# Appendix 5-A

## Operating Cost Memorandum

**Memorandum**

**Date:** July 11, 2011

**To:** Central Valley Regional Teams

**Re:** HST Operating and Maintenance Cost for Use in EIR/EIS Project Level Analyses

The memo documents the assumptions used to estimate Phase 1 and full system high-speed train (HST) operations and maintenance (O&M) costs. The Phase 1 estimates are based on an operations plan for service between Anaheim and San Francisco/Merced that takes into account the following elements: passenger ridership in the year 2035, levels of system activity, materials requirements, and basic staffing derived from overseas experience with HST, adjusted for California-specific requirements, and unit costs applicable to California conditions. The full system costs are estimated by pivoting from the Phase 1 costs and assumptions established in the Authority's 2008 business plan.

The memo is divided into four sections. Section I describes the schematic operations pattern developed for forecasting passenger volumes with frequency and speed of service, and stopping patterns for each train. This is followed by a summary of how the operations plan was developed to match the forecast levels of traffic, and the operating statistics resulting from the plan. Section III describes the assumptions for staffing, energy use, trainset and infrastructure maintenance, insurance, and administration and the resulting costs for Phase 1 in 2035. This section also presents the development of estimates of full system O&M costs. Finally, Section IV describes the assumptions used to allocate Phase 1 costs to each of the segments of the system alignment.

## I. Schematic Phase 1 Operations Pattern for Ridership and Revenue Forecasting

A schematic operations pattern describing how often trains would operate, the stations at which they would stop, and the time between station stops was developed from prior tests of operations and ridership forecasts. One pattern was created for the six hours of the peak morning and afternoon travel times, and a second for 10 hours of off-peak service. Table 1 shows the pattern for the peak period service in the southbound direction. The northbound service pattern mirrors the southbound. The peak period pattern features nine different train schedules to serve the various ridership markets forecasted for Phase 1. Many different schedules are possible because the alignment allows express trains to pass local trains at stations.

This peak schematic pattern provides 57 trains in each direction in 6 hours, for an average of just under 10 trains per hour. The off-peak for the initial phase of service provides 71 trains in each direction over a 10-hour period, for an average of 7 trains an hour.

The off-peak period pattern is simpler with only six different train schedules and fewer trains per hour as shown in Table 2. As in the peak pattern, the goal was to provide as many station pairs with relatively frequent and few-stop service given the lower ridership expected in the mid-day and tail ends of the day. The off-peak for the initial phase of service provides 71 trains in each direction over a 10-hour period, for an average of 7 trains an hour.

**Table 1: Schematic Operations Plan – Peak Southbound**

| Pattern# | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Frequency of service (mins) | 60 | 120 | 60 | 120 | 30 | 60 | 120 | 40 | 40 |
| | Run times from start in minutes | | | | | | | | |
| San Francisco | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Milbrae | \| | \| | \| | 15 | 15 | \| | \| | 15 | |
| Redwood City / Palo Alto | \| | 20 | \| | 25 | \| | 20 | 20 | 25 | |
| San Jose | \| | 35 | 30 | 40 | 35 | 35 | 35 | 40 | |
| Gilroy | \| | 51 | \| | 56 | \| | 51 | \| | 56 | |
| Merced | | | | | | | | 91 | 0 |
| Fresno | \| | \| | \| | 97 | 87 | \| | \| | | 22 |
| Bakersfield | \| | \| | \| | 136 | 126 | \| | \| | | 61 |
| Palmdale | \| | \| | \| | \| | \| | 151 | 145 | | 95 |
| Sylmar | \| | \| | \| | \| | 175 | \| | 167 | | 117 |
| Burbank | \| | \| | \| | \| | \| | 179 | 176 | | 126 |
| Los Angeles Union Station | 160 | 175 | 163 | 194 | 189 | 188 | 185 | | 135 |
| Norwalk | | 188 | \| | 207 | | | 198 | | 148 |
| Anaheim | | 200 | 184 | 219 | | | 210 | | 160 |
| # of trains | 6 | 3 | 6 | 3 | 12 | 6 | 3 | 9 | 9 |

For each pattern of service, the time for each train service was calculated, in general, from the curvature and grade of the current preferred programmatic EIR/EIS alignment (see 2005 Statewide Program EIR/EIS), and the ability of a standard high-speed train set currently in revenue service elsewhere in the world to accelerate, maintain top speeds, and brake comfortably and safely. Time was added at stations for picking up and dropping off passengers depending on the expected size of the flows and in some cases to allow overtaking by express trains while stopped trains are at the station platforms. Finally, extra operations recovery time, equal to roughly 3.5 percent of the normal trip time, was added to allow for unexpected delays in boarding or operation.

The high-speed trains operating on this pattern are assumed to be of the standard length of around 660 feet that has evolved in Europe and Asia, with a single level and seating comfortable by U.S. standards, resulting in either a single set with 450-500 seats, or two such sets coupled together, for a total seated capacity of 900-1,000. At this schematic stage, capacity for each pattern was not specified, but the later matching of forecast ridership to a detailed timetable verified that this schematic pattern was able to accommodate growth in demand to 2035, as well as to provide full initial system service in earlier years.

## II. The Phase 1 Detailed Operations Plan

A detailed operations plan was then developed from the schematic Phase 1 operating pattern for ridership forecasting. The types of trains in the pattern (express, local, limited stop) were arranged into a repeating hourly “clock-face” pattern to make the service more regular and predictable, and to reduce the number of different kinds of overtakes where express trains pass trains stopped at stations. The minimum time between trains following each other past a given point was set at three minutes, based on the practical capacity of the signal and train control system. Express trains were arranged to overtake stopping trains at intermediate stations, with local stopping trains pulling off the main track to the platform, allowing the non-stop train to pass. Although stations stops were swapped among some of the local and limited stop trains to make the schedule work better, the service levels between station pairs were kept at the same level.

**Table 2: Phase 1 Off-peak Operating Pattern - Southbound**

| Pattern# | 1 | 9 | 3 | 4 | 5 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| Frequency of service (mins) | 60 | 60 | 30 | 0 | 30 | 60 | 60 |
| | Run times from start in minutes | | | | | | |
| San Francisco | 0 | 0 | 0 | 0 | 0 | 0 | |
| Milbrae | \| | 15 | 15 | 15 | \| | 15 | |
| Redwood City / Palo Alto | 20 | 25 | 25 | \| | 20 | 25 | |
| San Jose | 35 | 40 | 40 | 35 | 35 | 40 | |
| Gilroy | 51 | 56 | 56 | \| | 51 | 56 | |
| Merced | | | | | | 91 | 0 |
| Fresno | \| | 97 | 97 | 87 | \| | | 22 |
| Bakersfield | \| | 136 | 136 | 126 | \| | | 61 |
| Palmdale | \| | 170 | \| | \| | 151 | | 95 |
| Sylmar | \| | 192 | \| | 175 | \| | | 117 |
| Burbank | \| | 201 | \| | \| | 179 | | 126 |
| Los Angeles Union Station | 175 | 210 | 194 | 189 | 188 | | 135 |
| Norwalk | 188 | 223 | 207 | | | | 148 |
| Anaheim | 200 | 235 | 219 | | | | 160 |
| # of trains | 10 | 10 | 20 | 0 | 20 | 10 | 10 |

Figure 1 shows a typical morning peak hour of the resulting detailed operational timetable, running south from the San Francisco Transbay Terminal and the spur from Merced joining the main line north of Fresno.

To help ensure that the timetable can be operated reliably and efficiently, a “string-line diagram” was plotted showing the path of each train from start-to-finish (vertical axis) over time (horizontal axis). This diagram is especially useful in ensuring that express trains overtake local trains running in the same direction at a station. Figure 2 shows the morning’s start of operation on the main line in both directions between San Francisco (top) and Anaheim (bottom). A good example of overtaking is the first train from Anaheim (red line), leaving at 5:05 a.m. northward (up and to the right) to San Francisco. It overtakes a northbound local train (in yellow) that is stopped at Bakersfield at 6:20 a.m. (Incidentally, the first southbound train from Merced (green) passes through the station at the same time on the other express track.) The express also catches up to and overtakes a northbound (blue) train stopped at Gilroy at 6:35 a.m. Working with the timetable and stringline diagram produced a realistic detailed operational timetable for operations and the basis for the number of train operations a day, and how many trainset miles are operated daily.

Each train may consist of one eight-car trainset or two such sets for a total of 16 cars. The double trainsets are assigned where capacity is needed to handle the forecast ridership demand. Since the costs of operation and vehicle maintenance for a double set train approach double those of a single set train, it was important to know the proportion to properly estimate the operating cost.

To determine the need for double set trains, the forecast daily ridership was distributed to each hour of the day, using factors from experience with high-volume rail traffic in the Northeast Corridor (New York to Washington), high-speed services overseas, and California travel patterns. Separate factors were developed for the peak morning and afternoon hours, the hours before and after those peaks (“peak shoulder” hours), and off peak hours.

## Figure 1: Phase 1 Typical AM Peak Hour Timetable, Southbound

| | | Direction → | SB | SB | SB | SB | SB | SB | SB | SB | SB | SB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Trainset → | **T18** | **T19** | **T22** | **T9** | **T20** | **T21** | **M1** | **T23** | **T24** | **T25** |
| | | Train No. → | S010700 | S290703 | S020730 | S150708 | S280708 | S040711 | S210733 | S180737 | S140752 | S010800 |
| | | Pattern → | **1** | **29** | **2** | **15** | **28** | **4** | **21** | **18** | **14** | **1** |
| **Southbound** | | Service Type → | Limited Express | Limited | Express | Merced All-Stop | Limited | All-Stop | Limited | Limited | Merced All-Stop | Limited Express |
| **Station** | | | | | | | | | | | | |
| SFT | **S.F.-Transbay** | Dep | 7:00 | 7:03 | 7:27 | | 7:08 | 7:11 | 7:33 | 7:37 | 7:52 | 8:00 |
| SFO | Millbrae | Dep | -- | -- | | | 7:23 | 7:26 | -- | 7:52 | 8:07 | -- |
| RWC | Redwood City | Dep | 7:21 | 7:24 | | | 7:31 | 7:34 | -- | 8:00 | 8:15 | 8:21 |
| SJC | San Jose | Dep | 7:35 | 7:38 | | | 7:45 | 7:48 | 8:05 | 8:14 | 8:29 | 8:35 |
| GLY | Gilroy | Arr | | | | | | | | | | |
| | | Dep | 7:50 | 7:53 | | | 8:00 | 8:03 | 8:21 | 8:29 | 8:44 | 8:50 |
| MCD | **Merced** | Dep. | | | | | | | | | 9:19 | |
| MCD | **Merced** | Dep | | | | 7:59 | | | | | | |
| FNO | Fresno | Arr | | | | | | 8:40 | | | | |
| | | Dep | | | | 8:20 | 8:38 | 8:45 | | 9:07 | | |
| BFD | Bakersfield | Arr | | | | 8:56 | | | | | | |
| | | Dep | | | | 9:01 | -- | 9:21 | 9:30 | -- | | |
| PMD | Palmdale | Arr | | | | | 9:40 | 9:52 | | | | |
| | | Dep | | 9:30 | | 9:34 | 9:43 | 9:54 | 10:03 | 10:10 | | |
| SYL | Sylmar | Arr. | | | | | | | | | | |
| | | Dep | | 9:46 | | 9:50 | -- | 10:10 | 10:18 | -- | | |
| BUR | Burbank | Arr | | | | 9:56 | | | | | | |
| | | Dep | | -- | | 9:59 | -- | 10:17 | 10:25 | 10:29 | | |
| **LAU** | **L.A. Union Station** | **Arr** | 9:47 | 9:58 | 10:05 | 10:08 | 10:10 | 10:26 | 10:34 | 10:38 | | 10:47 |
| | | **Dep** | 9:48 | 10:00 | 10:06 | 10:09 | 10:11 | 10:27 | 10:35 | 10:39 | | 10:48 |
| NSF | Norwalk | Arr | 9:55 | | 10:13 | 10:16 | 10:20 | 10:34 | | | | 10:55 |
| ANA | **Anaheim** | Arr | 10:10 | | 10:28 | 10:32 | 10:35 | 10:49 | | | | 11:10 |

**Figure 2: Typical Start of Week-Day Train Operations**

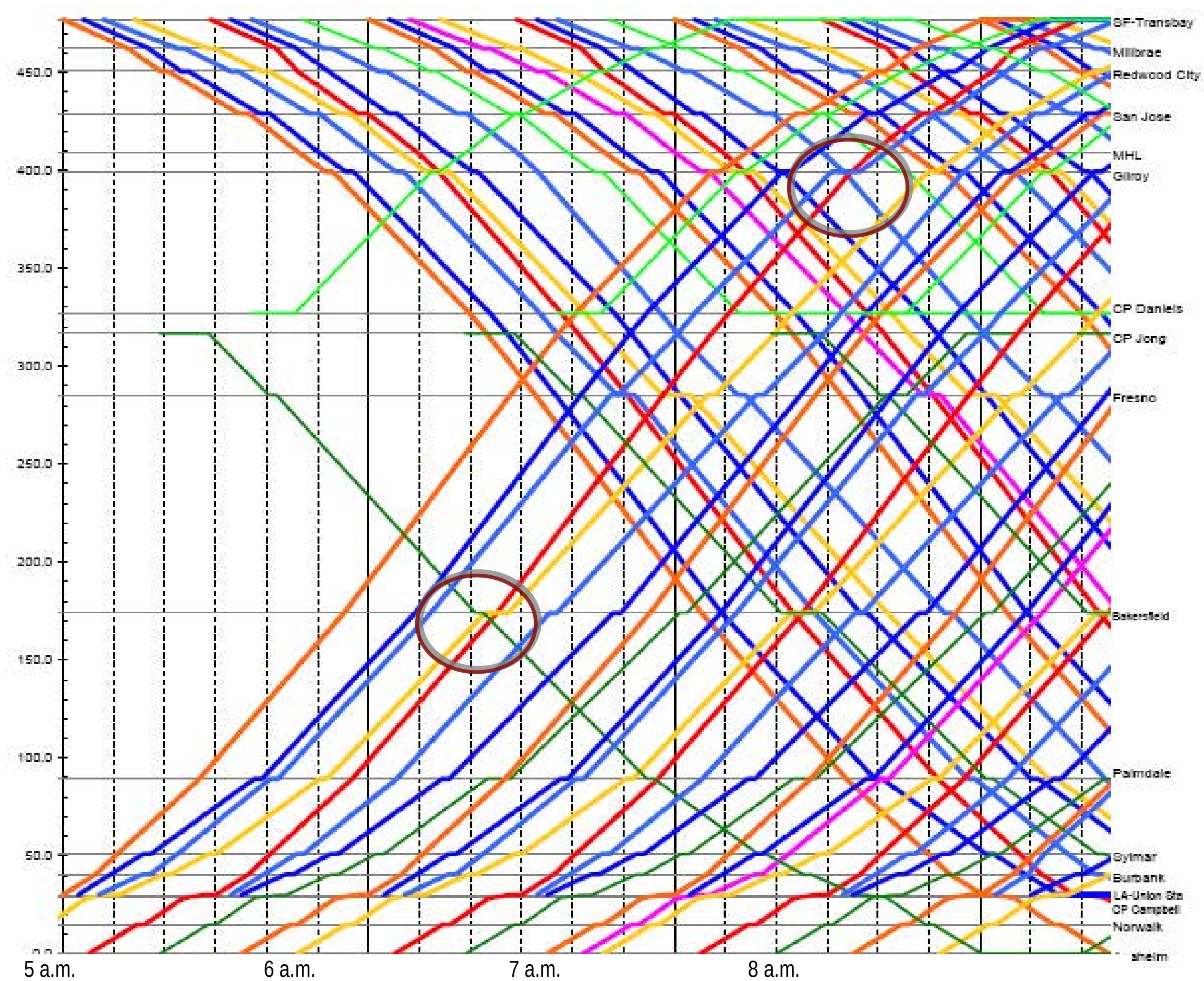


Table 3 shows the percentage of traffic assigned to each set of hours (i.e., peak, shoulder, and off-peak) for the three major high-speed train markets. To illustrate, interregional traffic, which is more evenly spread out through the day than traffic within the Bay Area or the LA Basin, has 12 percent of the day's traffic assigned to each peak hour, whereas the more commuter-oriented local markets have 15-17 percent in each peak hour. Over half of the traffic is expected in the 6 peak hours for each of the market type, and the remainder is in the 10 off-peak hours.

Higher system capacity is needed in both the Bay Area and LA Basin (MTC and SCAG) regions because a peak direction can be expected, based on existing flows of traffic. The strongest peaks are in the local MTC traffic on the HST, which is heavier out of San Francisco in the afternoon (and into the city in the morning) and requires 20 percent more seats than the average of both directions would have indicated. HST traffic in the SCAG region is expected to need 10 percent more seats in one direction than the average. On the other hand, the inter-regional traffic is equally heavy in both directions at the peak, and no additional seats are required. The cumulative effect of these peaking assumptions is to require nearly three times

**Table 3: Ridership Peaking Factors for Capacity Calculations**

**(% of Total Daily Traffic)**

| **Travel Market** | **Each peak - peak hour** (2/day) | **Each shoulder-peak hour** (4/day) | **6 hours peak period** | **10 hours off-peak period** |
|---|---|---|---|---|
| Inter-regional trips | 12% | 5-10% | 54% | 46% |
| Within-MTC trips | 17% | 4-11% | 67% | 33% |
| Within SCAG trips | 15% | 4-10% | 61% | 39% |

as many seats at the peak hour in the peak direction as would be indicated by the use of an average hour during the day.

Ridership was assigned to the available service schedule operating during each period. Trips were first assigned to the fastest trains available, i.e., Los Angeles to San Francisco passengers were assigned to the non-stop express train, San Jose to Anaheim to the two limited stop trains, Fresno to Norwalk trips to the 28 limited trains, and so forth. The loads were then compared to the capacity to determine whether one set (500 seats) or two (1,000 seats) were needed. In cases where even two-set trains would be over capacity, overflow passengers were re-assigned to the next fastest trains with available seating capacity operating within the same hour.

The levels of activity that are shown provide a sufficient basis to determine the operating costs needed to handle the forecast level of traffic. Handling the forecast loads with the assumed 260 trains per day plus a 10 percent allowance for non-revenue operations, e.g., moving a train from an end station to a maintenance facility, generates in total, 43 million train miles annually by 2035.

## III. Operations & Maintenance Costing Assumptions and Results

The costs of operations and maintenance (O&M) are based on

- California and U.S. costs and labor requirements,
- California's specific alignment, stations, and natural environment,
- Experience of maintenance frequency and magnitude from high-speed rail systems throughout the world, and
- The trainset mile estimate described above.

An average cost per employee was assumed of $35 per hour (2010 dollars), resulting in an average salary of approximately $73,100, well above the average salary of the highest California metro area, and slightly below the wages of an average employee of the seven largest freight railroads in the US. Based on U.S. experience, an additional 32 percent was assumed for total cost to the high-speed train operator to cover Social Security, Medicare, and other government payments, health and savings plans, paid vacation, holidays and sick leave resulting in an all-in hourly rate of $46.35, equivalent to $96,400 per year. In addition, based on railroad experience in the U.S. and overseas, a contingency was added to all labor costs of 15 percent for drivers and on-board train crew, and of 10 percent for all other labor to account for overtime and inefficiencies associated with scheduling.

Phase 1 operations costs, including train crews, power, station, administration, marketing, and control center costs are estimated at half the of total O&M costs in 2035, and are divided into seven categories as shown in Table 4.

**Table 4: Phase 1 Operating and Maintenance Cost by Category, 2035**

| Category | 2010 $$ in millions |
|---|---|
| Operations | |
| Train Operations and Staffing | $ 116.2 |
| Station Services and Security | $ 59.7 |
| Sales, Marketing, and Reservations | $ 66.6 |
| Control Center Operations | $ 4.2 |
| General /Admin Support | $ 19.1 |
| Power / Energy (w/ Green surcharge) | $ 367.2 |
| Total Operations Cost | $ 633.0 |
| Maintenance | |
| Maintenance of Infrastructure | $ 111.2 |
| Maintenance of Trainsets and Vehicles | $ 420.6 |
| Total Maintenance Cost | $ 531.8 |
| Insurance | $ 51.5 |
| Program Contingency | $ 60.8 |
| **Total O&M Cost** | **$ 1,277.1** |

Train Operations and Staffing include one locomotive engineer per train and four crew members per trainset (i.e., eight for a double trainset train). The number of hours worked includes time spent operating and serving on the train, reporting in, daily job briefings, pre-departure testing the equipment, release time at the end of the day, training refreshers, time between trains and similar non-revenue service time. Train Operations and Staffing accounts for 9 percent of total cost.

Station Services and Security plus Sales, Marketing, and Reservations includes station management, ticketing and customer service representatives, security and crowd control staff, janitorial services, and other specialty services. Three shifts are manned by management and security, and 2 shifts of 10 hours are assumed for the full staff. Seventeen staff per shift are assumed at nine stations, 25 for the largest five stations. These two categories account for 10 percent of total cost.

Control Center Operations include a staff of eight persons for three shifts to plan for daily operations, to control train dispatching and power distribution, and to restore normal service in case of disruption. General/Administration is calculated at 8 percent of the costs for the above categories. These two categories account for 2 percent of total cost.

Power/Energy (including a "Green Surcharge") is calculated from costs of 17.5 cents per kwh (2009 dollars), 3.5 cents of which covers the cost of using 100 percent renewable energy sources. This average was derived from PG&E's 2008 commercial rates in California. The rate is applied to power consumed by the trains, calculated for the specific California operating alignment and speeds from manufacturer and high-speed train operations information at 0.089 kw/seat mile, and to the much smaller power consumption of stations. Power accounts for 29 percent of the total cost.

The maintenance costs of infrastructure (structures, track, and systems), and of vehicles are based on international HST experience, primarily from French experience and within the range of costs provided by other national railways and transport ministries. California-specific labor costs and requirements are incorporated, as explained above.

Maintenance of Infrastructure labor is based on ratios per mile of track or right-of-way, resulting in a total of nearly 340 personnel in multiple specialized mechanized teams over two shifts. For track maintenance, more maintenance-intensive ballasted track was assumed throughout because the extent of slab track on the California high-speed line has not been decided. The category maintenance-of-way materials is based on percentages of the capital cost per year, varying according to the expected life of the investment, and with an allowance for tools and equipment. The cost in 2035 represents an average cost over the varying useful lives of the track, catenary, and other components. In earlier years, when new, these items will cost less to maintain and in later years as they age, will cost more. In 2035, maintenance of infrastructure accounts for 9 percent of the total cost.

Maintenance of trainsets and other vehicles is based on a materials cost per trainset mile per year, for routine maintenance, and labor in two shifts spread throughout the facilities around the state. The heavy overhauls are estimated based on materials at $1.05 per trainset mile per year (2010$) and additional staff in 2 shifts (eventually expanding to 3), all at the Central Valley heavy maintenance facility. An administrative staff of 120 persons is added as well. In total, 2,000 persons would be working on vehicle maintenance and cleaning. The maintenance of rolling stock category accounts for 33 percent of the total cost.

Insurance, at 4 percent of O&M cost, is estimated at a level more than twice the cost of insurance for the most expensive policies for commuter rail agencies in 2009/2010. Although HST safety records are far better than non-grade-separated rail passenger services, this has been done because of uncertainty as to what the cost would be in the U.S. Finally a program contingency of 5 percent for unknown costs is added.

A similar process was used to estimate the O&M costs of the full system and Phase 1 in the Authority's 2008 business plan for the estimation of benefits and costs. The O&M costs of the full system with service to Sacramento and San Diego were estimated and resulted in costs 17% higher than those of Phase 1. Assuming that these relationships remain similar, the full system O&M costs would be roughly twenty percent higher than Phase 1, or $300 million higher (rounded up) for a total of $1.6 billion.

## IV. Allocation of Phase 1 Costs to Each HST Section

For planning, engineering and design purposes, the 800-mile HST system has been divided into nine geographic sections. None of the sections would operate independently; rather, they would operate as part of an integrated system. However, to assist the regional teams in their evaluation of environmental impacts associated with the future construction and operation of individual HST projects, the Phase 1 O&M costs have been allocated by section. The estimate was based on an estimate of the employment at stations and maintenance facilities, and on the number of train miles operated over each segment in the Phase 1 service plan.

For the estimates of employment, account was taken of the number and intensity of activity of stations and operational/maintenance facilities in each section, based on the cost estimates for 2035 and documented in the Authority's 2009 business plan. Personnel estimated for general and administrative work, sales, marketing, and other such were distributed among the sections in proportion to other personnel. Table 5 shows the assumed distribution of personnel.

**Table 5: Estimate of Personnel Allocated by Section**

| SEGMENT | Vehicle Mtce. | Heavy Mtce. Facility | Infra-structure Mtce. | Ops Control | Stations | Sales, Market-ing, etc. | G&A | Total |
|---|---|---|---|---|---|---|---|---|
| SF-San Jose | 440 | | | | 168 | 180 | 39 | 827 |
| San Jose-Merced | | | 170 | | 34 | 45 | 9 | 258 |
| Merced-Fresno | | 800* | | | 50 | 45 | 11 | 106 / 906 |
| Fresno-Bakersfield | | 800* | 170 | 24 | 68 | 90 | 21 | 373 / 1,173 |
| Bakersfield-Palmdale | | | 170 | | | | 0 | 170 |
| Palmdale-LAUS | 440 | | 170 | | 102 | 135 | 27 | 874 |
| LAUS-Anaheim | 440 | | | | 134 | 135 | 30 | 739 |
| Total: | 1,320 | 800 | 680 | 24 | 556 | 630 | 137 | 4,147 |
| * Facility location to be decided between these two segments | | | | | | | | |

Since the heavy maintenance facility may be located in either the Fresno to Bakersfield or the Merced to Fresno section, the estimates for those two sections are shown with the heavy maintenance facility as well as without.

The remaining costs and all contingency were allocated to each section in the ratio of train miles operated within the section to the total. Table 6 below shows the percent of train miles in each section.

**Table 6: Train Miles Estimated in Each Section**

| Environmental Segment | % of train miles |
|---|---|
| San Francisco to San Jose | 10% |
| San Jose to Merced | 22% |
| Merced to Fresno | 11% |
| Fresno to Bakersfield | 24% |
| Bakersfield to Palmdale | 18% |
| Palmdale to Los Angeles | 12% |
| Los Angeles to Anaheim | 3% |
| Total: | 100% |

The resulting allocation of cost was then adjusted to include the insurance amounts included in the April 2010 addendum to the Business Plan, and to reflect the operation of more trainset miles in the lower fare scenario that forms the basis of the environmental work. The resulting cost allocation estimates are shown in Table 7 on the following page.

**Table 7: Estimate of Cost Allocation by HST Section -- Phase 1**

| 2010$ in millions | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MCD-FNO | | FNO-BFD | | | | | |
| | SFT-SJC | SJC-MCD | no HMF | with HMF | no HMF | with HMF | BFD-PMD | PMD-LAUS | LAUS-ANA | TOTAL |
| Operations | $93.2 | $112.7 | $68.2 | $68.2 | $136.5 | $136.5 | $83.3 | $89.2 | 49.8 | $633.0 |
| Maintenance | 73.2 | 60.0 | 20.9 | 121.7 | 64.2 | 164.9 | 52.9 | 98.9 | 60.9 | $531.7 |
| Contingency | 6.1 | 13.2 | 7.2 | 12.2 | 9.4 | 14.4 | 10.7 | 7.4 | 1.8 | $60.8 |
| Insurance | 5.2 | 11.1 | 6.1 | 6.1 | 12.3 | 12.3 | 9.1 | 6.3 | 1.5 | $51.5 |
| TOTAL: | $177.7 | $197.0 | $102.5 | $208.3 | $222.3 | $328.1 | $156.0 | $201.8 | $114.1 | $1,277.1 |

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