4-1: BART system load for Transbay Lines

It can be observed from Figure 4-1 that the highest peak demands are at Montgomery Street and Embarcadero BART stations. For both of those stations, non-peak hour demands are not high. Then again, this figure did not show the capacity of the direction of a line. But it did, however, demonstrate the morning peak hours indicating the passenger demand towards San Francisco from the East Bay, while the afternoon demands indicated high volume passengers from San Francisco to the East Bay. The reverse directions, even in the two peak hours, still have very low volume. Therefore, the extra directional capacity in one direction could also be utilized for air freight movement in two peak hours.

There are more than simply the social benefits of using urban rail lines, previously used for solely people transport, for mixed passenger-good movement. Many rail transit systems are operated under the supervision of public agencies and use public funds to support their operation. However, many systems rarely recover even 50 percent of their operating costs. Furthermore, transit systems in general are often underutilized during off-peak periods, as well as in the "reverse commute" direction during peak hours.

The following ongoing and planned projects are designed to specifically modernize the current BART system and to increase its line capacity [17-20]:

- BART car renewal: BART's New Rail Vehicle Program under execution will replace all the current cars which are over forty-years old, and will add more cars for operation;
- BART system bottleneck: BART's current single Transbay Tube system has several major choke points which limits peak period/direction throughput to 24 trains per hour including:
    - The Oakland Wye (tunnel?)
    - Transbay Tube
    - Market Street Corridor
- Train Control System Modernization Project: could increase throughput to about 30 trains per hour;
- New BART Transbay Tube Project: The MTC 2035 proposed to build a new BART Transbay Tube to remove the bottleneck; also proposed is to build by-pass lines at some critical stations with large demand.
- By-passing (pocket) track at critical station: A proposed project to build Glen Park Pocket Track would allow other BART trains to move along while other BART trains are stopped at the station for passenger service. If planned correctly, pocket track should be built at well-selected critical BART stations to allow direct and express service, which could significantly improve BART's capacity and service qualities in both peak hours and non-peak hours.

While these projects are absolutely necessary to resolve congestion problems causing (line and station capacity limit) in peak hours, they bring extra capacity to the system in non-peak hours and in the reverse direction of certain lines during peak hours. This will provide more potential opportunities to use extra capacity for other transportation purposes.

4.2 Economic Analysis

To examine the potential costs and benefits of the use of BART for FedEx package movement, four alternatives – A1, A2, B1, and B2 - were compared to the status quo of truck-only transportation. Alternatives A1 and A2 consider only minor capital investment, while alternatives B1 and B2 assume far greater capital investment, including a jointly operated BART/FedEx facility at OAK. However, Alternatives A1 and B1 make use of FedEx long-haul trucks for all goods movement, while Alternatives A2 and B2 utilize FedEx electric delivery trucks for local transshipments. The truck vehicle miles travelled (VMT), FedEx operating costs, BART operating costs, and CO_2 emissions are determined for the status quo in each alternative. Analyses show 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 both be profitable for passenger rail systems and cost-effective for integrated air freight 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 less BART 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 service of the BART system.

Table 4-1 Summary of Case-Study Alternatives

	1	2
A	Little capital investment Deliver Trucks for local transshipment; s Existing BART yards and maintenance areas for access point; Dedicated freight train	Little capital investment Electric trucks for local transshipments; Existing BART yards, stations and maintenance areas for access point; Dedicated freight train
B	CTV5 Trucks for local transshipments; BART connection between OAK and Coliseum Station; Certain capital investment for retrofitting of existing BART stations for goods movement; Dedicated freight train	Electric trucks for local transshipments; BART connection between OAK and Coliseum Station Certain capital investment for retrofitting of existing BART stations for goods movement; Dedicated freight train

1

The presented economic feasibility study in Table 4-1 shows significant promise for exploring the possibility of mixed-goods service on passenger rail systems. Both BART service alternatives show a trend suggesting that the higher the demand the lower the level of subsidy required from government. Furthermore, with sufficient demand and significant capital investment, the passenger rail system, BART, can actually derive profit from such service while the air freight carrier (FedEx Express, in this case study) can derive savings. These findings should motivate researchers to investigate how other potential demand sources might be exploited such that mixed-goods service can become both profitable and environmentally sustainable.

There are several opportunities for research that arise from this study that should be pursued Given the tremendous capital costs required for Alternative B, the government may be unwilling to fully cover capital expenditures for a service that might primarily benefit a single private company, such as FedEx. Thus, it is of critical importance to develop a valid estimate of initial capital and other "start-up" costs, such that all future benefits can be discounted and compared against the full project cost. Furthermore, the assumed level of infrastructure investment can greatly influence certain components of freight service, such as the handling time at transshipment points.

Future studies should also examine the logistical barriers inherent in mixed-goods service, including non-interference with existing passenger transport operations and routine maintenance activities. For example, because morning freight service would fall outside of current BART operating hours, analysis should also include the additional overhead and logistical costs required during this specific time period.

Researchers might also consider latent demand, perhaps by assuming that cars will fill the available road space left by the removal of trucks from freeway corridors; doing so would provide a more valid estimate of social benefits. From proceeding analyses, latent demand was assumed negligible because the daily truck flows were found to utilize a marginal percentage of freeway capacity (~1 percent).

Other elements, not yet included, might prove beneficial to mixed-goods service. One such critical element is the inclusion of other freight carriers besides FedEx as BART "customers" such as UPS, legal courier services, medical deliveries and the U.S. Postal Service Overlaps in demand patterns across different customers can lead to even greater economies of scale for

BART freight transport, particularly in comparison with truck transport. Other potential demand sources in the Bay Area include UPS containers, agricultural produce, and containerized/non-containerized products from the Port of Oakland. Tailoring BART service to just a single customer may be risky, given that DHL, a company similar to FedEx, recently ceased service within the Bay Area. Thus, any mixed-goods service providers should attempt to accommodate several different sources of freight demand. However, additional costs might arise when different demand sources are accommodated, due to variations in container characteristics and service requirements. Another element not quantified here is the higher level of reliability afforded by rail transport in comparison to truck transport. Including this benefit for freight carriers may further skew the results in favor of mixed-goods service.

As identified in a previous study (Sivakumaran et al. [26, 17]), 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.

The results should be of particular interest to other urban areas across the U.S., such as Los Angeles, Washington D. C., New York City metropolitan region, and Chicago, where passenger rail systems exist in proximity to major air freight terminals. Some of these systems may possess favorable characteristics towards mixed-goods movement, such as intermodal transfer stations, containers with the ability to interface between different modes, and standard gauge rails.

4.2.1 Benefit to BART

Mixed goods movement essentially presents a business opportunity for increasing a public transit operators' total revenue. However, passenger movement is the primary mission of nearly all public operators, and, consequently, freight movement would have to take place in such a way to resolve any conflicts with existing and planned passenger service. Furthermore, this necessitates the need for full cost recovery of the rail system in providing goods movement, because it would, for all purposes, be unlikely that public funds could be funneled towards the movement of private goods. This cost recovery will of course depend on the fixed and variable costs of operation by the transit operator, the demand presented by the freight carrier, and potentially others such as high-tech manufacturers and farmers. Additionally, 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.

4.2.2 Benefits to Freight Carrier

A mixed-goods method of transport also presents several benefits to the freight carrier. First, the independent guide-ways offered by urban rail prevent the potential for delays due to congestion and consequently provide a more reliable mode of transport to the freight carrier. For high priority products in particular, this can provide significant cost savings. Second, the transport mode in itself may prove to be more cost effective than truck transport for high levels of demand, when one considers that the “road” equivalent of a long freight train would likely be several trucks. In other words, urban rail offers economies of scale, or decreasing transport unit costs with increasing demand. Using trucks to accommodate increasing demand does not offer this advantage, and can in fact compound congestion on freeways, which in turn produces even greater uncertainty in delivery times.

Furthermore, a single freeway disturbance can have far-reaching implications, as shown with the recent gas tanker explosion on Interstate 880. I-880 is considered the primary north-south route for freight movements originating from and arriving at the Port of Oakland. The gas tanker explosion on October 22, 2008 created significant delays to both commuters and freight shippers, as vehicles were suddenly detoured to more circuitous routes with limited capacity. Recent discussions between PATH researchers and FedEx confirmed an increased interest in alternative freight transport in lieu of this recent event.

4.2.3 Benefits to Society

Much of the benefits that arise from the use of transit infrastructure for mixed goods movement stem from the accompanying decrease in truck volumes along urban roadways. Decreasing the number of freight vehicles on urban roads can include decreased pollution, accidents, and congestion. The negative externalities produced by truck traffic have been explored and confirmed in several academic studies, which have been outlined in [19]. We identified the following aspects of benefits to the public due to reduced truck activities:

- Reduced Green House Gas (GHG) emissions and other pollutants to the environment;
- Recycling heavily invested BART cars for dedicated freight movement;
- Reduced road maintenance cost;
- Potentially reduced fatal highway accident.

Truck activities have a great impact on the environment. Ground level ozone, the main ingredient of smog, is formed by complex chemical reactions of volatile organic compounds and nitrogen oxides in the presence of heat and sunlight. Particulate matter, a diesel engine pollutant, is easily inhaled and disposed in lungs. Goods movement generates emissions both during on-road activity (truck driving) and non-road activity (cargo loading/unloading and idling). The reduction of pollution is proportional to the reduction of truck activities. It is well-known that trucks, particularly heavy-duty trucks, are the main cause of pavement damage [12]. As an example, one fully loaded 102' wide truck does as much damage to the road surface as nearly 10,000 cars. Although such damages are slightly different due to the difference in the number of axles, they are still very significant. Therefore, maintenance cost could be significantly saved by reducing truck activities. In addition, as reported in previous research, 80 percent of the victims killed in crashes involving trucks are occupants of smaller vehicles. Reducing trucks on busy highways can reduce such fatalities.

4.3 About Demand

A report from the MTC [17, 18, 19, 20] presented the results from extensive studies conducted on Bay Area regional airports. The main objective of the projects was to redistribute the demand of the three major airports (SFO, OAK, and SJC - San Jose International Airport) through policy in order to balance their capacity for maximum use of the airport facility in air traffic management. Currently, the regional air cargo shipment percentages (based on 2009 operating statistics) for the three major airports are: SFO serves 43 percent, OAK serves 52 percent, and SJC serves 5 percent.

MTC also forecasted the demand for each airport up to 2035 to fit the requirement of their long term planning. Air cargo is forecasted under the base, low and high scenarios are shown in Figure 4-2 and Figure 4-3. 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 percent, largely due to the projected increase in international air cargo, while OAK's share would drop to 43 percent. This forecast implies that more ground access to SFO will be required. With the increasing traffic congestion on the Bay Bridge and U.S. 101, an alternative for airport ground access to handle the demand would be necessary. This could be a great opportunity for shipping those products via the BART system. With these results, we should begin to think about modifying the BART system for direct services with higher operating frequency as we suggested before (Sivakumaran, [27]), which has been recognized as the highest benefit-to-cost ratio and thus identified as the highest priority transportation project in the Bay Area. The execution of this project will definitely reduce BART travel time for those direct service lines and further increase the BART's capacity for passenger movement. The further increased capacity and reduced travel time would be more favorable for air freight movement.

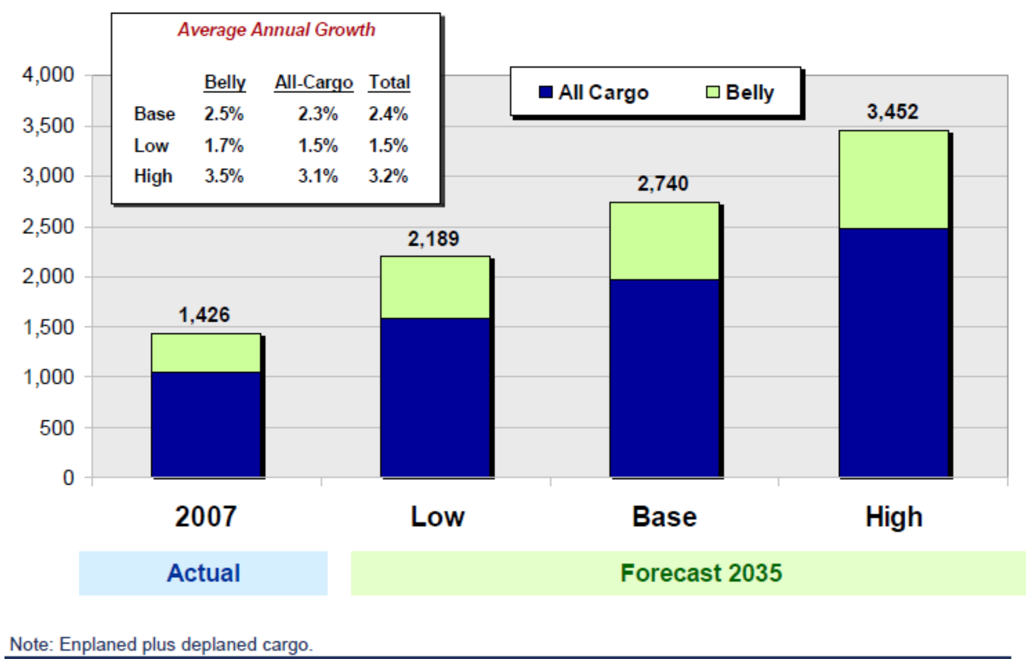


Figure 4-2: MTC prediction of Average Annual Growth of Air Cargo in Greater Bay Area (2011)

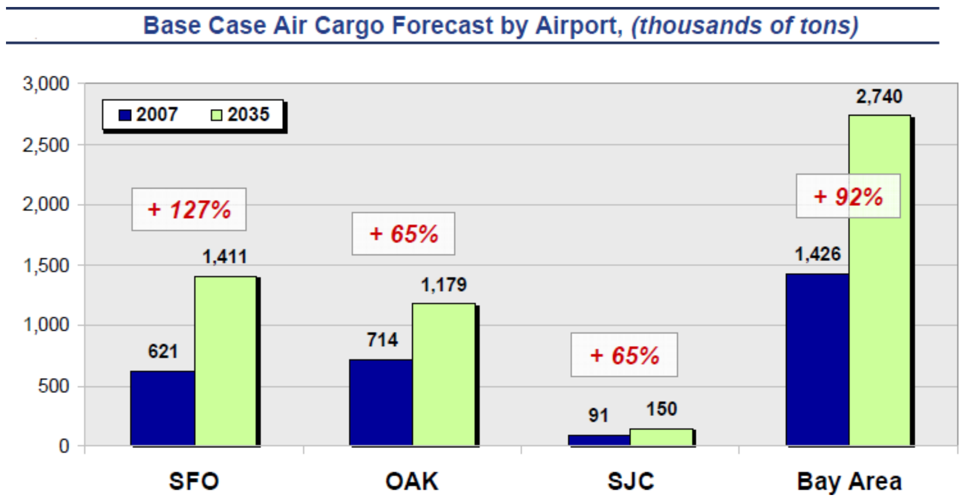


Figure 4-3: MTC Air Cargo forecast in Greater Bay Area by Airport (2011)

Since last year, the Departments of Transportation (DOT) in several states, including Texas, has started thinking about using regional rail system for combined passenger and freight movement. Most recently, *Freight on Transit Delphi Study* was initiated at the University of Toronto. Urban freight movement activities in Toronto and the Hamilton Areas generate over 20 percent of road traffic resulting in pavement damage, congestion, pollution and noise. In order to reduce these negative effects, alternative strategies must be explored through support and encouraging the use of lower impact modes such as walking, cycling, and public transit. Understanding those impacts requires collaboration across a range of fields including public transit, logistics, planning, and other stakeholders. The goals of this study are to guide future research, design possible implementation strategies, and identify key challenges and opportunities related to freight and transit integration.

All demands of FedEx products between O-Ds follow the time windows when all distribution takes place during the morning period, and all collection takes place during the evening period (Table 4-2). Because items may be particularly time sensitive, both the morning and evening periods have been split into two sub-periods, and demand has been assumed to be split equally amongst those sub-periods.

Table 4-2: O-D Demand Matrix (from OAK or to OAK)

	Milpitas	Union City	Dublin/ Pleasant Hill	Concord	SFO	Colma
From OAK	12,200	9,200	8,600	8,800	17,000	10,600
To OAK	40,000	14,600	66,000	34,000	51,000	24,000

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 SFO. If this portion of the demand utilizes BART's services, the inventory cost could be significantly reduced.

BART is already planning to extend service to City of San Jose by 2018. Considering the current high level of congestion on Interstate (I)-880 and I-80, the route through BART is highly competitive in terms of travel time and level of service. In addition, FedEx went through some modifications in the Bay Area in April 2010. These involved more trucking input and more service frequency from SFO to OAK. The demand table used in our analysis will increase, and therefore, the related benefits it generates will increase too.

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 are also potential future air freight demand resources. This could include products from the electrical, biological, and medical industries. In other words, 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 Jock O'Connell, 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 produced in California is forecast to expand dramatically, especially in such fast-growing economies of China and India. In both China and India, the ranks of upper middle-class consumers are rapidly expanding and 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 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 steadily increasing in recent years, much exported agricultural air cargo shipping has shifted from SFO to LAX (Figure 4-5). 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 products 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 product shipment. Renting warehouses in those locations could be significantly less expensive. Further, an extension of the BART in the Bay Area has been laid down by the MTC San Francisco Bay Area Regional Rail Plan as shown in Figure 4-4. The future BART extension to Central Valley will be next on the agenda.

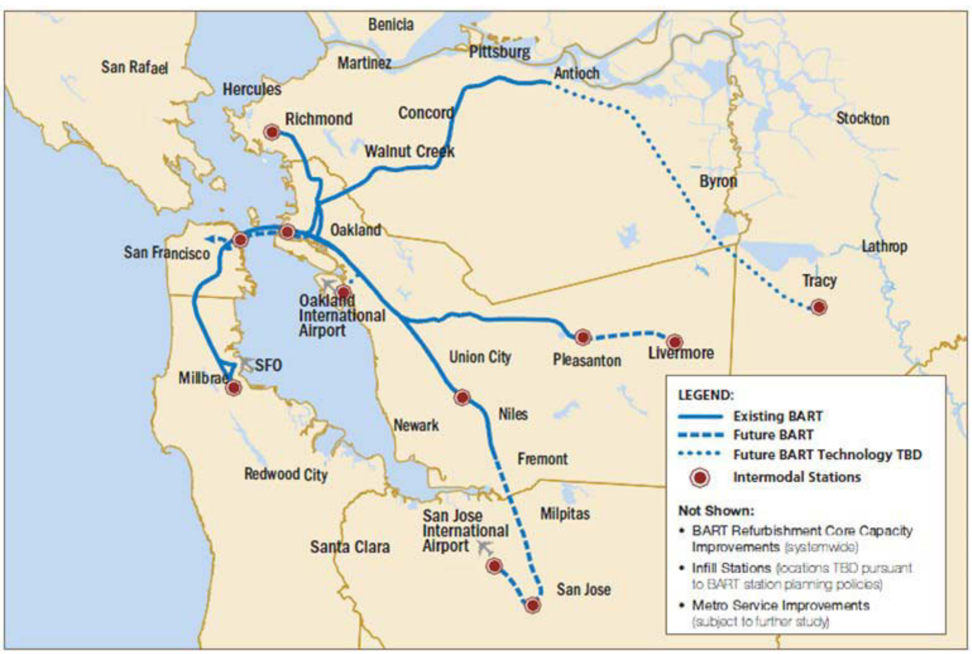


Figure 4-4 MTC San Francisco Bay Area Regional Rail Planning, 2007

BART is a closed-operational system and meets Federal Aviation Administration's security consolidation requirements. It could be advantageous to be a consolidated security company using BART to bring products into the airport. FedEx already has some shipping interests in internationally exported agricultural products. In the long run, FedEx can also act as the consolidator 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.

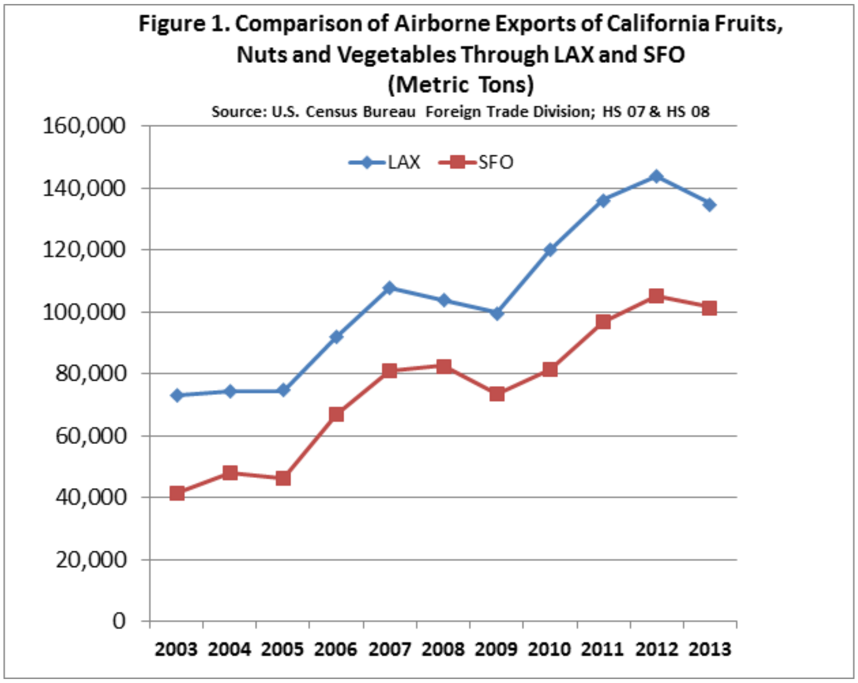


Figure 4-5. Comparison of specialty crop export through San Francisco Airport (SFO & Los Angeles Airport (LAX)

4.4 About Infrastructure Feasibility

4.4.1 BART Cars

All BART freight cars are assumed to be bidirectional operable "C" cars, which should be available for use after BART begins its fleet overhaul in 2016. These cars could be stripped of seating and fitted with locking mechanisms for wheeled United States Postal Service (USPS) containers. A single BART freight car, when considering container weight and shape, as well as doorway dimensions, can hold 24 USPS containers.

Note that if trucks and BART cars were completely packed with containers, they would be able to carry 24 and 36 containers, respectively. However, some room must be within vehicles for access to containers. Finally, while consolidation is the aim, vehicles may have to leave their origin before being completely filled due to delivery time constraints. Thus, slightly reduced capacity constraints are used.

Table 4-3. BART New Vehicle Procurement Milestone

Milestone	Date
Award of Contract	May 2012
Complete Final Design Phase	December 2013
Complete Pilot Car Delivery	July 2015
BART Original Fleet 45 Years Old	2016
Delivery of First Production Vehicle	December 2016
775 Car Contractual Option Deadline	June 2017
1000 Car FTA Change Order Deadline	May 2019
Complete Delivery 410th Vehicle	August 2019
BART Original Fleet 50 Years Old	2021
Complete Delivery 775th Vehicle	October 2021
Complete Delivery 1000th Vehicle	February 2023

BART's New Rail Vehicle Program, as shown in Table 4-3, is the plan for renewal and addition of more cars to the system, which is under execution [3]. There are two implications of this program: (a) the new cars will have better performance and would allow operations under a modernized control system, which could increase the capacity of the BART system; (b) possible opportunities for recycling retired BART cars for freight movement. The retired BART cars can be modified by removing all the seats and installing on the floors roller mats to assist with speed and convenience of container movement in the cars. It is also necessary to install locking mechanism to avoid container moving relative to the car floor. It is expected that the recycled BART cars could potentially save a significant amount of investment. However, there is one problem to be revolved: the storage of the retired BART cars since BART system does not have enough spare tracks to store those cars. The current storage capability is just enough to store spare cars for passenger operations.

4.4.2 Container for Integrated Air Freight Carriers

Granted that all FedEx container types, other than the USPS. containers, would not be able to both fit through existing BART car doors and be transported via BART, because they require caster decks for container loading and unloading. Thus, rather than completely retrofitting BART cars to fit all FedEx container types, which could be prohibitively expensive, it may be more reasonable to only consider transport of USPS containers due to its smaller size using modified BART cars. The USPS container size is 5.75 ft X 3.5 ft X 5 ft (length X width X height). A load density of 5.5 pounds lbs/ft^3 is assumed, which is roughly equivalent to the average load density of most existing FedEx container types (unpublished data). Empty container returns must also be considered since the demand is likely to be greater in one direction than for the other for all lines. The number of empty containers which must be transported to and from a given location is simply the difference between the location's outgoing and incoming demands.

4.4.3 BART System Accessibility

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 of containers between BART train and collection/distribution center of integrated air freight carriers includes the following two main steps: the truck carries the container between the FedEx center(s) to the access point (yard, shop, and tail track); and then the containers are moved to a BART freight train from a truck for loading, or the other way around for unloading. For the 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. Furthermore, 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.

For the Greater Bay Area, collection and distribution of air freight products of both FedEx and UPS to access BART at the closest proximity to OAK is critical. It is necessary to investigate the accessibility of BART's shop and spur track in Oakland near the BART's Coliseum 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 to and from 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 freight between the airports instead of using trucks on congested freeway corridors, such as U.S. 101 and I-880.

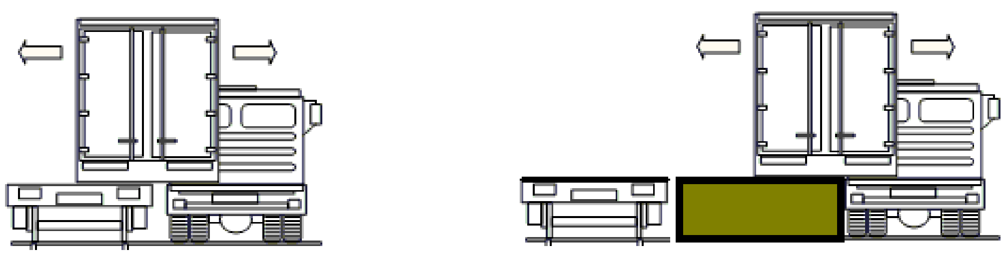
4.4.4 Transshipment

Transshipment between BART freight cars **and** trucks of integrated carriers is an important connection. The transshipment need to be efficient. This could be conducted in the following ways:

- Directly move between the truck and BART freight car if they are at the same height with or without a platform;

- Using a special crane to directly move between the truck and BART freight car if they are not at the same height;

The work of Bozicnik [6] 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. It has been adopted and preliminarily modified for our purposes. Basically, there were two ways for moving containers between BART cars and trucks: (a) pushing over on a roll-mat or a ball bearing equipped floor; or (b) using a flexible hydraulic crane. These two proposed solutions will be technically discussed below.



(a) (b)

Figure 4-6 Truck-train Transshipment Solutions

Directly pushing if the roller-mat or ball-bearing 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

<u>Solution A</u>. As shown in Figure 4-6 (a), 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 is parked very close to the train and that the two are at 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.

<u>Solution B.</u> Using a flexible hydraulic crane, as shown in Figure 4-6 (b), 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.

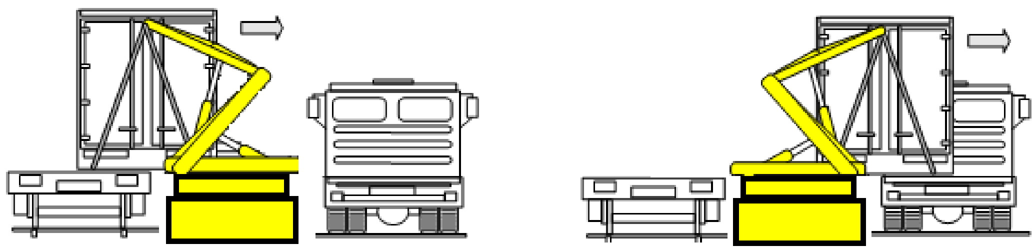


Figure 4-7 Truck-train Transshipment Solution 2: Side Loading Using Flexible Crane Mounted on Rail on the Platform

It is also possible to build a vehicle-mounted crane, which could move longitudinally between the truck and the BART car (Figure 4-7). 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.

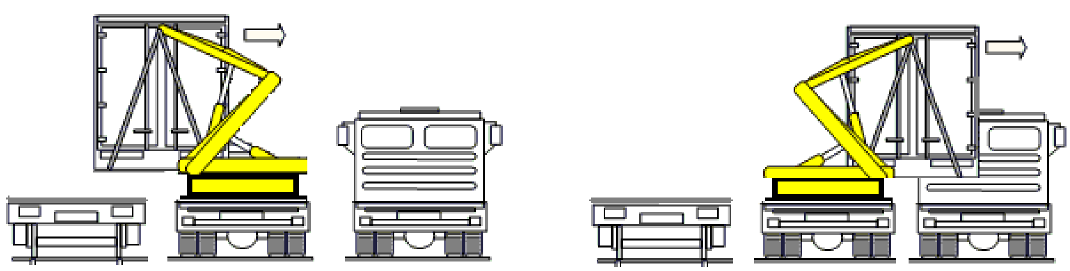


Figure 4-8 Truck-train Transshipment Solution 3: Side loading using a flexible crane on a heavy-duty-vehicle

Transshipment between BART access point and integrated air freight carrier collection/distribution center could use low-emission-heavy-duty trucks or electric vehicles (EV) in our analysis. An ongoing project is being carried out by FedEx 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.

4.5 About Energy Consumption

Table 4-4 Energy Resources and Efficiency Factors for BART

	BART	**Truck**
Energy Resource	Electricity	Fuel Combustion
Renewable Resource	53%	0%
Fossil Fuel	47%	100%
Energy Efficiency	1	0.3

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

From Table 4-4 above, 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, which. This is important since energy resources, especially fossil fuels, are increasingly problematic resources [14].

The percentage of renewable energy is increasing for both transportation modes. If a longer period of time is considered, it could be that within ten years the percentage of renewable energy used will increase significantly in general due to gradual maturity of technologies. However, the energy switch by the trucking industry will slightly slower than passenger cars.

Furthermore, taking into account the energy use efficiencies for BART trains and trucks as shown in Table 4-4 above, the predicted fuel and energy saving comparison for the four scenarios in the considered time horizon are shown in Figure 4-9 and Figure 4-10.

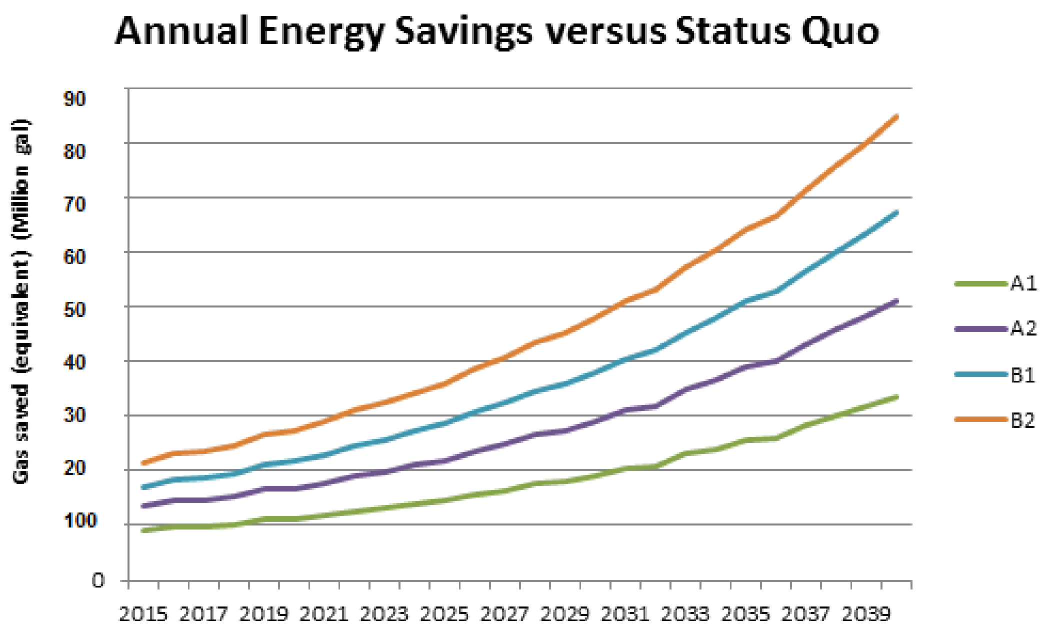


Figure 4-9. Predicted annual Gas (Million Gal) saving vs. Status Quo for the 4 alternatives

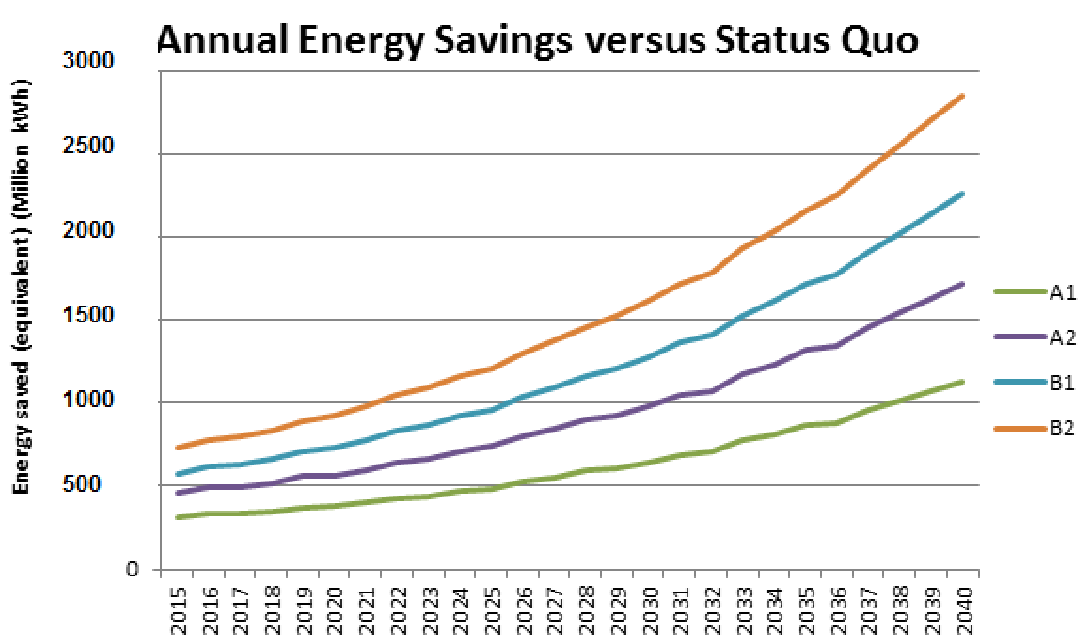


Figure 4-10. Predicted energy (kw/h) saving vs. Status Quo for the 4 alternatives

If we continue with the current energy consumption the way we are now, it can be predicted that in 20 to 50 years, the percentage of renewable energy used in electricity generation will increase significantly.

As a result, changing traffic modes is a good solution to the current energy situation. The best time to do it is now.

4.6 About Emission and Environmental Impact

These calculations are based on the VMT during truck activities using various alternatives: A1, A2, B1 and B2 (Sivakumaran et al., [26, 27]), 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) 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 it.

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. Serious emission-reduction procedures must be implemented by all means. They are absolutely necessary and the timing is urgent.

4.7 About Security Issues

An air freight security checks would meet FAA requirement: all the products must be x-rayed (screened) before they are loaded into an aircraft. As we discussed before with BART Operation Division and FedEx Operation Engineers, the security level of the integrated air freight carriers would satisfy the security level of passenger service of BART systems. However, any other activities related to loading and unloading from BART cars will need to be closed from any public access, including platforms, elevators, containers, vehicles, and other equipment. To make sure the system is closed to public access, it will need a contractual agreement between BART operators and the operators of integrated carriers for operation at the proper times and locations. Such an agreement or protocol needs to be determined along with regulation needed to be established between BART and the integrated carriers, which must be abided to by all the parties involved.

4.8 About Operational Logistics

In summary, two factors are critical for dedicated freight train operation in the current the BART system: (a) availability of convenient access point of a BART line close to OAK; and (b) properly scheduling the operation for BART line in downtown San Francisco. The focus in San Francisco runs from Daly City to Embarcadero BART stations. The trends for the NB and SB directions are similar, showing many feasible slots in the morning before 6:00 am, and later in the evening after 7:00 pm. However, the SB direction has fewer available slots in both cases analyzed above and, therefore, becomes the critical direction for further analysis. In the current weekday BART schedule, the total number of possible insertions is 4 from 4:30 am to 6:00 am and 28 after 7:00 pm in the evening [15].

There are two possible ways to use the extra capacity for the reversed direction in peak hours: (a) combine passenger movement and air freight movement in the same consist - only use an adequate number of passenger cars for passenger movement, and the rest can be freight cars; and (b) run dedicated passenger service consist less frequently than the current schedule so that some dedicated freight trains combined with empty passenger cars can be inserted in between. Adding empty passenger cars allows the return of the empty car to the other end for passenger service.

FedEx has its Western Regional Hub at OAK. Therefore, any FedEx products between the Bay Area and all the 11 Western states of the U.S. will also go through this location. UPS also has its sorting center at OAK and it has flight operation in SFO as well target for Asian markets. Therefore, it needs to transfer products between OAK and SFO. Both carriers would require a convenient links between OAK and the BART system for air freight movement. The current OAK Airport Connector between BART Coliseum Station and OAK uses smaller trains instead of direct BART system link. This link could possibly be used for air freight movement if product quantity is not very large, the containers need to be small and need roller wheels for transshipment. Obviously, this is not good for large quantity of products.

Based on this, it is recommended that, if the BART system is to be used for operation of air freight movement in the Greater Bay Area, it is necessary to build an access point at BART line near OAK, which could be used for loading and unloading containerized products of integrated air freight carriers. An alternative is to expand the BART Annex Shop spare tracks so that loading/unloading and train access to BART lines would become more convenient.

4.9 Institutional Issues

Possible institutional issues related to BART and air cargo freight movement may include the following:

(a) Labor union issues: BART and UPS have unions, but FedEx does not. For BART, added air freight movement could increase revenue and more job opportunities. However, using the BART system to move freight in the Greater Bay Area means that truck drivers for UPS and FedEx could face possible layoffs, which might cause some union issues for UPS. Nevertheless, this could possibly be addressed by internal job shifting: truck drivers could work transshipment, product security screening, containerizing and sorting. As long as the demand is high enough, business expansion will lead to creation of new jobs, which could result to a virtuous circle for BART operations; and

(b) Insurance of products through the BART system

Most products of integrated air freight carriers have low weights with high values. The corresponding insurance would be higher. Particular, time critical products – such as those with limited pick-up and distribution time windows would require the intermodal service to be reliable.

(c) Funding for BART System

Currently, the BART system is primarily government funded (mainly from Federal government with relatively small amount from the state government and MTC) and a small percentage coming from fare box recovery such as ticket fares and parking. It is expected that if the BART system added air freight movement capability, government subsidies will remain at the current level and not reduced. The extra revenue obtained from air freight cargo (parcel) movement could be used for the BART system for maintenance, operations, capacity and safety improvements so that the BART system could provide with this source of revenue an overall higher quality of passenger services.

(d) Cost sharing among public and private stakeholders

(e) Collaboration between the public sector entity and the private business sector

4.10 Connection with High Speed Rail in the Future

Looking ahead, a new mode in the U.S., high-speed rail (HSR), could potentially be added in California connecting the Bay Area to Los Angeles. There is a possibility it could be used for combined passenger and faster freight services, such as long distance haul of air freight cargo. Considering this factor in the HSR design and construction from the very beginning, the following could be possible advantages:

(a) freight movement in HSR could definitely increase the total demand, generate more favorable business cases, and make the costly system more efficient providing a non-governmental source of revenue and cost sharing;

(b) incorporation of freight movement elements could avoid future system modifications which, if implemented later into the system, could be cost prohibitive.

Although HSR load is limited to approximately two tons per car, such loads could be satisfactory for air freight movement since it is generally low in weight and high in value. Some air freight type containers could be modified to fit into the train car. If a direct connection becomes available, it would be sufficient to design optimal operational logistics to link the HSR to other modes, such as passenger train, BART, and other transit systems. These seamless intermodal transportation chains can be created and integrated in the overall transportation system for efficient and smooth movement of passengers and freight.

4.11 Recommendations

After careful consideration of all of the important aspects of the feasibility for using the BART system for air freight movement, consideration should be given to the following recommendations:

(1) Sustainable demand for practical operation of air freight movement in BART is the most critical part. In the short run, it is necessary to find out if the exported agricultural products

could generate the require demand. If this is proved to be feasible, a small demonstration could be conducted to show the feasibility of operation to all the stakeholders and the public.

(2) In the long run, E-commerce or internet (on-line) shopping is experiencing extraordinary growth both domestically and internationally. Accompanying this is increased need of speedy delivery. Delivering packages to customers will naturally increase on the local, regional, State, and national level for air freight cargo demand. Since there are many delivery companies besides the integrated carriers (such as FedEx, UPS, and DHL), such demand is sparsely distributed among all the shippers and transportation system including rail. This is the reason why there are so many trucks, large and small, on the highways. To integrate those businesses and move them to completely different transportation modes, it may be necessary, at least in the beginning to incentivize.. Maybe, charging vehicle license fees according to both VMT and vehicle size (weight) could provide a push for shippers to think about other possible alternatives for their ground transportation.

(3) A convenient access point to the BART system is the second critical point for practical operation of air freight movement on the system. Using BART Millbrae tail track to access SFO only needs some minor modifications. For practical operation to happen, it is suggested that Caltrans sponsor a modification project so that ground vehicles could use the tail track for container loading and unloading. For accessing OAK, it is necessary to build a BART system access point with spare tracks which can easily access both directions of the BART lines. This would need a large investment and a may need to be funded by the project's benefited stakeholders. benefiting

(4) Over four-hundred, old BART cars will be retiree in the next few years. Reuse of retired BART cars for air freight movement will potentially save a significant amount of funding. With some minor modifications, such as removing the seats and adding roller mats on the floor, those cars can be made suitable for exported agricultural products. However, to recycle those cars for freight movement (particularly, exported agricultural products), it is necessary to find storage locations. In addition, some minor maintenance may be necessary to keep them in workable conditions.

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