PMOC REPORT

OP 32A – Project Transit Capacity Review

Honolulu Rail Transit Project
Honolulu Authority for Rapid Transportation (HART)
City and County of Honolulu
Honolulu, HI

July 2012 (FINAL)

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1.0 EXECUTIVE SUMMARY

1.1 Introduction

The Honolulu Authority for Rapid Transportation (HART) continues to advance development of its proposed Honolulu Rail Transit Project ("Project"), formerly known as the Honolulu High-Capacity Transit Corridor (HHCTC) Project, in accordance with the Federal Transit Administration (FTA) New Starts requirements. The Project is intended to provide improved mobility in the highly-congested east-west corridor along Oahu's south shore between Kapolei and the Ala Moana Center. The Project would provide faster, more reliable public transportation services than those currently operating in mixed-flow traffic.

FTA assigned Jacobs as a Project Management Oversight Contractor (PMOC) on September 24, 2009, for the purpose of monitoring the Project and providing FTA with "information and well-grounded professional opinions regarding the reliability of the project scope, cost, and schedule" of the Project. That effort continues with this update report, which represents the PMOC's assessment of the Project's Transit Capacity.

1.2 Project Description

The Project is an approximately-20-mile-long elevated fixed guideway rail system along Oahu's south shore between East Kapolei and Ala Moana Center. The alignment is elevated, except for a 0.6-mile at-grade portion at the Leeward Community College station. The proposed investment includes 21 stations (20 aerial and 1 at-grade), 80 "light metro" rail transit vehicles, administrative/operations facilities, surface and structural parking, and maintenance facilities. The grantee plans to deliver the Project in four guideway segments:

- Segment I (West Oahu/Farrington Highway) – East Kapolei to Pearl Highlands (6 miles/7 stations)
- Segment II (Kamehameha Highway) – Pearl Highlands to Aloha Stadium (4 miles/2 stations)
- Segment III (Airport) – Aloha Stadium to Middle Street (5 miles/4 stations)
- Segment IV (City Center) – Middle Street to Ala Moana Center (4 miles/8 stations)

Additional Project information:

- **Additional Facilities:** Maintenance and Storage Facility (MSF) and parking facilities
- **Vehicles:** 80 vehicles, supplied by the Core Systems Contractor (CSC), which is also responsible for systems design and construction and operations. The CSC is a Design-Build-Operate-Maintain (DBOM) contract.
- **Ridership Forecast:** Weekday boardings – 97,500 (2019); 116,300 (2030).
- **Target Revenue Service Date (RSD):** March 2019

1.3 Jacobs Scope of Work

Under this Work Order, Jacobs is to provide the following deliverables:

- OP 32A: Project Transit Capacity Review
- OP 32C: Project Scope Review

- OP 32D: Project Delivery Method Review
- OP 33: Capital Cost Estimate Review
- OP 34: Project Schedule Review
- OP 40: Risk and Contingency Review

This update report is limited to OP 32A: Project Transit Capacity. It was triggered by a March 2012 update to the Honolulu Authority for Rapid Transportation's (HART) Operations and Maintenance Plan. The 2011 edition of this plan had been reviewed by the PMOC in October 2011. A red-lined update was received in March 2012 for review and comment. In general the updates to the document are limited to changes in nomenclature related to the creation of the HART to manage construction and operation of the new rail system and the designation of the Ansaldo Honolulu Joint Venture (AHJV) as the Core Systems Contractor and system operator. HART plans that the draft document will be reviewed and validated by the AHJV. The PMOC presumes that this draft will be reissued after AHJV validates it and updates the plan as the system evolves through design, construction, commissioning and operations.

The PMOC appreciates AHJV's involvement in reviewing and validating the report and suggests that, during that review, HART and AHJV should work to jointly address the several discrepancies and oversights that concerned the PMOC in October 2011. Addressing these concerns should strengthen and improve this valuable and important project.

1.4 Methodology

The PMOC followed the requirements outlined in the *FTA OP 32A – Project Transit Capacity Review*, dated May 2010, to assess and evaluate operational capacity of the Project. This analysis employs practices recommended in the Transportation Research Board's *TCRP 100* to evaluate proposed operations and the capacity of the planned rail transit system.

At the most basic level, rail transit capacity is a seemingly simple concept that addresses the question of how many persons can be moved within a period of time. The actual calculation of that capacity, however, is somewhat more complex, involving considerations relating to car capacity, train length, maximum train speeds, train acceleration and braking characteristics, station dwell times, operating margin, track configuration, traction power system capacity, and safe following distances between trains. For rail transit, *TCRP 100* defines capacity in two ways:

- ***Line capacity***: the maximum number of trains (made up of some number of vehicles forming a "consist") that can pass a point during an interval of time (i.e., cars per hour). Line capacity is a function of train (or consist) length, maximum train speeds, train acceleration and braking characteristics, station dwell times, operating margin, track configuration and associated speed restrictions, terminal station configuration, and safe following distances between trains.

- ***Person capacity***: The maximum number of persons that can be carried in one direction past a point during an interval of time under specified operating conditions (i.e., passengers per hour) without unreasonable delay, hazard, restriction or uncertainty. Person capacity is a function of line capacity and rail car capacity. *Rail car capacity* is a

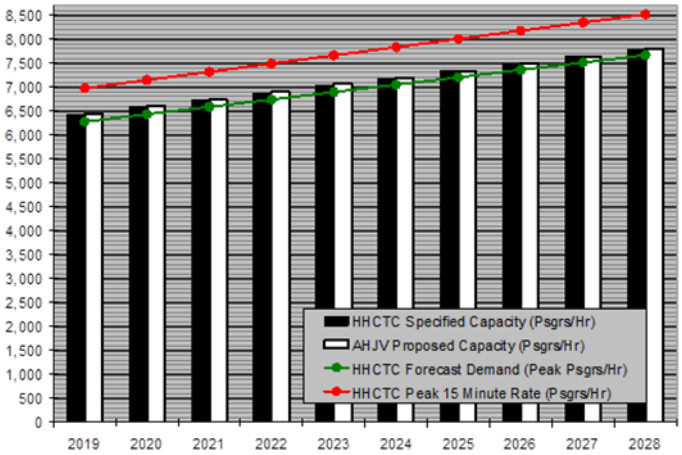
function of the number of seats on each rail car, the amount of usable standing space on each rail car and the acceptable level of crowding among standing passengers. *TCRP 100* specifies that 3.2 ft^2 of space per standing passenger is "reasonable service load with occasional body contact. Moving to and from doorways requires some effort."[1]

This document evaluates the proposed Project infrastructure and operation:

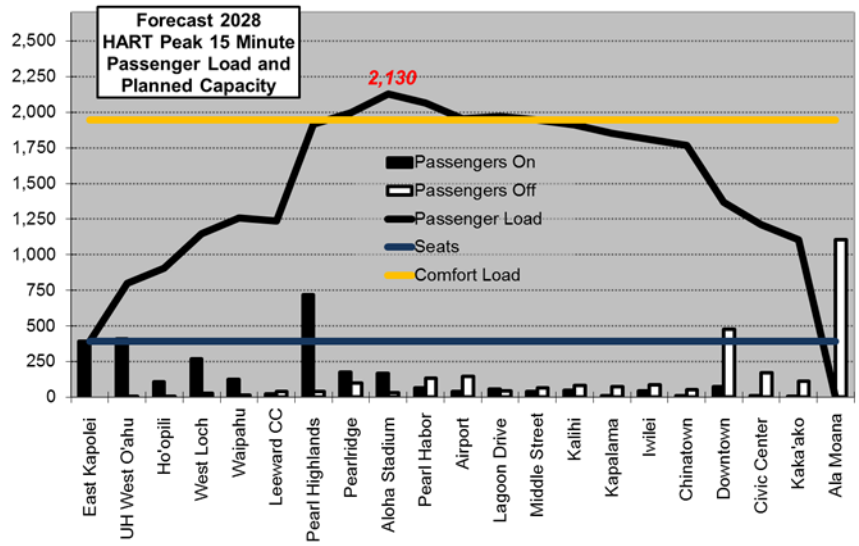
- to determine if it provides sufficient ***person capacity*** to carry the forecast volumes of design year peak period passengers and,
- to determine the theoretical ***line capacity*** (provided a sufficient pool of vehicles were available).

1.5 Key Findings from the Spring 2012 Update Car Capacity

The hourly passenger capacities specified by the grantee and subsequently offered by AHJV were calculated in a manner that eliminated virtually all capacity for peak of the peak surges in ridership. This oversight in specifications illustrated by Figure 6 (reproduced to the right) is covered in Section 3.3.2. *Forecast Year Peak System Capacity* of the October 2011. The oversight has not been addressed in the new draft plan and remains outstanding.

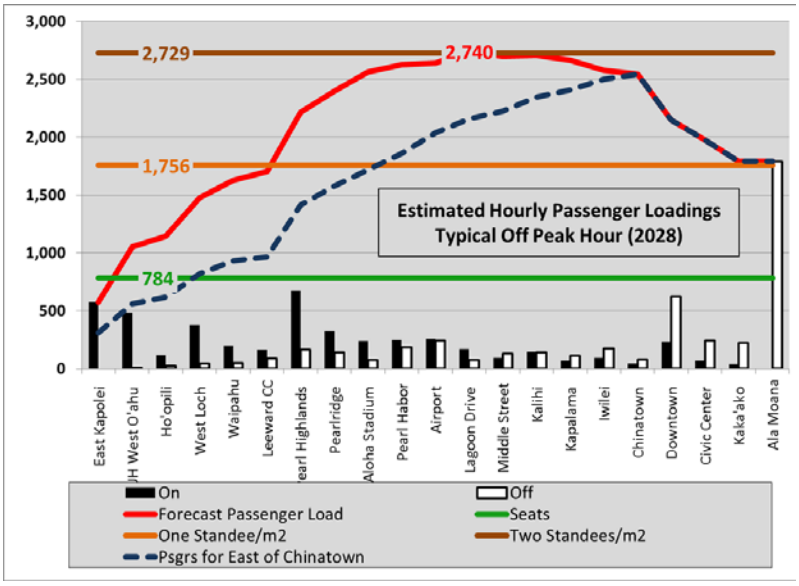


[1] Kittleson and Associates et al, Transit Capacity and Quality of Service Manual: 2nd Edition (TCRP Report 100) Transportation Research Board, Washington DC, 2003. pp. 5-5.



Close inspection of the pattern of boardings and alightings raises concerns over the limited number of seats and the likelihood of most rush hour customers having to endure long rides while standing. It is understood informally that HART is considering adding seats to every car and perhaps run three car trains at longer intervals. These adjustments are clearly on the road to addressing many of the PMOC's concerns related to seating and overall capacity.

The OP 32A process does not include a specific consideration of off peak capacity, but the 2011 analysis expressed concern that cramped conditions and the lack of seats for riders could hinder the project's capacity to attract and retain all the peak and off peak riders forecast to travel on the system.



Using data provided by the project, the PMOC was able to estimate an off peak loading profile for the eastbound service. The Project is somewhat atypical from other metros because such a large fraction of the overall ridership will board at the four westernmost stations bound for one of the four easternmost stations, particularly, Ala Moana. Because of this circumstance, eastbound riders boarding east of West Loch station during a typical off peak hour will not have much opportunity to obtain a seat because nearly all the seats will already be filled with passengers for destinations east of Chinatown. It appears that there will be approximately 1,000 to 2,000 standees every off peak hour with fewer than 800 seated passengers between Leeward and Ala Moana. At some times of day the condition will be worse. It should be noted that HART is investigating the ability to add 8-10 seats per car.

Headways
AHJV's proposal is inconsistent between its operating plan and the reported limits of its proposed train control system. HART's O&M plan does not address this discrepancy. AHJV's Train Control Simulation Report indicates that the system will not support headways shorter than 134 seconds without adjusting train speeds to maintain safety. At reduced train speeds, the service will not achieve travel time goals. It should be noted HART has concurred that this discrepancy must be resolved. Simulations will be run to determine magnitude of issue.

Table 1. AHJV Train Control Simulation Headway Parameters[2]

Headway	Seconds	Comments
Safe Separation Headway	<90 seconds	With minimum (20 second) dwell
Non-Interference Headway	133.9 seconds (2:14)	With city specified nominal dwells
Minimum Operating Headway	155 seconds (2:35)	Non interference headway plus 15% for normal service perturbations.
Operating Headway	=>155 seconds	To be varied with passenger demand

The Minimum Operating Headway was established by HART to provide a 15% cushion for normal service perturbations. However, HART's operating plan for the eighth and subsequent years of full operation requires headways tighter than the Minimum Operating Headway of 155 seconds. As the design year approaches, HART's operating plan shows trains operating every 147 seconds with no downward adjustment in running times. A plan to run longer trains at slightly longer peak headways would address this problem while also providing more seating for off peak passengers. Conversely, AHJV could also demonstrate that the 155 second minimum operating headway is overly conservative as automated metros routinely operate at shorter headways elsewhere in the world. The running time and fleet size impacts of running tighter headways would need to be explored.

Dwell Times
In the aggregate, HART and the PMOC agree on estimated dwell times for peak trips. However, it is understood that HART has decided to add platform screen gates to the Project. AHJV and HART should review how this addition may impact the time for door operation and the possible cascade impacts on overall running times and car requirements.

Round Trip Time and Terminal Turnback Time
Estimates of station-to-station running times vary among the AHJV's O&M proposal, vehicle performance simulations, and train control simulations reviewed in 2011. HART should be congratulated for using the most conservative estimates in its O&M plan. The combination of running time and forecast dwell times necessary for the operation of doors and service of peak passengers sums to 88:58. HART's O&M plan calls for a round trip time of 89:36. This allows only 38 seconds over a run of 5,376 seconds (0.7%) for unforeseen events. This seems like a small cushion. Nevertheless, with automated operations where movements are scheduled and

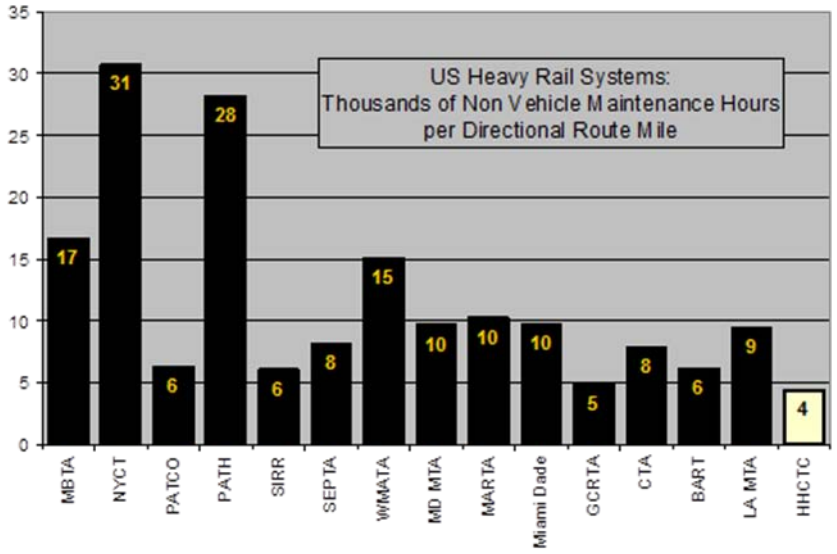
[2] AHJV. TECHNICAL SPECIFICATION AF-902 Train Control System C9M HNL 2X 001 Rev. 01 January 18, 2011 Page 43

controlled to the second, it is conceivable that this small allowance might be sufficient to avoid cascading delays were it not for concerns about turnback time at the both ends of the line.

AHJV's Train Control Simulation Report illustrates that, at headways of less than 240 seconds, the following train behind any train turning at either terminal presents a conflict for its turning leader until the second train arrives at the terminal. Operationally, this sets the minimum turn time at terminal stations to a value roughly equivalent to the prevailing service headway. This margin of time is much greater than had been considered in the O&M proposal and its resulting fleet size estimates. None of the simulations documented in the AHJV simulation reports integrate line operations with terminal turnbacks. Moreover, the PMOC has found no evidence that the timing and sequencing of turnbacks at terminal stations were considered in making fleet size calculations. HART's O&M plan must show how the time required to turn back trains without retarding other revenue trains was factored into fleet size calculations.

Staffing Capacity

The PMOC staffing review identified areas of concern with respect to fare enforcement and revenue processing. Minor changes in the O&M Plan between the 2011 and 2012 editions suggest that HART has recognized these problems and may be taking measures to address them.



The new plan does not address concerns with respect to infrastructure maintenance staffing and safety management. The PMOC notes that disparity in the infrastructure maintenance staffing ratios between HART's plans and typical industry performance is substantial.

1.6 Recommendations

The PMOC recommends that HART issue an updated O&M plan after this draft plan has been reviewed and validated by AHJV. The PMOC suggests a joint HART/AHJV review of the O&M plan where the partners address the several discrepancies and oversights that have concerned the PMOC since the Fall of 2011. Addressing these concerns should strengthen and improve this valuable and important project.

PMOC looks forward to reviewing a revised O&M plan that addresses concerns relative to car capacity and seating, minimum headways, dwell times with platform screen gates, times to turn back trains at terminals, and staffing and management plans for infrastructure maintenance, fare control, revenue processing, and safety management.

Table 1, which follows, provides a summary of this capacity evaluation's Findings, Concerns, and Timeframes for Reconciliation.

Table 2. HRTP Capacity Evaluation: Findings, Concerns and Timeframes for Reconciliation

Topic	Findings	Concerns	Timeframe for Reconciliation
Car Capacity	The grantee's 2009 Fleet Sizing Plan showed how it expected to carry the projected 2030 peak surge load with all passengers traveling with at least 3.4 sq ft of space per standing passenger. But later specifications issued to bidders for the Core Systems contract simplified and smoothed the 2009 plan such that it falls consistently 9% short of the promised standard designed to address the peak surge.	HARTs approach to determining peak capacity requirements ignores the 15- minute surge specified in TCRP 100, the controlling technical standard for OP32A Evaluations. This may result in overcrowding and degradation of peak service as dwell times increase in response to crowded trains. This is a problem expected to emerge in the first year of full operation. In the early years it can be addressed by accelerating the planned deployment of peak trains. Eventually, however, AHJV will not have trains on hand to address the shortfall and/or the service headway will be cut to the point where the signal interaction between successive trains will increase running times and reduce overall carrying capacity. <u>ACTION</u> Redefine service requirements to include a peak hour within the peak period with two and eventually three more trains in the peak hour.	These car capacity issues should be resolved before HART and AHJV place the initial rolling stock order. Frame and propose change in peak operations to AHJV as soon as possible

Topic	Findings	Concerns	Timeframe for Reconciliation
Car Capacity	Close inspection of the forecast pattern of boardings and alightings indicates that the average passenger trip length and duration will be longer than most other rapid transit networks and that the number of seats per car and per train will be very low compared with other systems with long average trip lengths.	Cramped conditions and the lack of seats for riders could hinder the project's capacity to attract and retain all peak and off peak riders forecast to travel on the system. It is understood that HART is considering adding seats to every car and perhaps run three car trains. These adjustments are clearly on the road to addressing many of the PMOC's concerns related to seating and overall capacity. <u>ACTION</u> Consider adding 8 to 10 flip up seats to every car. This will increase overall seating per car by 24% from the current 38 to a proposed 46-48 seats per car. Revise base period headway from 2* peak period headway to 1.5*peak hour headway. This will substantially reduce but not eliminate base period standees. This should also reduce standees overall.	HART and AHJV need to finalize their approach to seating and train length before they place the initial rolling stock order.

Topic	Findings	Concerns	Timeframe for Reconciliation
Headways	AHJV's proposal is inconsistent between its operating plan and the reported limits of its proposed train control system. HART's O&M plan does not address this discrepancy. AHJV's Train Control Simulation Report indicates that the system will not support headways shorter than 134 seconds without adjusting train speeds to maintain safety. Applying the HART-established 15% cushion for normal service perturbations, the Minimum Operating Headway becomes 155 seconds. However, AHJV's proposal and HART's operating plan for the eighth and subsequent years of full operation requires headways tighter than that Minimum Operating Headway of 155 seconds. As the design year approaches, HART's operating plan shows trains operating every 147 seconds with no downward adjustment in running times or increase in trains required to sustain necessary headways.	At reduced train speeds, the service will not achieve travel time goals. Slower overall travel times will affect peak vehicles required necessary to sustain desired service frequency. <u>ACTION</u> Hold discussions with AHJV to resolve questions related to headways and running times. It should be noted HART has concurred that this discrepancy must be resolved. Simulations will be run to determine magnitude of issue.	HART and AHJV need to address questions related to interaction between headways and speeds before they place the initial rolling stock order.
Dwell Times	In the aggregate, HART and the PMOC agree on estimated dwell times for peak trips. However, it is understood that HART has decided to add platform screen gates to the Project.	PMOC is concerned that Platform Screen Gates may add time for door operation, with possible cascade impacts on overall running times and car requirements. <u>ACTION</u> Present documentation and analysis that shows whether the dwell time impact of PSG is expected to be neutral or positive.	HART and AHJV need to address questions related to interaction between platform screen gates and dwell times before they place the initial rolling stock order.

Topic	Findings	Concerns	Timeframe for Reconciliation
Terminal Operations and Cycle Times	AHJV's Train Control Simulation Report illustrates that, at headways of less than 240 seconds, the following train behind any train turning at either terminal presents a conflict for its turning leader until the second train arrives at the terminal. Operationally, this sets the minimum turn time at terminal stations to a value roughly equivalent to the prevailing service headway. This margin of time is much greater than had been considered in the O&M plan and its resulting fleet size estimates. None of the simulations documented in the AHJV simulation reports integrate line operations with terminal turnbacks. Moreover, the PMOC has found no evidence that the timing and sequencing of turnbacks at terminal stations were considered in making fleet size calculations.	Given the proposed configuration of the two terminal stations, the interaction between a turning train and its follower at headways of less than four minutes will "trap" the turning train at the terminal until the following train has arrived on the adjacent terminal track. This interaction between trains at the terminals adds to overall cycle times and increases the number of trains that need to be deployed to maintain the desired peak service frequency. An appropriate response to this issue should consider both fleet size and the proposed terminal configuration. In particular, a tail track with universal crossovers behind the terminal platforms might substantially increase the speed and flexibility of terminal operations. <u>ACTION</u> Start dialogue with AHJV concerning their plans and intentions for turns at terminals. Consider revising plan for East Kapolei to put crossover behind the passenger platforms.	AHJV **must** provide a set of simulation reports that integrates line operations with terminal turnbacks in their response that "validates" HART's 2011 O&M plan. This will inform final design of the terminals, the fleet plan and the next O&M plan.
Maximum Line and Person Capacity	The Minimum Operating Headway of 155 seconds represents the most frequent service that could be reliably offered on the specified infrastructure within the grantee's 45-minute end-to-end travel time goals. A four-car train is the longest consist that can be accommodated by the station design. Using a Comfort Load capacity of 32 seated and 127 standing passengers and the grantee-specified Peak Hour Factor of 0.9, the maximum person capacity of the system is 13,381 persons per hour. This provides for 50% growth over the design-year peak flow of 8,982 passengers.	With cars added to the future fleet, the overall system design can accommodate future growth up to 50% higher than the design year. Therefore, PMOC has no concerns about overall system capacity <u>ACTION</u> No action required.	None

Topic	Findings	Concerns	Timeframe for Reconciliation
Staffing	The staffing review found areas of concern with respect to fare enforcement and revenue processing, infrastructure maintenance, and safety management.	The O&M Plan is unclear concerning how the fare enforcement function will be provided and shows a potentially awkward approach to revenue management. AHJV's proposed staffing for infrastructure maintenance seems very optimistic compared with peer systems. <u>ACTION</u> Revise O&M Plan to provide more specificity concerning how HRTP will protect and collect revenue. Discuss and clarify safety management organization with AHJV. Future revisions to the O&M Plan must address concerns regarding infrastructure maintenance.	A clearer explanation of how the HRTP will protect and collect and protect revenue should be included in the next periodic release of the O&M plan. (2013?) AHJV should show how it is able to provide adequate infrastructure conditions and availability elsewhere with similar staffing levels. The next release of the O&M plan should justify or revise the proposed approach to safety management.
Capital versus Operating Cost and Service Trade-offs	The grantee's decision regarding trade-offs between capital costs and operating costs and level-of-service was made early in the project, when the grantee decided to proceed with design of a grade-separated driverless system. Since that decision was well thought out and firmly entrenched in the environmental documents, it is no longer subject to discussion. The grantee has also made a long-term capital cost investment in building platforms that are already long enough for the eventual use of four-car trains, thus assuring capacity 50% above its design year needs.	HART is now discussing the use of shortened platforms and reduced numbers of platform screen gates as potential cost-saving measures. These changes would eliminate or postpone the project's ability to provide for increased ridership and would thus no longer assure capacity 50% above its design year needs. <u>ACTION</u> No action required.	Prior to implementing any platform or platform screen gates reductions, the O&M Plan must address future needs for longer trains and how the original four-car train capacity will be restored.

Topic	Findings	Concerns	Timeframe for Reconciliation
Impact on Existing System	Since this is the first rail system to be implemented by the grantee, no adverse effects on the "existing transit system," of rubber-tired road vehicles is anticipated. The rail line will relieve crowding on the bus network by providing express service along the service network's main east-west trunk. The project is not causing any physical obstacles to the grantee's ability to maintain or even expand its bus system.	None	Not applicable
Route Selection and Station Design	Route selection was complete and approved at the end of Alternatives Analysis. Station design has been, and will continue to be, a constant subject of PMOC scrutiny, but is not expected to be a controlling factor in this project's line or person capacity. If constraints to capacity become apparent as station designs progress, they will be highlighted by the PMOC.	None	Not Applicable
Maintenance Infrastructure	The PMOC has reviewed plans for the MSF complex and found it to be reasonably sized and efficiently organized. As the project evolves it is likely that the plans for the MSF configuration may change as the DB and DBOM contracts move further into Final Design. The CSC has, for example, expressed its desire to convert some of the yard to unmanned operations, which may affect facility design and capacity. The PMOC expects the DB and DBOM contractors to identify, address, and resolve shop, yard, and other maintenance facility issues as they arise.	None	Not Applicable
Build Out Approach	The PMOC has not received much information on the grantee's proposed build out approach beyond the current project.	None	Not Applicable

1.7 Final Observations

- The Project meets its stated purposes and goals, to provide safe and reliable transit service to the Honolulu community.
- The project is both “right-sized” and justifiable in its choice of technology.
- The project has rightly taken advantage of its substantial scale as evidenced by its obtaining bids that are favorable in relation to expectations.
- By locking in operating and maintenance costs with the CSC and by using a driverless vehicle, the grantee has assured reasonable operating and maintenance costs.
- Rebuild costs could be another issue, as the track structure would be difficult to replace under traffic.
- The grantee needs to resolve a number of issues with its Car Builder/Systems Designer and Builder/Operator, the CSC, particularly as they relate to
    - Seating capacity
    - Train Headways in the Peak Period and the Maximum Operating Headway
    - 2-car versus 3-car or 4-car trains
    - Possible substitution of M-cars (middle cars) for some of the E-cars (end cars) in the vehicle order
    - Terminal operations and efficient turnbacks.
    - Adequacy of maintenance staffing.

2.0 OP 32A: PROJECT TRANSIT CAPACITY REVIEW

2.1 Purpose and Objective

This Project Transit Capacity Review seeks to ensure that sufficient service capacity is being programmed, contracted, and constructed to provide safe and reliable transit service to the Honolulu community, and to answer the questions: Can the system carry the anticipated passenger volumes? Can the system deliver the required vehicle throughput? Is the proposed system staff sufficient to sustain operations?

Many analytical approaches are available to assess service capacity, often tailored to the unique operating and regional characteristics of a given project. At each design stage of a major transit program, various capacity assessment methodologies are applied to updated plans and system designs that produce more resolution and serve to update the service plan. This on-going, evolving process improves project accountability and ensures that the scale of investment in major infrastructure systems is adequate for operating conditions.

The industry best practice for assessing transit capacity has become *TCRP 100, Transit Capacity and Quality of Service Manual, Report 100 (TCRP100).*[3] This compendium provides a broad toolbox of transit capacity assessment methodologies to establish a common FTA and industry-accepted approach to review both current and proposed transit services across a wide range of critical system elements, including corridor throughput, passenger crowding, dwell time, running time, and track capacity at terminals. It is important to note that *TCRP 100* is a survey of different methodologies and presents them not as standards, but as general approaches that require careful application within a local project context.

2.2 Methodology

The PMOC followed the requirements outlined in the *OP 32A, Project Transit Capacity Review*, Rev. 2, dated May 2010, to assess and evaluate operational capacity of the Project. This analysis employs practices recommended in the *TCRP 100* to evaluate proposed operations and the capacity of the planned rail transit system. ***This analysis was based on all information made available to the PMOC by the grantee from March 2011 through April 2012. It includes documents employed in the procurement of the Core System Contractor (CSC) and submissions by the selected bidder for that contract. The only submission since the last update to this report in October 2011 was a red-lined March 2012 update to the HART's Operations and Maintenance Plan.*** The March 2012 updates to the document are primarily focused on changes in nomenclature related to the creation of the Honolulu Authority for Rapid Transportation (HART) to manage construction and operation of the new rail system and the designation of the Ansaldo Honolulu Joint Venture (AHJV) as the Core Systems Contractor and system operator.

At the most basic level, rail transit capacity is a seemingly simple concept that addresses the question of how many persons can be moved along a corridor within a period of time. The

[3] Kittleson and Associates et al, Transit Capacity and Quality of Service Manual: 2nd Edition (TCRP Report 100) Transportation Research Board, Washington DC. 2003

actual calculation of that capacity, however, is somewhat more complex, involving considerations relating to car capacity, train length, maximum train speeds, train acceleration and braking characteristics, station dwell times, operating margin, track configuration, traction power system capacity, and safe following distances between trains. *TCRP 100* defines capacity in two ways for rail transit:

- ***Line capacity***: the maximum number of trains (made up of some number of vehicles forming a "consist") that can pass a point during an interval of time[4] (i.e., cars per hour). Line capacity is a function of train (or consist) length, maximum train speeds, train acceleration and braking characteristics, station dwell times, operating margin, track configuration and associated speed restrictions, terminal station configuration, and safe following distances between trains.

- ***Person capacity***: the maximum number of persons that can be carried in one direction past a point during an interval of time (i.e., passengers per hour) under specified operating conditions without unreasonable delay, hazard, restriction or uncertainty[5]. Person capacity is a function of line capacity and rail car capacity. *Rail car capacity* is a function of the number of seats on each rail car, the amount of usable standing space on each rail car and the acceptable level of crowding among standing passengers. *TCRP 100* presents 3.2 ft^2 of space per standing passenger as a "reasonable service load with occasional body contact. Moving to and from doorways requires some effort"[6]

This document evaluates the proposed Project infrastructure and operation:

- to determine if it provides sufficient ***person capacity*** to carry the forecast volumes of design year peak period passengers and,
- to determine the theoretical ***line capacity*** (provided a sufficient pool of vehicles were available).

It also reviews the staffing plans for the proposed service to determine if the staffing levels and management organization are sufficient to sustain operations.

2.3 Document Review

The PMOC relied on the documents supplied by the grantee to prepare this analysis as identified in Appendix B.

2.3.1 Project Specifications

The March 2012 update did not revise the basis project specifications.

The Honolulu Rail Transit Project (HRTP) will provide high-capacity rail transit service along an east-west corridor of approximately 20 miles from East Kapolei to Ala Moana Center. Nearly all of the transit guideway will be elevated and most of that will be constructed in the medians of

[4] Ibid. pp. 5-2
[5] Ibid. pp. 5-5
[6] Ibid. pp. 5-27

existing roadways. It is proposed that the service will be offered with a fleet of two-car driverless metro trains operating in a fully automated mode with an interval to 2:28[7] to 8:24 between trains depending upon time of day during the last year of the ten year O&M contract. The grantee forecasts that the Project will attract approximately 116,000 daily weekday passengers by the year 2030.

Table 3. Forecast Passenger Volumes[8]

Forecast Travel Volumes	2019	2030
Daily Riders	99,110	116,340
Peak Hour Riders	11,418	13,739
Peak Hour Peak Link Riders	6,429	8,083

The contractor for the service is a joint venture led by two Italian firms (Ansaldo STS and Ansaldo Breda) controlled by Finmeccanica SpA of Rome. The Ansaldo Honolulu Joint Venture (AHJV) proposed to deliver vehicles, train control, traction power, communications, fare collection equipment, and operations and maintenance services for a grantee-specified rail transit system. The basic infrastructure (elevated guideway and stations) is to be built by others under different contracts with the grantee. AHJV intends to install and operate vehicles and systems proven with several years of successful operation in Copenhagen, Denmark.

Because of its exclusive right of way, high level platforms, frequent service and third rail power distribution system, the PMOC applied heavy rail system standards in preparing the capacity analysis.

Car Specifications

AHJV specifications for the proposed rail vehicles are summarized below.

Table 4. AHJV Car Specifications[9]

Length	64.1	Feet
Width	10.0	Feet
Fixed Seats	32	Passengers
Flip up Seats	6	Passengers
Standing Space	427.4	Square Feet
Maximum Acceleration	3	Miles per hour per second (mphps)
Average Acceleration	2.7	mphps - (from zero to 25 mph)
Deceleration	3.2	mphps - (from 55 to 45 mph)
	3.0	mphps - (from 45mph to stop)
Maximum Speed	55	mph
Door Width	55.11	inches
Number of Doors	3	per side

[7] m:ss AHJV Technical Proposal Volume 3 C9M HNL 00003 02 February 24, 2011 Page 3-327

[8] Honolulu High-Capacity Transit Corridor Project, Draft Operations and Maintenance Plan Dated August 2009 (Updated Draft April 2011) Page 4-10
HHCTCP/PMOC Meetings, June 2, 2009.

[9] AHJV Proposal for HHCTCP – Core Systems DBOM: Vehicle General Characteristics and Performance C9M HNL 1X 002 Feb 24, 2011 Pages 1-3 to 1-5

Train Control

AHJV's AF-902 Train Control System will control revenue train operation throughout the 21 passenger stations and non-revenue operations through most of the maintenance and storage facility. The installation will provide for automated driverless operation, including:

(1) Train protection - prevention of collisions and derailments
(2) Train operation - control of train movement and stopping at stations
(3) Train supervision - direction of train movement in relation to schedule and
(4) Communication - interchange of information among elements of the system

AHJV's Technical Specification and Automatic Train Control (ATC) Simulation Report purports to demonstrate that the "moving block" installation will support the operating parameters listed in Table 5.

Table 5. AHJV System Headway Parameters[10]

Headway	Seconds	Comments
Safe Separation Headway	<90 seconds	With minimum (20 second) dwell
Non-Interference Headway	133.9 seconds (2:14)	With city specified nominal dwells
Minimum Operating Headway	155 seconds (2:35)	Non interference headway plus 15% for normal service perturbations.
Operating Headway	=>155 seconds	To be varied with passenger demand

When operating in passenger service with headways less than the non-interference parameter, speeds are reduced to maintain safe operations. At reduced train speeds, the service will not achieve travel time goals.

Limited service is proposed to start on a partial system in 2015 with full service starting upon completion of the entire 20 mile system in 2019. The grantee has developed specifications and AHJV has proposed operating plans for service through the first ten years of full operation (to the end of 2028). After that time, the grantee plans to award a new service operating contract based on new competitive bids.

The grantee specified that the total round trip travel for the full service should not exceed 90 minutes (1:30:00)[11]. AHJV proposes to operate the service with a round trip travel time of 89 minutes and 33 seconds (1:29:33).

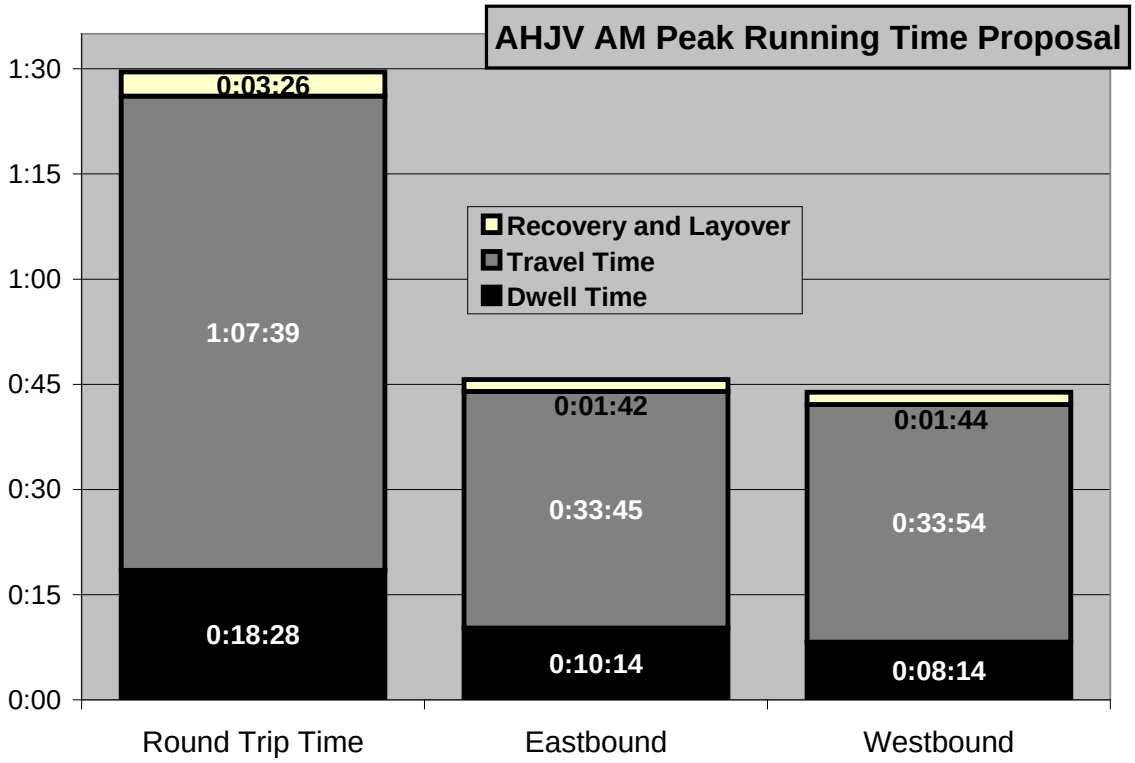
[10] AHJV. TECHNICAL SPECIFICATION AF-902 Train Control System C9M HNL 2X 001 Rev. 01 January 18, 2011 Page 43

[11] This reflects a somewhat longer trip time than earlier estimated at the environmental impact statement phase of planning primarily due to longer (and more realistic estimates) of required dwell times by HHCTC.

Table 6. AHJV Proposed Travel Times[12]

Morning Peak Service	Dwell Time	Travel Time	Recovery and Layover	Total
Eastbound	0:10:14	0:33:45	0:01:42	0:45:41
Westbound	0:08:14	0:33:54	0:01:44	0:43:52
Round Trip Time	0:18:28	1:07:39	0:03:26	1:29:33
Percent of Total	20.6%	75.5%	3.8%	100%

Figure 1. Proposed Morning Peak Running Times



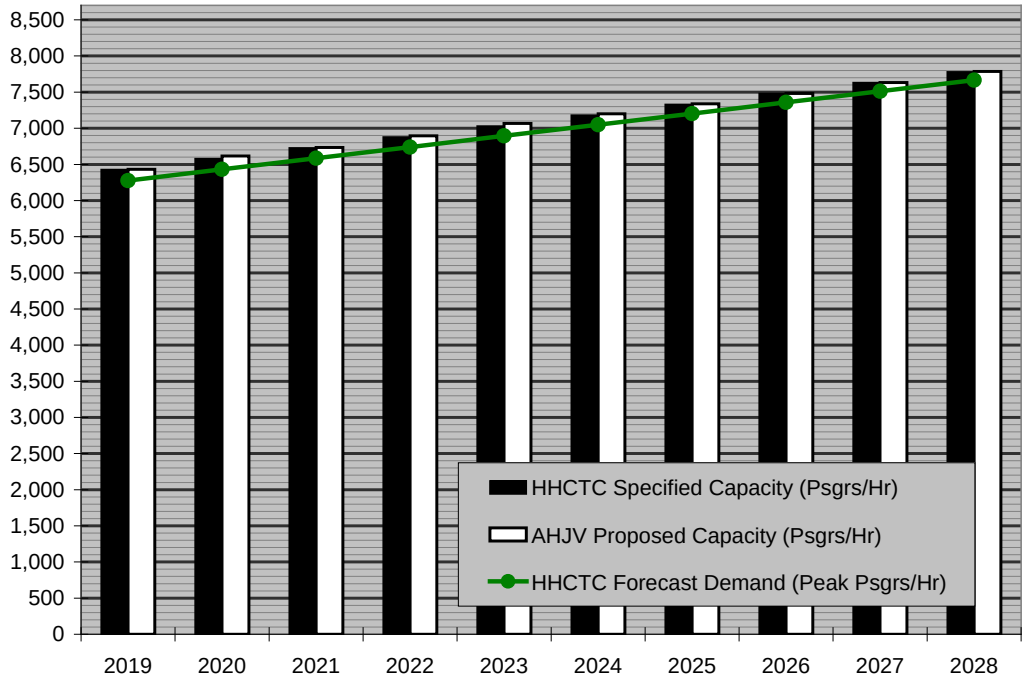
Over the first twelve years of full service, typical weekday ridership is projected to grow from 99,110 in the first year of full operations (2019) to 116,340 in the design year (2030). AHJV proposes to operate the service with a fleet of two-car trains running at headways set to keep forecast ridership generally at or below a "comfort level" of crowding at the peak-load point on the line. Each two-car train is projected to hold 318 passengers (64 seated and 254 standing at a density of 3.4 ft^2 per standee.)

[12] BAFO2\AHJV BAFO Feb 24 Clean Files\Technical Proposal Volumes 1-6 and Appendix A\Volume 3\Part 2\Volume 3 - Part 2 Pages 305 to 327.pdf

Table 7. Proposed Headways and Peak Passenger Capacities

`	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
AHJV Proposed Base Headway (Seconds)	356	347	340	332	325	318	312	306	300	294
AHJV Proposed Base Trains	16	16	16	17	17	17	18	18	18	19
AHJV Proposed Peak Headway (Sec)	178	173	170	166	162	159	156	153[13]	150	147[14]
AHJV Proposed Peak Trains	31	32	32	33	34	34	35	36	36	37
Comfort Capacity Peak Hour Loads (Psgrs/Hr)										
Grantee Specification	6,429	6,580	6,730	6,880	7,031	7,181	7,331	7,482	7,632	7,782
AHJV Proposal	6,431	6,617	6,734	6,896	7,066	7,200	7,338	7,482	7,632	7,735
Grantee Forecast Hour Peak Demand	6,277	6,458	6,638	6,819	7,000	7,181	7,361	7,542	7,723	8,084

Figure 2. Peak Capacity Specifications and Peak Demand Forecasts



Inspection of Table 7 and Figure 2 shows that the grantee's specified peak period hourly capacity closely tracks the forecast growth in peak hourly demand and that AHJV's proposal for each year exceeds the grantee specification by a marginal increment of standing room.

It is concerning that the headways required to supply necessary peak capacity in 2026 and subsequent years are below the Minimum Operating Headway supported by the train control

[13] Note: Proposed peak headway is less than minimum operating headway for proposed train control system.
[14] Based on its calculations PMOC presumes there is a typo in the AHJV documentation which shows a headway of 148 seconds. All other figures in the table indicate that 147 is the appropriate headway,

system. It is also a concern that this consideration was not addressed in the March 2012 update to the HART O&M plan.

Traction Power[15]

- Using the revenue vehicle and auxiliary equipment power consumption specifications and data from the AHJV proposal, the PMOC has performed an independent analysis on the traction power requirements.
- AHJV provides a description of the results of the electrical simulation study that has been done to analyze the Traction Electrification System of the Project. Two load flow analyses have been performed as part of the AHJV design activities:
  - Service conditions load flow analysis: The first load flow analysis is based on the Service conditions of the Project. This simulation has been performed on the basis of the Traction Power Substation (TPSS) and GBS described in the RFP documentation, consistently with the proposed vehicle and with the operational conditions used to determine the fleet size. The following main operating characteristics (both for normal and contingency operation) are listed below and are in accordance with the service conditions proposed by AHJV:
    - Peak hour passenger capacity: 7200 passengers per hour per direction (pphpd)
    - Peak hour headway: 159 s
    - Two-car train with 318 passengers at the comfort load capacity
    - Station Dwell Time in accordance with TP 3.4.2.3
  - Design criteria load flow analysis: The second load flow analysis has been performed on the basis of the requirements included in Chapter 13 of Design Criteria (TP9 - Design Criteria - §13.5.3.Train Operations Plan). The purpose of this study is to verify the behavior of the Traction Electrification System provided for the Project under the following conditions, updated as per AHJV:
    - Headway:
      (1) 90 seconds operating for 2 hours (only for Normal Operation)
      (2) 180 seconds operating continuously (both for Normal and Contingency Operation)
    - Four-car train with 770 passengers at the design load capacity
    - Station Dwell Time in accordance with TP 3.4.2.3
- The grantee has developed specific requirements and AHJV has provided preliminary design to comply with the RFP guidelines that require sufficient traction power to operate the maximum number of trains at designated speeds and projected load requirements.[16]According to the RFP Technical Documents, the traction electrification system must be designed in compliance with the following requirements:
  - with the substations operating normally, the power system shall be designed to support the system capacity (refer to § 1.1 of this document) with no overload
  - the failure of one TPSS shall not lead to any operational disturbance to the scheduled revenue service, even momentarily, and shall not require line personnel to carry out any emergency action

[15]*The system configuration proposed by AHJV has been slightly modified and the outcome of the sample simulations shows these changes have an impact of the order of magnitude of 1%, which are negligible.*
[16] HHCTCP Design Criteria – Traction Power, June 26, 2008[16] AHJV CSC Proposal, February 24, 2011

- the line voltage as seen at the transit vehicle power collector shall not fall below the recommended values; for a nominal traction voltage of 750 V, the lowest permanent voltage is fixed at 525 V
- during the outage of one Traction Power Substation, the loads on the transformer rectifier units of the adjacent substations shall be within the normal rating of the equipment in order to accommodate instantaneous or transient overloads during contingency situations,
- The nominal power of the TPSS have to be sized such that these higher loads shall be within the following and the transformer-rectifier sets shall withstand: 1.5-In rated power for 2 hours maximum 3-In for 5 period of 1 minute, and 4.5-In for 15 seconds at the end of the 2 hours-hours load cycle period.
- The overload capability of the transformer-rectifier units is only used for transient overload such as traction motor starting, not for back up of failure.
- The TPSS out-of-service condition considered involves loss of the primary utility power or of the substation's transformer/rectifier unit. It is assumed in such condition that the dc bus remains energized, with the dc feeder breakers staying closed.

- The main electrical quantities taken into consideration in this simulation are:
  - The root mean square (rms) currents and average power delivered by each substation related to a time period equal to the headway, according to the different phases corresponding to the different required system capacities
  - The line voltage distribution, measured at the transit vehicle power collector, with the respective maximum and minimum values.
  - Track to ground potentials (equivalent to train touch potentials) being within acceptable limits: not exceeding 75 V dc in normal operations, and 100 V dc in contingency conditions
- Initial review of the preliminary plans shows electrical sub-stations at approximately one to one-and-one-half mile intervals along the corridor. The Traction Electrification System is serviced by 13 mainline traction power substations (TPSS) rated at 3000 kW nominal each. In addition, there are also three gap breaker stations (GBS), located at double crossovers where a TPSS is not required. The full list of traction power facilities, counting from West to East, is provided in the table below:

Table 8. Traction Power Facilities

Substations	Name	Stations UP Chainage [foot]	TPSS/GBS UP Feeders Positive Connect Points [foot]
TPSS 1	EAST KAPOLEI	397+65	40900
TPSS 2	WEST OAHU	448+24	45000
GBS 1	HO'OPILI	500+43.6	49800
TPSS 3	WEST LOCH	583+80.62	58600
TPSS 4	WAIPAHU T.C.	651+99.79	69900
GBS 2	LEEWARD CC	725+62.86	73050
TPSS 5	PEARL HIGHLANDS	748+48.97	77250
TPSS 6	PEARLRIDGE ST	885+48.28	89000
TPSS 7	ALOHA STADIUM	973+82.95	98850
GBS 3	PEARL HARBOR	1047+11.99	104950
TPSS 8	HONOLULU AIRPORT	1141+48.98	114400
TPSS 9	LAGOON DRIVE	1192+83.21	119550
TPSS 10	MIDDLE STREET T.C.	1266+39.05	127000
TPSS 11	CHINA TOWN	1393+57.15	138550
TPSS 12	CIVIC CENTER	1440+31.19	144250
TPSS 13	ALA MOANA CENTER	1504+65.2	150200

Traction Electrification Systems will include the following Traction Power substations (TPSS), all within prefabricated enclosures:

- Eight (8) TPSS (East Kapolei, West Loch, Pearlridge, Airport, Lagoon Drive, Middle Street, Chinatown, and Civic Center) are provided with one traction group supplying 3000 kW
- 750 Vdc to the third rail, a Low Voltage (LV) section supplied by an auxiliary transformer and five (5) DC feeders;
- Two (2) TPSS (West Oahu, and Pearl Highlands) are provided with one traction group supplying 3000 kW - 750 Vdc to the third rail, an LV section supplied by an auxiliary transformer and two (2) DC feeders;
- One (1) TPSS at Ala Moana with one traction group supplying 3000 kW - 750 Vdc to the third rail, a LV section supplied by an auxiliary transformer and six (6) DC feeders;
- One (1) TPSS at Waipahu with one traction group supplying 3000 kW - 750 Vdc to the third rail, an LV section supplied by an auxiliary transformer and seven (7) DC feeders;
- One (1) TPSS at Aloha Stadium with one traction group supplying 3000 kW - 750 Vdc to the third rail, an LV section supplied by an auxiliary transformer and eight (8) DC feeders;

The system will also include the following track parallel points within prefabricated enclosures:

- 3 Gap Breaker Stations (Leeward, Ho'opili, and Pearl Harbor Naval Base), including five (5) DC feeders.

For each positive feeder and negative return connection, the quantity of cable is based on Part 6 – RFP Drawings – Volume 1- Rev. 01

- The specific data provided in the RFP for simulations are preliminary. The grantee has indicated, and the criteria documentation has shown, that the intent is "to provide sufficient interface information to allow revenue vehicle and other Project systems design development during the PE phase, and to develop estimates of capital, operating, and maintenance costs."[17] The following are simulation and motor results provided by AHJV based on the RFP documents:
  - AHJV Simulation results analysis for Service Condition – 159 Seconds Headway -- The analysis of the simulation results obtained through the input data described in § "*4 - Honolulu power load flow simulation - input data*" and in § "*4.3.1 First scenario – Service Condition simulation*" shows that, for each configuration of the Traction Power System (normal operation or out of service of one TPSS), the following conditions are always verified:
    - The minimum line voltage measured at transit vehicle power collector is always greater than 525 V, during both the normal operation of all substations and the contingency operation.
    - The rms traction current delivered by each TPSS, during both the normal operation of all substations and the contingency operation, is always lower than the continuous current rating corresponding to one transformer-rectifier group (3000 kW - 4000 A).
    - The maximum rail potential calculated, during both the normal operation of all substations and the contingency operation, is always lower than the permissible touch.
    - Voltage limit (75 Vdc for normal operation and 100 Vdc in contingency operation).
  - AAHJV Simulation results analysis for Service Condition – 90 Seconds Headway - The analysis of this simulation results obtained through the input data described in § "*4 -Honolulu power load flow simulation - input data*" and in § "*4.3.2 Second scenario – Design Criteria simulation*" at 90 seconds of headway shows that, for the Traction Electrification System (only during normal operation), the following conditions are always verified:
    - The TPSS and GBS can support the system power demand (some TPSS rectifier are in overload < 150% as allowed and foreseen by Design criteria).
    - The minimum line voltage measured at transit vehicle power collector is always greater than 525 V.
    - The maximum rail potential is always under 75 Vdc.
  - AAHJV Simulation results analysis for Service Condition – 180 Seconds Headway – The analysis of this simulation results obtained through the input data described in § "*4 - Honolulu power load flow simulation - input data*" and in § "*4.3.2 Second scenario – Design Criteria simulation*" at 180 seconds of headway shows that the following conditions are always verified:

[17] Ibid. pp. 4AHJV CSC Proposal, February 24, 2011

Normal Operation

- TPSS and GBS can support the system power demand.
- Minimum line voltage measured at transit vehicle power collector is always greater than 525 V.
- Maximum rail potential is always under 75 Vdc.

Contingency Operation

As far as contingency operation at 180 s is concerned, simulations show that, also in such a situation, the TPSS and GBS can support the system power demand (only in one case simulation results have identified one TPSS rectifier in a situation of limited overload, <110%; however, PMOC is confident that, during the development of the design and on the basis of more consolidated inputs, this condition will be solved by a more detailed technical analysis).

Regarding the minimum line voltage measured at the transit vehicle power collector, some scenarios have been found where the voltage, being always greater than 500 V (in case of TPSS 3 -West Loch is out of service), is lower than 525 V. Regarding the rail potential, other scenarios have been found where a peak potential exceeds the limit of 100V, such effect being limited only to the line (not in the platform area) and 100 Vdc (in particular between West Loch and Waipahu T.C).

It should be noted that the above results in terms of line voltage and rail potential are not cause for concern, because they occur in very limited and particular cases of a single out-of-service TPSS and because the system has means to mitigate such situations. In fact, because the substations will be equipped with negative grounding devices (NGDs), which will temporarily ground the running rails if the track potential exceeds the NGD set point, the running rails' potentials in contingency operations will be significantly reduced and the above theoretical values will not be of concern.

As an additional result of the performed simulation, it was found out that by exchanging the Ho'opili GBS position with the UH-West Oahu TPSS position, the minimum line voltage measured at transit vehicle power collector would be always greater than 550V (also in case of TPSS 1 "East Kapolei" Out of Service.) and rail potentials values would also improve.

- AHJV Motor results for Service Conditions – 159 Seconds Headway – The paragraph below includes the simulation results relevant to the following operational configurations:
  - Normal operation
  - Out of service TPSS#13
  - Out of service TPSS#3

  During the AHJV preliminary design, all the "Out of service" scenarios related with the operational conditions described in this document have been subject to a simulation study. As stated, in the following paragraph, the results relevant to the

TPSS#3 and TPSS#13 being out of service will be included. These two scenarios have been chosen because they are the most significant and are the worst-case scenarios from the following points of view:

- TPSS Energy load
- Line Voltage
- Rail Potential

It must be pointed out that these AHJV results are based on an initial analysis, which will be fully and extensively developed during the detailed design stage; for this reason, their results must be considered preliminary.

2.4 Capacity Analysis

TCRP 100 outlines procedures for transit capacity and levels of service analysis that typically use project-specific data sets as input variables. The PMOC used available project specific information. Where data are not available, *TCRP 100* provides general default values derived from representative rail transit systems.

This capacity analysis focuses on peak system demand, since that drives the requirements for maximum capacity. For many urban transit systems, there is an established 15-minute period during the morning weekday period, or the "peak-of-the-peak," during which maximum regular utilization can be projected. However, recent demographic and employment trends have challenged the classic "9 to 5" commutation model, causing this 15 minute peak period to become more dispersed and distributed across the peak hour, and thus lessening peak system demand.

This section summarizes the transit demand forecasts, evaluates the planned peak service capacity, tests the grantee and AHJV dwell time and running time estimates, and generates analyses of cycle time and vehicle requirements. Finally, the peak line and person capacity of the Project are calculated following *TCRP 100* methodologies.

2.4.1 Forecast Design Year Peak Period Passengers

The 2030 forecast ridership for the Project is 116,340 daily weekday round trip passengers. The ridership forecast also estimates the number of passengers boarding and alighting at each station and in each direction during the morning peak hour.

As discussed in an earlier PMOC report[18], typical passenger loadings are not uniformly distributed throughout the peak period. An adjustment called the 'peak hour factor' (PHF) is routinely used to estimate passenger volumes during the "peak-of-the-peak" 15-minute time period. In its calculations, the grantee indicated it would employ a PHF of 0.90, which is more moderate and less intensive that the *TCRP 100* default PHF of 0.80 for a heavy rail system.[19]

[18] FEDERAL TRANSIT ADMINISTRATION, PROJECT MANAGEMENT OVERSIGHT PROGRAM, Contract No. DTFT60-04-D-00015; Project No. DC-27-5044; FTA Task Order 12 – Programmatic Services; Work Order 5G; CLIN 0005: PMOC Report; Subtask 32A: Project Capacity Review HONOLULU HIGH-CAPACITY TRANSIT CORRIDOR PROJECT (Airport Alternative) Date Issued: July 2009

[19] TCRP Report 100. pp. 5-68

This PHF implies that 28% of peak hour passengers will ride in the peak 15 minutes. The TCRP default value implies 31% of peak hour riders using the system during the peak 15 minutes.

In the summer of 2009, the PMOC recommended further refinement and calibration of ridership utilization to fully substantiate grantee's current and future use of the higher PHF. The grantee has presented no documentation concerning further refinement or calibration through March 2012.

The peak-of-the-peak 15-minute ridership estimate from the morning peak hour forecasts is derived by dividing the peak hour interval into four typical 15-minute slots, then dividing the average 15-minute load by the 0.90 PHF, to estimate the 15-minute peak boardings. The net effect of this adjustment is to add 11% more riders to the peak-of-the-peak above the average 15-minute peak ridership, in order to reflect the non-uniformity of passenger arrivals at the stations. This factoring provides capacity for the surge of riders that is commonly observed during the peak of the peak on mature systems. Table 9 shows the forecast morning peak hour and the forecast 15-minute peak-of-the-peak passenger activity.

Table 9. 2030 Station Passenger Morning Peak Hour[20]

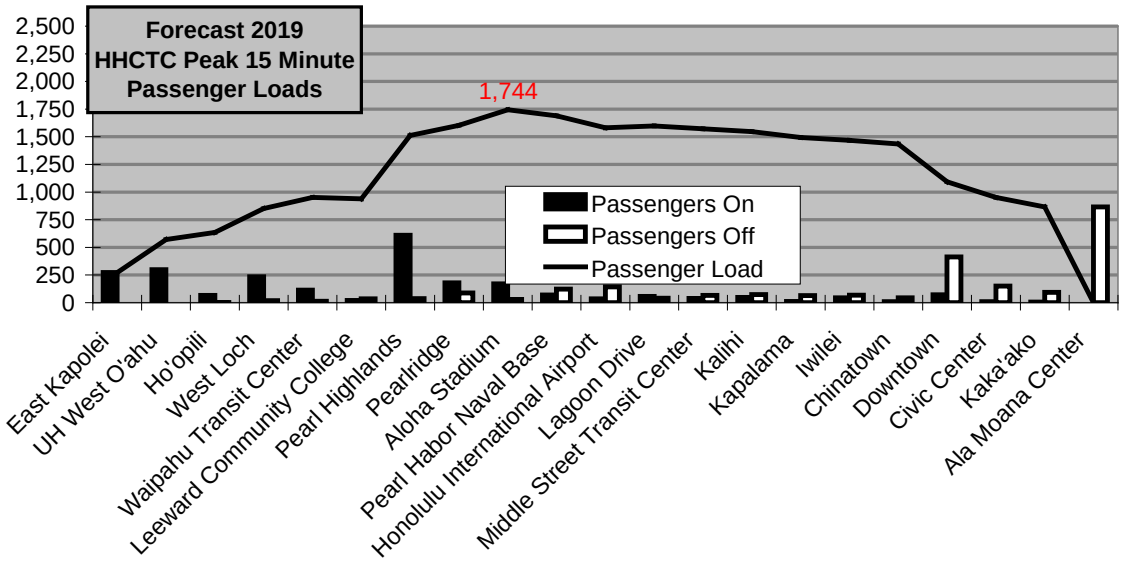
Eastbound	1 Hour peak		15 minute peak		
Station	Ons	Offs	Ons	Offs	Line Volume
East Kapolei	1,546	0	429	0	429
West Oahu	1,588	4	441	1	869
Ho'opili	439	20	122	6	986
West Loch	1004	104	279	29	1,236
Waipahu Cntr	466	61	129	17	1,348
Leeward CC	83	156	23	43	1,328
Pearl Highlands	2,712	148	753	41	2,040
Pearlridge	630	368	175	102	2,113
Aloha Stadium	591	114	164	32	2,246
Pearl Harbor	241	488	67	136	2,177
Airport	146	539	41	150	2,068
Lagoon Drive	211	156	59	43	2,083
Middle Street	154	232	43	64	2,061
Kalihi	174	311	48	86	2,023
Kapalama	45	277	13	77	1,959
Iwilei	162	331	45	92	1,912
Chinatown	43	202	12	56	1,868
Downtown	272	1,778	76	494	1,449
Civic Center	48	633	13	176	1,287
Kaka'ako	28	422	8	117	1,178
Ala Moana	0	4,239	0	1,178	0

Westbound	1 Hour Peak		15 minute peak		
Station	Ons	Offs	Ons	Offs	Line Volume
Ala Moana	1,004	0	279	0	279
Kaka'ako	83	41	23	11	291
Civic Center	101	98	28	27	291
Downtown	278	252	77	70	299
Chinatown	48	41	13	11	301
Iwilei	240	66	67	18	349
Kapalama	34	82	9	23	336
Kalihi	86	141	24	39	320
Middle Street	172	75	48	21	347
Lagoon Drive	47	177	13	49	311
Airport	62	193	17	54	275
Pearl Harbor	62	284	17	79	213
Stadium	145	100	40	28	226
Pearlridge	123	256	34	71	189
Highlands	443	119	123	33	279
Leeward CC	22	232	6	64	220
Waipahu Cntr	108	133	30	37	213
West Loch	40	290	11	81	144
Ho'opili	61	34	17	9	151
West Oahu	1	225	0	63	89
East Kapolei	0	321	0	89	0

The morning peak direction is eastward, or Koko Head. The ons and offs and the line volume for the 15-minute peak-of-the-peak at each station in the peak direction are shown in Figure 3 and Figure 4 for the first and last year of the ten year AHJV operating contract ending in 2028.

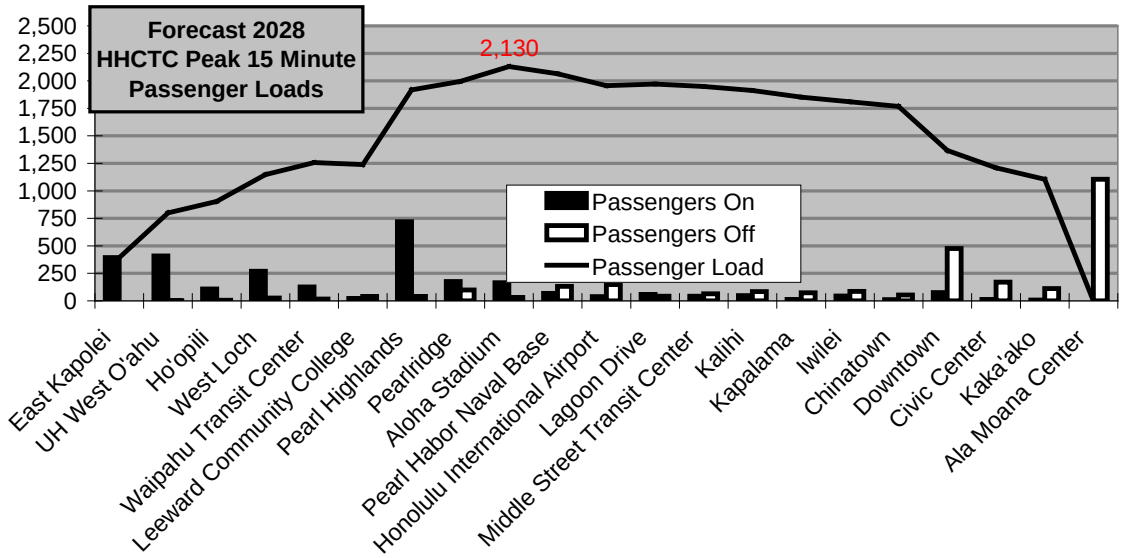
[20] Honolulu High-Capacity Transit Corridor Project Draft Operations and Maintenance Plan (Feb 2010) pp 4.4, 4.5, 4.6 and 5-2 Found at J:\Hawaii\Honolulu Procurement Documents\Addendum 23\Reference Documents\HHCTCP Draft Operations and Maintenance Plan (Revised).pdf

Figure 3. Eastbound Peak 15 Minute Period: First Full Year of Operation



Aloha Stadium is the eastward peak load point of the line. The peak line segment will be between Aloha Stadium and Pearl Harbor with 1,744 passengers forecast to be traveling east on the line during the morning 15-minute peak-of-the-peak in the first year of full operation. That volume is projected to grow 22% to 2,130 in the first ten years of operation. Nearly 40% of the eastbound peak period passengers are projected to alight at the eastern terminal at Ala Moana. Another 17% will disembark at the Downtown station. Eastbound passenger boarding will be concentrated on the western end of the line with 56% of the total peak boardings forecast to load at just three stations.

Figure 4. Eastbound Peak 15 Minute Period: Tenth Year of Full Operation



2.4.2 Forecast Year Peak System Capacity

The grantee specifications and the AHJV proposal describe a service plan intended to provide sufficient person capacity, with only minor exceptions, to meet its adopted loading standard. That standard is well within acceptable limits on passenger crowding for a typical US rapid transit service. However, the circumstance that plans for operations in the out years[21] of the O&M contract call for peak service frequencies that violate the "minimum operating headway" is cause for concern. The assumption that peak passengers will stand for as many long trips as forecast is also questionable. Given that the forecast average trip length on the Project is twice the length of the typical US rapid transit journey, it is possible that standards based on industry averages may not be appropriate to attract and retain the volumes for traveler forecast to use the system. The March 2012 update to HART's O&M Plan did not address any of the PMOC's 2011 concerns related to peak service frequencies that violate the "minimum operating headway" and that some passengers may not tolerate the long periods of standing expected when the passenger forecasts are overlaid unto the operating plan.

<u>Capacity and Crowding</u>
Grantee passenger capacity planning is based on a "Comfort Load" of crowding as defined below:

> **Vehicle Comfort Load Capacity ($L^{Comfort}$)** is the number of passenger spaces within a vehicle represented by the sum of the passenger seating spaces, except flip-up and stowable seats, no wheelchair passengers, no baggage, no surfboards, and no bicycles, plus the effective standee passenger spaces remaining, calculated at 3.2 passengers per square meter (3.4 square feet per standing passenger).

[21] After seven years of full operation

The grantee Comfort Load is slightly more generous than the 3.2 standees per square meter characterized as "reasonable" by *TCRP 100*. This TCRP standard is termed "TCRP Optimal" for the purposes of this capacity analysis

Grantee capacity planning also relies on a "Design Load" Level of crowding as defined below.

> **Vehicle Design Load Capacity (L^{Design})** is the number of passenger spaces within a vehicle represented by the sum of the passenger seating spaces, except flip-up and stowable seats, no wheelchair passengers, no baggage, no surfboards, and no bicycles, plus the effective standee passenger spaces remaining, calculated at four (4) passengers per square meter (2.7 square feet per standing passenger)

The grantee's Design Load (2.7 SF/passenger) is midway between TCRP 100's definition of an "uncomfortable near-crush load" (2.15 SF/passenger) and a "reasonable service load with occasional body contact" (3.2 SF/passenger). The lower TCRP value is considered allowable for short segments for limited periods of time during the peak-of-the-peak and is generally been accepted as an absolute upper bound on acceptable levels of passenger crowding.[22]

Table 10. Passenger Standing Room Summary

Loading	Passengers per Sq Meter	Sq Feet per Passenger
Comfort Load ($L^{Comfort}$)	3.2	3.4
TCRP Optimal Load	3.4	3.2
Design Load (L^{Design})	4	2.7

Grantee Capacity Specifications

During its planning in the spring and summer of 2009, the grantee developed a Fleet Sizing Plan and operating regime that would operate a mix of two- and three-car trains every three minutes during peak periods. Capacity requirements were met by changing train length while holding headways constant. Under this plan and its assumptions, the grantee showed how it intended to carry the projected 2030 peak hour load at three-minute headways with all passengers traveling with at least 3.4 ft^2 of space per standing passenger. Furthermore, the grantee's plan indicated that, during the first few years of operation, the grantee would set the loading standard for the peak of the peak to 90% of the load that could be accommodated at the "comfort load" level.[23]

During the ensuing months, the initial operating specifications published for the proposed system were less specific than outlined in the June 2009 Fleet Sizing report. The grantee specified a prescribed level of peak hour comfort level capacity to be provided by the operator during each year of the contract, as shown in Table 5 and Figure 2.

The PMOC was not able to determine exactly how required capacities were estimated, but it is evident that the required peak hourly volume is a blend of the capacity that would accommodate a surge in the peak of the peak and the balance of the forecast peak hour ridership during the

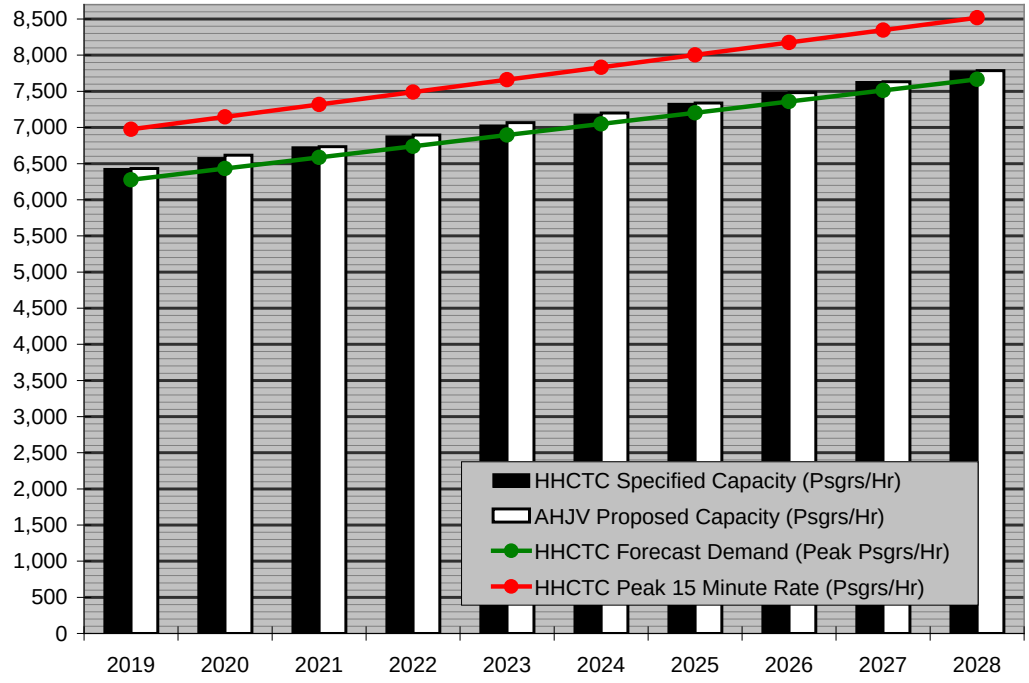
[22] TCRP 100, (pp 5-27)
[23] Fleet Sizing Report June 2009

balance of the hour. By subtracting the surge riders from the balance of the hour and averaging required capacities over the entire hour, capacity set aside for any surge in ridership is sharply reduced and spread across the entire peak. In fact, after Year Five "extra" capacity to accommodate any surge in forecast ridership is completely eliminated.

AHJV responded to the grantee's specification by proposing to operate a growing fleet of two-car trains at shorter and shorter headways each year to provide the specified capacity. It is a matter of concern that AHJV proposes, in 2026 and subsequent operating years, to operate peak service at headways less than its own calculated minimum operating headway.

Figure 5 illustrates the gap between average hourly peak flows and the ridership that would be expected if passengers arrived at a rate 3% higher than the typical peak hour forecast during any rush hour period. It is a matter of some concern that the 2012 O&M plan update did not address this concern. It is hoped that AHJV's review of the draft plan with PMOC comments will not ignore this discrepancy.

Figure 5. Peak Capacity Specifications and Peak Demand Forecasts with Peak 15 Minute Rate shown



The overall effect of this approach is forecast to adversely affect the comfort of some peak passengers, but, since the desired level of crowding set by grantee is relatively generous, the system should still be able to physically carry all forecast passengers in each year of forecast operation.

AHJV has proposed to operate the service with two-car trains providing 64 fixed seats and 854.8 feet of useable standing space. Table 11 shows the capacity provided by the AHJV two-car train at each of the three capacity levels.

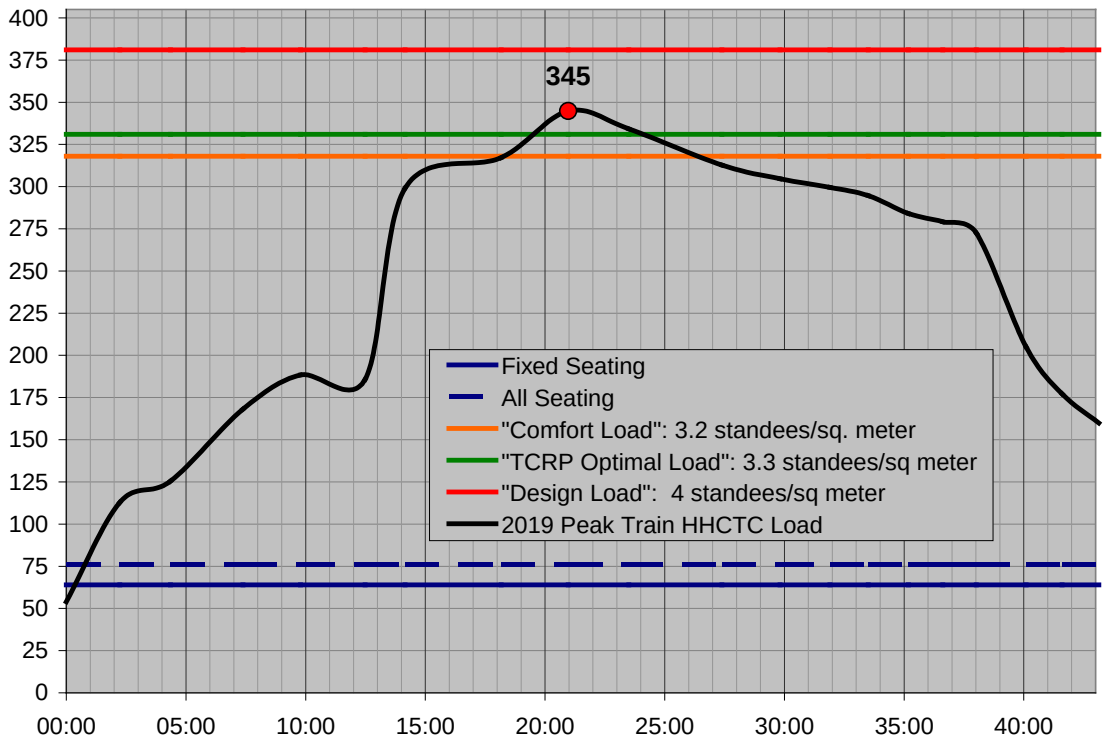
Table 11. AHJV Two Car Train Capacity by Loading Density Level[24]

Loading Density Level	Grantee "Comfort Load"	TCRP "Optimal Load"	Grantee "Design Load"
Space per Standing Passenger *(sq/ft per standee)*	3.4	3.2	2.7
Fixed Seats	64	64	64
Standees	254	268	318
Total capacity per train	**318**	**331**	**382**

Figure 6 illustrates how the peak morning train on a typical weekday during the first year of full operation would be expected to load relative to various capacity standards. The figures relate forecast peak-of-the-peak passenger volumes to the peak service headways and vehicles proposed by AHJV in conformity with grantee O&M specifications.

Figure 7 shows how the typical peak train would be likely to load in 2028 if AHJV found an acceptable way to operate peak service more frequently than the minimum operating headway. Since the proposed peak headway is reduced by 17% between 2019 and 2028 while the forecast peak ridership increases by 22% over the same period, the magnitude and extent of crowding is forecast to increase slightly over the life of the contract.

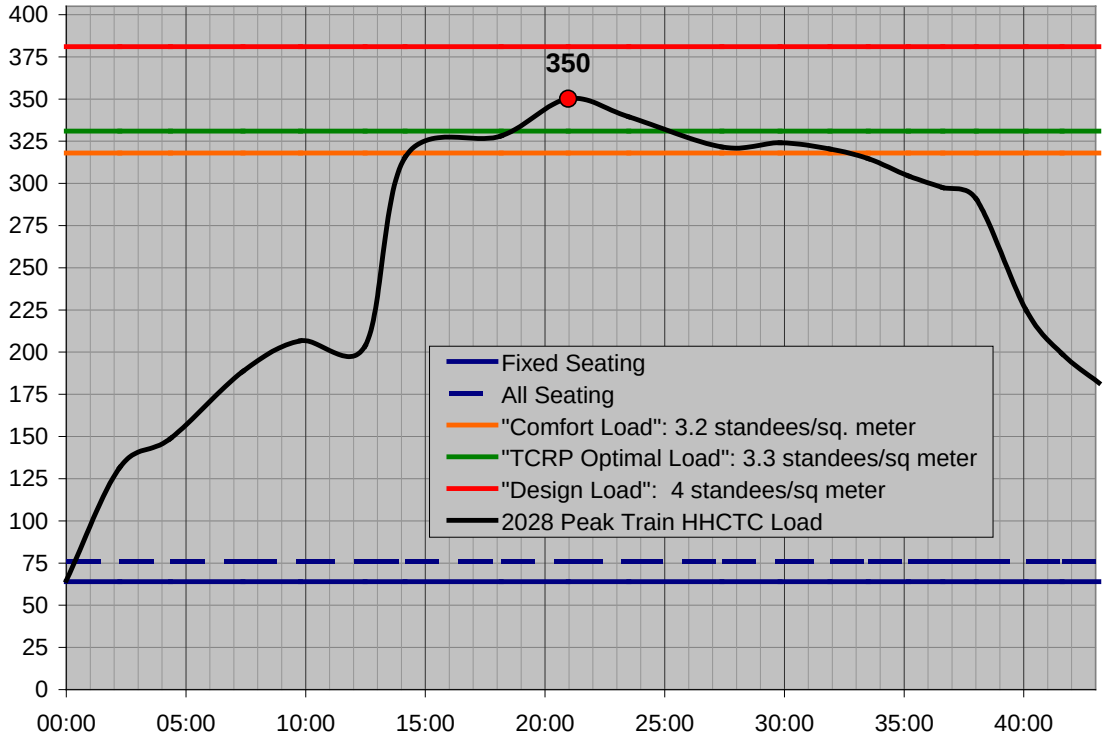
Figure 6. Forecast Passenger Loads and Capacity (2018)
Typical Eastbound Peak of Peak Train



[24] Assumes 427.4 sq/ft of floor space in each car as documented by AHJV

In the first full year of operation, the typical train in the peak of the peak will carry a maximum load of 345 passengers, which is below the "Design Load" of 382 passengers but slightly above the "TCRP Optimal Load" of 331 passengers. Peak passengers on eastbound trains moving between the Stadium and the Airport would be on trains exceeding the "Comfort" standard of crowding for up to 6 minutes. It is estimated that 1,813 passengers would ride on "overcrowded" peak of the peak trains each morning. This would constitute only 4% of the total forecast weekday ridership[25] but 21% of all eastbound peak hour passengers.

Figure 7. Forecast Passenger Loads and Capacity (2028)
Typical Eastbound Peak of Peak Train



Should AHJV and the grantee agree on a plan to operate service at frequencies that exceed the minimum operating headway, the peak train in the last year will carry a maximum load of 350 passengers. Peak passengers on eastbound trains moving between the Pearl Ridge and Kalihi would be on trains exceeding the "Comfort" standard of crowding for up to 15 minutes. It is estimated that 2,368 passengers would ride on "overcrowded" peak trains. This would still constitute only 4% of the total forecast weekday ridership[26] but 23% of all eastbound peak hour passengers.

Trip Duration and Passenger Crowding

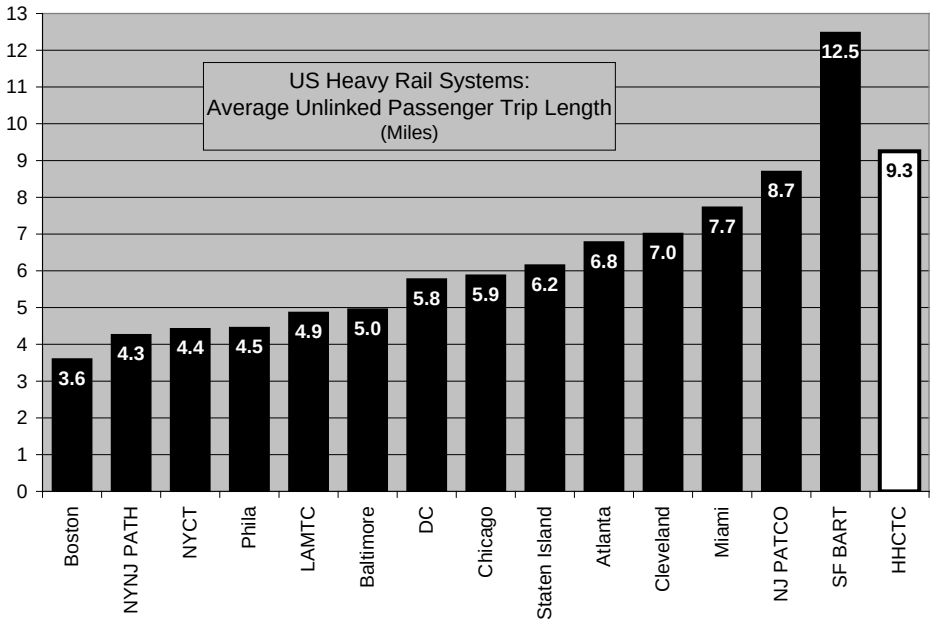
Despite the analysis offered above, the PMOC has a lingering concern with respect to crowding and the passenger experience on the proposed system. TCRP 100 is based on best practices and experience of the North American transit industry. In that experience, the typical passenger

[25] presuming that the afternoon peak would mimic the morning in reverse.
[26] presuming that the afternoon peak would mimic the morning in reverse.

makes a much shorter trip than forecast for the system. Figure 8 shows the length of the average passenger trip (unlinked) for all heavy rail rapid transit services in the US as reported to the FTA's National Transit Database. It also shows the average passenger trip length forecast for the system.

Inspection of the figure shows that only San Francisco's BART, Philadelphia/NJ's PATCO and Miami's Metrorail serve average passenger journeys in the vicinity of those forecast for Honolulu's system. Since BART and PATCO opened approximately 40 years ago they've been characterized as functioning almost like commuter rail due in part to the long trip lengths of their passengers. To provide comfort for passengers making longer trips, the configuration of the BART and PATCO cars provide a higher "*Comfort Rate*" with 64 to 80 seats per car. Miami's rapid transit cars offer a similar level of comfort providing for 70 seated and 90 standing passengers per car. By contrast, the grantee plans to carry 32 seated and 127 standing passengers in each car.

Figure 8. US Heavy Rail Passenger Trip Lengths



Most (74%) of the forecast system AM peak eastbound ridership boards west of Pearl Ridge. About 67% of these riders are forecast to disembark at destinations east of Chinatown. This indicates that most peak hour passengers will be expected to stand for well more than 20 minutes on the most common journeys. Given the geographic spread between the locus of trip origins and the locus of trip destinations, the grantee may wish to reconsider the train and car configuration planned for the system to ensure that the system supplies the degree of comfort necessary to actually attract and satisfy forecast passengers.

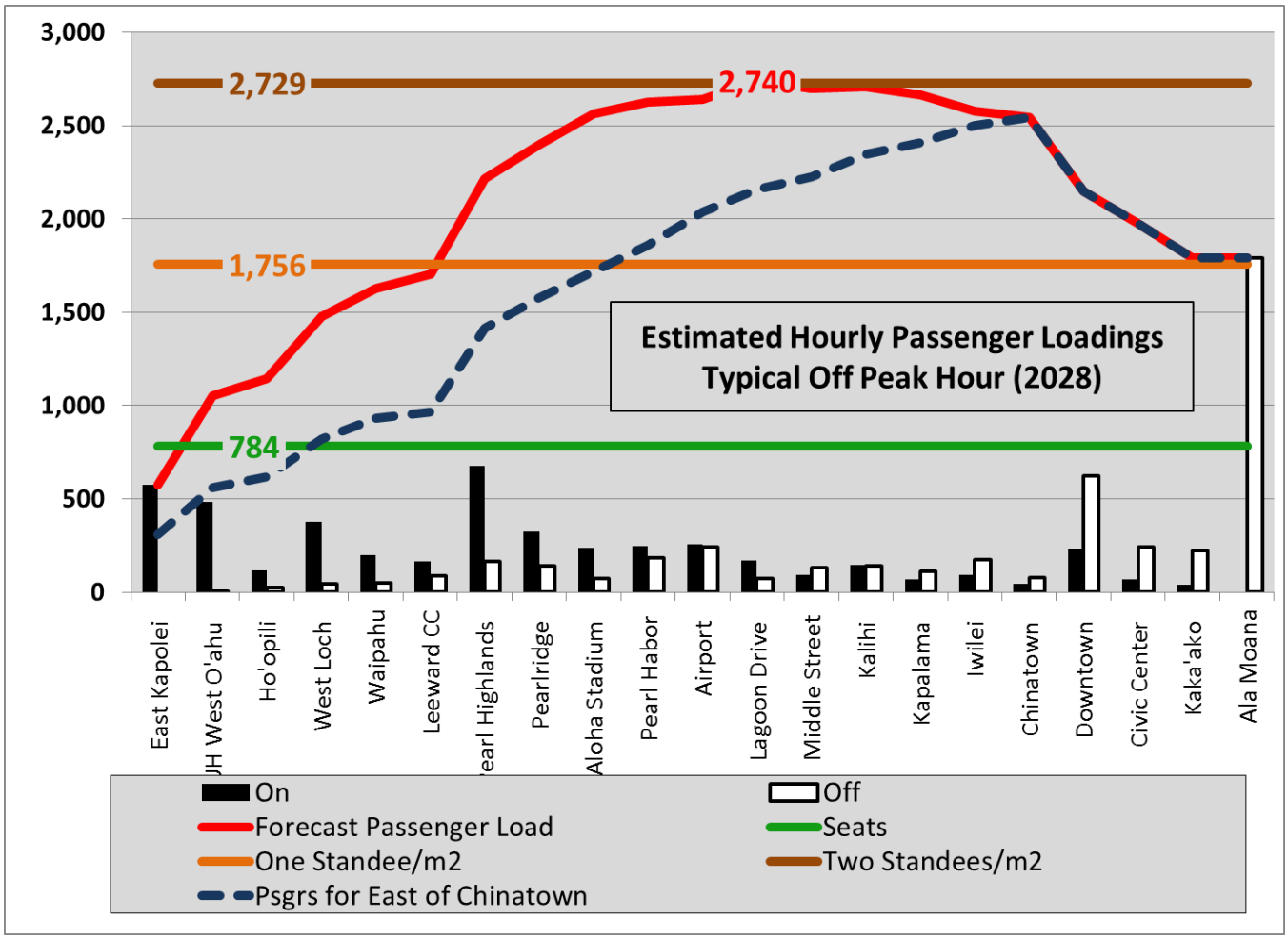
The PMOC is concerned that, given the length of time that most passengers would be expected to stand on most trips, the system might fail to achieve forecast ridership levels. After trying the system, many passengers may decide that they are unwilling to endure such crowded conditions for such long trips. It should be noted that HART is investigating the ability to add 8-10 seats per car.

Off Peak Standees and Crowding

After reviewing the March 2012 O&M plan update that did not address this concern, the PMOC further explored the depth of this possible deficiency by considering off peak trips.

Using Table 4.11 of Addendum 01 to the Travel Demand Forecasting Results Report (October 1, 2009) prepared by Parsons Brinckerhoff for the Project, the PMOC estimated an off peak loading profile for the eastbound service. The findings are illustrated in Figure 9. As noted above, the Project is somewhat atypical from other metros because such a large fraction of the overall ridership will board at the four western most stations bound for one of the four eastern most stations, particularly Ala Moana. Because of this circumstance, eastbound riders boarding east of West Loch station during a typical off peak hour will not have a much opportunity to obtain a seat because nearly all the seats will already be filled with passengers for east of Chinatown. There will be approximately 1,000 to 2,000 standees every off peak hour between Leeward and Ala Moana. Fewer than 800 seats will be available during the typical off peak hour. At some times of day the condition will be worse. It should be noted that HART is investigating the ability to add 8-10 seats per car.

Figure 9. Estimated Passenger Loadings for Typical Off Peak Weekday

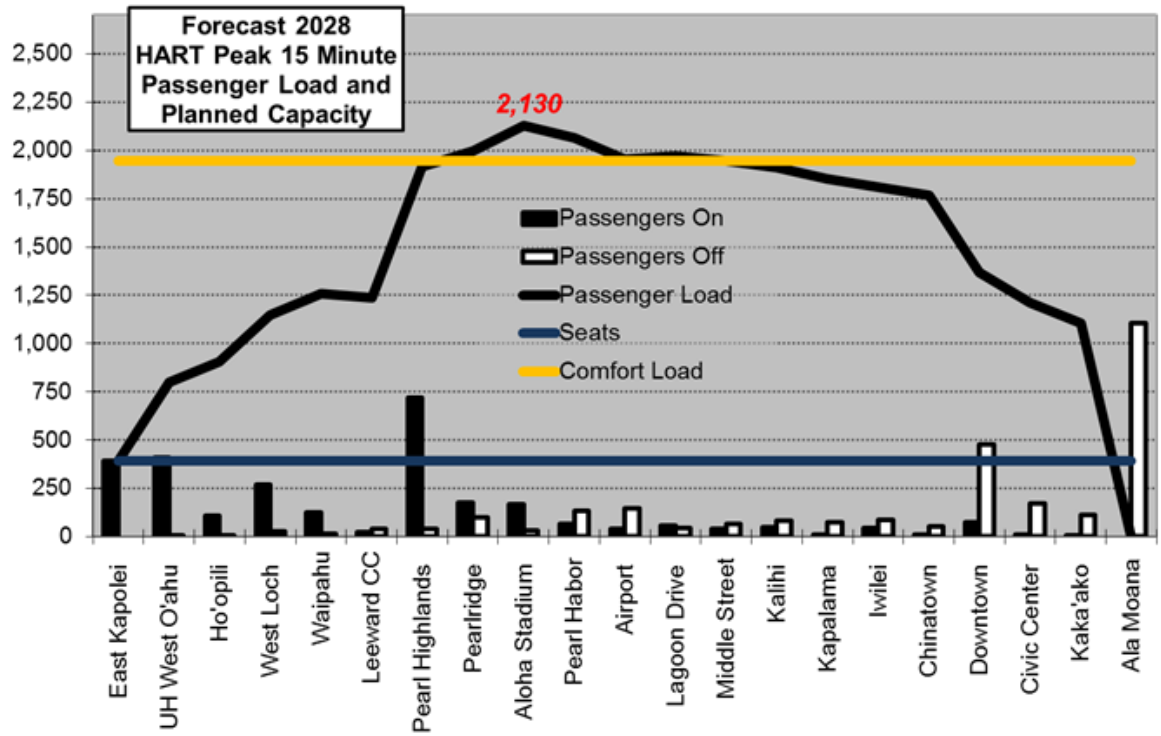


Assumptions

- Since the operating plan ends at 2028 but the forecast ridership represents 2030, it was interpolated that 2028 ridership would be 95% of the 2030 forecasts.
- Inspection of Table 4.11 Daily Station to Station volumes showed that they represent only the "outbound" or "leaving home" portion of every passenger round trip. The eastbound and westbound totals don't match. (83,060 eastbound versus 33,188 westbound).
- Off peak travel will be 50% of total travel as observed on other Metro rail systems.
- The "typical" hour will be one twelfth of forecast off peak travel. HART is planning 8 weekday hours of peak service and 12 weekday hours of base or evening service.
- The typical hour will occur during the base period with a 2028 base headway (294 seconds) twice as long as the peak headway (147 seconds).
- The typical eastbound off peak hour will include both eastward "outbound" trips and an equal proportion of the return legs of round trips that started in the east for westward destinations.

Methodology

The chart and analysis were framed to mirror and expand the peak 15 minute analysis prepared in 2011. This analysis showed that during the peak 15 minutes all seats will be filled at every stop east of West Oahu.



Assessment
It would be disappointing if the project fell short of achieving its potential because the planners and engineers failed to provide adequate passenger comfort and convenience. HART and AHJV have several options to address this concern. From a capital perspective, the least expensive option would be to simply add off peak trips to increase seating availability during periods when ridership is stronger. As noted in 2011, they could also address the peak and off peak seating shortage by adding seats to every car and adding a third car to every train.

Benchmarking the Project against the universe of 41 other Unattended Train Operation (UTO) lines operated worldwide, the Project will be the world's fourth longest UTO line but will rank in the bottom third with respect to passenger capacity per train. Since most UTO's offer frequent service, there is an obvious disconnect between the lengths of trips offered on the Project and the seating/standing capacity planned to service passengers.

Overall Car Capacity Assessment
The PMOC has three concerns with respect to planned capacity. None of these concerns were addressed in the March 2012 update to the Operations and Maintenance Plan.

- First, despite assurances to the contrary, the operating plan provides no capacity for a surge in ridership after the fifth year of operations and falls well short of the surge that would have been accommodated by the 2009 Fleet Sizing Report. The level of forecast peak crowding fails to meet AHJV's stated standards but lies within a range that is generally considered acceptable for peak rapid transit passenger comfort.

- Second, AHJV's proposal to provide required capacity for 2026 and subsequent years calls for it to operate service at less than the minimum operating headway. Since the minimum headway includes a 15% cushion above the non-interference headway, it is possible that service could be operated without degradation on some days. But, on many days, service would be degraded with longer trip times and more uneven service than had been specified as acceptable.

- The final concern is more qualitative. When fully operational, the system is forecast to carry some of the longest average passenger trips of any US rapid transit system. The vehicles planned for the service do not seem to offer a degree of comfort suitable for the journey length. So while the capacity of the proposed system falls within the average range for typical rapid transit systems, it falls well short of the seating and capacity offered by the transit lines that carry passengers for journeys of similar length and duration.

In 2011, it was recommended that the grantee and AHJV confer regarding plans to operate at frequencies that violate the minimum operating headway. A likely possible response will be to offer service with longer trains operating at four-minute headways. The change in overall fleet size necessary to operate with three-car trains at slightly longer headways should be negligible. The fleet would also include a number of presumably less expensive middle cars and the level of comfort (seats/passenger) afforded passengers that are not riding in the peak of the peak would

be increased. Operating at four-minute peak headways with longer trains would also provide more capacity for surges in demand during the first several years of the contract.

2.4.3 Running, Station Dwell, and Cycle Time Assessment

The running, dwell, layover/recovery, and resultant cycle times determine the number of trains and cars necessary to serve forecast passenger loads. The March 2012 O&M plan did not provide any update regarding running times, dwell times, or cycle times, despite substantial PMOC concerns in this area.

2.4.4 Running Time

Station-to-station running time estimates for the planned service were prepared by AHJV using train performance calculation software and the known characteristics of the proposed vehicle and route. Table 12 shows the inter-station running time forecasts proposed by AHJV. The grantee specified that these estimates reflect trains carrying a "Design Load' (aka AW2) weight of passengers to help ensure that the cars and traction power system can more than handle anticipated loads.

Table 12. AHJV Proposed Inter-station Running Times[27]

EASTWARD			
From	**To**	**Miles**	**Time**
EAST KAPOLEI	WEST OAHU	0.97	0:01:30
WEST OAHU	HO'OPILI	0.99	0:01:40
HO'OPILI	WEST LOCH	1.58	0:02:16
WEST LOCH	WAIPAHU T.C.	1.29	0:01:51
WAIPAHU T.C.	LEEWARD CC	1.38	0:02:14
LEEWARD CC	HIGHLANDS	0.43	0:00:57
HIGHLANDS	PEARLRIDGE	2.28	0:03:13
PEARLRIDGE	STADIUM	1.45	0:02:08
STADIUM	PEARL HARBOR	1.26	0:01:59
PEARL HARBOR	AIRPORT	1.85	0:03:11
AIRPORT	LAGOON DR	1.18	0:01:59
LAGOON DR	MIDDLE ST	1.04	0:01:39
MIDDLE ST.	KALIHI	0.49	0:01:05
KALIHI	KAPALAMA	0.75	0:01:15
KAPALAMA	IWILEI	0.48	0:01:01
IWILEI	CHINATOWN	0.38	0:00:59
CHINATOWN	DOWNTOWN	0.45	0:01:15
DOWNTOWN	CIVIC CENTER	0.41	0:00:53
CIVIC CENTER	KAKA'AKO	0.47	0:01:01
KAKA'AKO	ALA MOANA	0.74	0:01:39
		19.90	0:33:45

WESTWARD			
From	**To**	**Miles**	**Time**
ALA MOANA	KAKA'AKO	0.74	0:01:39
KAKA'AKO	CIVIC CENTER	0.47	0:01:01
CIVIC CENTER	DOWNTOWN	0.41	0:00:54
DOWNTOWN	CHINATOWN	0.45	0:01:14
CHINATOWN	IWILEI	0.38	0:01:00
IWILEI	KAPALAMA	0.48	0:01:03
KAPALAMA	KALIHI	0.75	0:01:16
KALIHI	MIDDLE ST	0.49	0:01:05
MIDDLE ST	LAGOON DR	1.04	0:01:38
LAGOON DR	AIRPORT	1.18	0:01:59
AIRPORT	PEARL HARBOR	1.85	0:03:09
PEARL HARBOR	STADIUM	1.26	0:02:00
STADIUM	PEARLRIDGE	1.45	0:02:08
PEARLRIDGE	HIGHLANDS	2.28	0:03:14
HIGHLANDS	LEEWARD CC	0.43	0:00:58
LEEWARD CC	WAIPAHU T.C.	1.38	0:02:13
WAIPAHU T.C.	WEST LOCH	1.29	0:01:51
WEST LOCH	HO'OPILI	1.58	0:02:22
HO'OPILI	WEST OAHU	0.99	0:01:40
WEST OAHU	EAST KAPOLEI	0.97	0:01:30
		19.90	0:33:54

The station-to-station running times found in the Section 3.16.2.4 of the AHJV proposal vary slightly from running time estimates reported elsewhere in the AHJV proposal. The car performance simulation results indicate that, overall, the eastbound service is actually 50 seconds

[27] BAFO2\AHJV BAFO Feb 24 Clean Files\Technical Proposal Volumes 1-6 and Appendix A\Volume 3\Part 2\Volume 3 - Part 2 Pages 305 to 327.pdf Pages 3-15 and 3-16

faster and the westbound is 10 seconds faster than reported in AHJV proposal Section 3.16.2.4. These two sets of figures disagree with the Train Control Simulation Results,[28] which indicate a running time of 35:19 Eastbound and 35:11 Westbound. It appears that "recovery and layover" roughly corresponds to the signal system impacts on running times when operating at 178-second headways. Other simulations in the train control simulation report indicate that operations at shorter headways have a negative effect on running times[29].

PMOC recommends that the grantee work with AHJV to develop station-to-station running time estimates that reflect impacts of the train control system and terminal turnback operations. These more robust and realistic estimates should be the basis for future fleet plans and capacity planning.

Table 13. AHJV Running Time Estimates

Source	Eastward	Westward	Total
Section 3.16 Travel Time Only	0:33:45	0:33:54	1:07:39
Section 3.16 Travel Time w/ Recovery and Layover[30]	0:35:17	0:35:28	1:10:45
Passenger Vehicle Performance Simulation Results[31]	0:32:35	0:33:24	1:05:59
Train Control System Simulation Results[32]	0:35:19	0:35:11	1:10:30

2.4.5 Station Dwell Time

The grantee approach to forecasting dwell time has changed several times since the last formal capacity review. Each change has added dwell time to the overall travel time. The cumulative effect of the changes has (in the aggregate) virtually eliminated earlier discrepancies between PMOC estimates based on TCRP 100 standards and the dwell times proposed by AHJV.

As discussed in the 2009 PMOC Report, *TCRP 100* presents three methods[33] to estimate station dwell times. The grantee did not employ any of these methods. Instead, a fourth approach is

[28] J:\Hawaii\Honolulu Spring 2011\BAFO 2\BAFO2\AHJV BAFO Feb 24 Clean Files\Technical Specifications\5 Train Control\C9M HNL 2X 002_Train Control AF-902 Simulation_02.pdf
C9M HNL 2X 002 02 13 February 24, 2011 Pages 13 and 16

[29] For instance compare Table 6 with Table 8 and Table 8 with Table 11 to see how shorter headways (with the mitigating impact of shorter dwell times) affect forecast inter-station running time.

[30] See Section 1.3.6.

[31] J:\Hawaii\Honolulu Spring 2011\BAFO 2\BAFO2\AHJV BAFO Feb 24 Redlined Files\Technical Specifications\4 Passenger Vehicle\1 General Characteristic\Performance Specification. Page 2-20

[32] J:\Hawaii\Honolulu Spring 2011\BAFO 2\BAFO2\AHJV BAFO Feb 24 Clean Files\Technical Specifications\5 Train Control\C9M HNL 2X 002_Train Control AF-902 Simulation_02.pdf
C9M HNL 2X 002 02 13 February 24, 2011 Pages 13 and 16

[33] The most developed and tested is based on its predecessor, *TCRP 13*, which models dwell times as a function of passenger activity, an overhead value related to door operation and signal system, and a loading diversity factor, which compensates for unevenly dispersed passenger boarding.[33] It is worth noting that *TCRP 13* notes the ongoing analytical dilemma by stating, "None of these methods are entirely satisfactory. It is regrettable that the study failed to find a better method of estimating dwell or controlling dwell times and explains why other practitioners over a period of three decades have resorted to simply assigning a reasonable value to dwell." The second methodology presented in *TCRP 100* uses a traditional "mean plus two standard deviations, while the third method utilizes professional peer system performance and experience.

applied. While it is not clear whether the method is justified, it does yield credible estimates of aggregate dwell time.

Grantee Proposed Station Dwell Time

The grantee's specified methodology for estimating station dwell times used a novel approach that integrated car characteristics (such as comfort level capacity and door configuration) with generous assumptions concerning the turnover of passengers on cars to provide a dwell time estimation algorithm that could be used by a variety of proposers offering different equipment and operating plans.

Nominal station dwell times for each station were to be calculated by the Core Systems Contractor on the basis of the following criteria:

(1) Vehicle loaded to the vehicle comfort load capacity ($L^{Comfort}$), as described earlier.

(2) At all stations, the following percentages of the vehicle comfort load capacity board and alight each vehicle through the doors on only one side:

Table 14. Fraction of Comfort Load Passengers Expected to Board/Alight at Each Station

	Eastward (Read Down)		Westward (Read Up)	
Station	**Board**	**Alight**	**Board**	**Alight**
East Kapolei	100%	25%	*Turnback*	
UH West Oahu	100%	25%	25%	25%
Ho'opili	25%	25%	25%	25%
West Loch	100%	25%	25%	50%
Waipahu Transit Center	50%	25%	25%	25%
Leeward Community College	25%	25%	25%	25%
Pearl Highlands	100%	25%	50%	25%
Pearl Ridge	75%	50%	25%	25%
Aloha Stadium	75%	25%	25%	25%
Pearl Harbor	25%	50%	25%	50%
Honolulu International Airport	25%	75%	25%	25%
Lagoon Drive	25%	25%	25%	25%
Middle Street Transit Center	25%	25%	25%	25%
Kalihi	25%	50%	25%	25%
Kapalama	25%	25%	25%	25%
Iwilei	25%	25%	25%	25%
Chinatown	25%	25%	25%	25%
Downtown	50%	100%	50%	25%
Civic Center	25%	75%	25%	25%
Kaka'ako	25%	50%	25%	25%
Ala Moana Center	*Turnback*		75%	100%

(3) Vehicle door size represents the actual dimensions of the proposed car.

(4) The passenger load/unload rate assumes that one passenger per second can move through each 25-inch unit of clear width at each doorway. The effective clear width of each doorway is divided by 25 inches and rounded downward to the nearest 0.1 units. (Partial door width adds to estimated throughput.)

(5) A time allowance that represents actual equipment performance is included for all ATP interlock functions, plus door unlocking/opening and closing/locking times;

this time allowance shall not include door fully-open time. This allowance may not exceed ten seconds.

(6) No station shall have a nominal doors fully-open period of less than five (5) seconds.

The grantee specified that these calculated nominal station dwell times would be used to determine the round trip travel time and the headways to be offered in the proposer's operating plan. AHJV's proposed train holds a comfort load of 318 passengers with six 55.1 inch doors (13.2 door equivalents) on each side. Based on these parameters, AHJV's dwell time estimates are summarized in Table 15. Calculations for each stop include 4.5 seconds for door opening and 5.5 seconds to close and lock doors before departing. HART has decided to add platform screen gates to the Project specification. Adding these doors may increase the time required for door opening upon arrival and for door closing at departure. HART and AHJV should address this consideration in the O&M plan for the platform screen gates.

Table 15. AHJV Dwell Time Calculation Summary

	Eastward (Read Down)			Westward (Read Up)		
Station	**Psgrs Served**	**Psgr Service Time (secs)**	**Total Dwell including door time (seconds)**	**Psgrs Served**	**Psgr Service Time (secs)**	**Total Dwell including door time (seconds)**
East Kapolei	398	30.2	40.2	*Turnback*		
UH West Oahu	398	30.2	40.2	160	12.1	22.1
Ho'opili	160	12.1	22.1	160	12.1	22.1
West Loch	398	30.2	40.2	239	18.1	28.1
Waipahu Transit Center	239	18.1	28.1	160	12.1	22.1
Leeward Community College	160	12.1	22.1	160	12.1	22.1
Pearl Highlands	398	30.2	40.2	239	18.1	28.1
Pearl Ridge	398	30.2	40.2	160	12.1	22.1
Aloha Stadium	319	24.2	34.2	160	12.1	22.1
Pearl Harbor	239	18.1	28.1	239	18.1	28.1
Honolulu Airport	319	24.2	34.2	160	12.1	22.1
Lagoon Drive	160	12.1	22.1	160	12.1	22.1
Middle Street Transit Center	160	12.1	22.1	160	12.1	22.1
Kalihi	239	18.1	28.1	160	12.1	22.1
Kapalama	160	12.1	22.1	160	12.1	22.1
Iwilei	160	12.1	22.1	160	12.1	22.1
Chinatown	160	12.1	22.1	160	12.1	22.1
Downtown	477	36.1	46.1	239	18.1	28.1
Civic Center	319	24.2	34.2	160	12.1	22.1
Kaka'ako	239	18.1	28.1	160	12.1	22.1
Ala Moana Center	*Turnback*			557	42.2	52.2
Total	**5,500**	**416.7**	**616.7**	**3,913**	**296.4**	**496.4**
			10:17			08:16

This approach grossly overestimates that number of passengers forecast to use any train with the equivalent of 2,750 unique passengers riding portions of the 20 mile eastbound peak trip. But

the overall approach yields aggregate dwell time estimates that are much closer to TCRP 13 estimates than estimated earlier. See Table 16 for current estimates.

Table 16. Comparison of AHJV and PMOC 2028 Dwell Time Estimates

	Eastward (Read Down)			Westward (Read Up)		
Station	**AHJV Estimate**	**PMOC Estimate[34]**	**Difference**	**AHJV Estimate**	**PMOC Estimate**	**Difference**
East Kapolei	40.2	29.2	11.0	*Turnback*		
UH West Oahu	40.2	29.3	10.9	22.1	27.0	-4.8
Ho'opili	22.1	27.3	-5.2	22.1	26.8	-4.7
West Loch	40.2	28.4	11.7	28.1	27.1	1.0
Waipahu Transit Center	28.1	27.4	0.7	22.1	27.0	-4.9
Leeward CC	22.1	27.0	-4.8	22.1	27.0	-4.9
Pearl Highlands	40.2	32.5	7.7	28.1	27.6	0.5
Pearl Ridge	40.2	28.2	11.9	22.1	27.2	-5.1
Aloha Stadium	34.2	27.8	6.4	22.1	27.1	-4.9
Pearl Harbor	28.1	27.6	0.5	28.1	27.2	0.9
Honolulu Airport	34.2	27.5	6.6	22.1	27.0	-4.9
Lagoon Drive	22.1	27.2	-5.0	22.1	27.0	-4.9
Middle Street	22.1	27.2	-5.0	22.1	27.1	-5.0
Kalihi	28.1	27.3	0.8	22.1	27.0	-4.9
Kapalama	22.1	27.0	-4.9	22.1	26.8	-4.7
Iwilei	22.1	27.3	-5.2	22.1	27.2	-5.1
Chinatown	22.1	26.9	-4.8	22.1	26.8	-4.7
Downtown	46.1	29.7	16.4	28.1	27.6	0.5
Civic Center	34.2	27.5	6.7	22.1	27.0	-4.8
Kaka'ako	28.1	27.2	0.9	22.1	26.9	-4.7
Ala Moana Center	*Turnback*			52.2	28.7	23.5
Total	616.7	559.4	57.3	496.4	543.1	-46.6
mm:ss	10:17	09:19	00:57	08:16	09:03	-00:47
			Grand Total	**18:33**	**18:22**	**00:10**

For the eastbound peak trip, the overall AHJV estimate is 57 seconds longer than the PMOC estimate based on TCRP 13. For the westbound trip, the PMOC estimate is 47 seconds longer than the overall AHJV estimate. Combining both directions the net difference is a negligible 10 seconds over 18+ minutes of estimated dwell time.

2.4.6 Recovery and Layover Time

AHJV's station-to-station travel time estimates include an allowance for "recovery and layover" at each station that is not explicitly called for in the grantee specification. The allowances range from 4.0% to 5.7% of estimates of inter-station travel times. AHJV's proposal does not indicate how these allowances were derived. The overall effect is to add slightly more than 3 minutes to overall travel times in addition to estimated travel time and dwell time.

[34] Based on method described in Parkinson, Tom and Fisher, Ian. Rail Transit Capacity (TCRP Report 13). Transportation Research Board, Washington DC. 1996. pp. 48

Recalling Table 13, it is notable that "recovery and layover" allowance roughly corresponds to the additional travel time estimated by the Train Control Simulation for operations at 178-second headways. As headways grow shorter, the chance that the movements of leading trains will influence their followers increases, resulting in longer simulated running times.

Table 17. Recovery and Layover Time[35]

Eastward (Read Down)				Westward (Read Up)		
Travel Time	**Added Allowance for Recovery and Layover**	**% Recovery and Layover**	**Arrival Station**	**Travel Time**	**Added Allowance for Recovery and Layover**	**% Recovery and Layover**
			East Kapolei	01:39	00:04	4.0%
01:30	00:04	4.4%	UH West Oahu	01:01	00:03	4.9%
01:40	00:05	5.0%	Ho'opili	00:54	00:03	5.6%
02:16	00:06	4.4%	West Loch	01:14	00:03	4.1%
01:51	00:05	4.5%	Waipahu Transit Center	01:00	00:03	5.0%
02:14	00:06	4.5%	Leeward College	01:03	00:03	4.8%
00:57	00:03	5.3%	Pearl Highlands	01:16	00:03	3.9%
03:13	00:08	4.1%	Pearlridge	01:05	00:03	4.6%
02:08	00:06	4.7%	Aloha Stadium	01:38	00:04	4.1%
01:59	00:05	4.2%	Pearl Harbor Naval Base	01:59	00:06	5.0%
03:11	00:08	4.2%	Honolulu Airport	03:09	00:08	4.2%
01:59	00:05	4.2%	Lagoon Drive	02:00	00:06	5.0%
01:39	00:04	4.0%	Middle Street Transit Center	02:08	00:06	4.7%
01:05	00:03	4.6%	Kalihi	03:14	00:09	4.6%
01:15	00:04	5.3%	Kapalama	00:58	00:03	5.2%
01:01	00:03	4.9%	Iwilei	02:13	00:06	4.5%
00:59	00:03	5.1%	Chinatown	01:51	00:05	4.5%
01:15	00:04	5.3%	Downtown	02:22	00:07	4.9%
00:53	00:03	5.7%	Civic Center	01:40	00:05	5.0%
01:01	00:03	4.9%	Kaka'ako	01:30	00:04	4.4%
01:39	00:04	4.0%	Ala Moana Center			
33:45	**01:32**	**4.5%**	**TOTAL**	**33:54**	**01:34**	**4.6%**

2.4.7 Cycle Time & Vehicle Requirements

Cycle time is the sum of the inter-station running time, dwell time and recovery and layover time, as a multiple of the headway. The vehicle requirement (number of trains) is a function of the headway and cycle time.

The grantee's specifications indicate that the round trip time necessary for a train to complete one circuit around its route should not exceed 90 minutes. The grantee further specifies the round trip time as the sum of all inter-station travel times (at AW2 or "L^{Design} weights) and station dwell times (based on the nominal estimates described earlier).

[35] BAFO2\AHJV BAFO Feb 24 Clean Files\Technical Proposal Volumes 1-6 and Appendix A\Volume 3\Part 2\Volume 3 - Part 2 Pages 305 to 327.pdf. Pages 315-316

AHJV's Technical Proposal (Volume 3: Part 2: Section 3.16.2.4) calls for a round trip time of 89:33, as summarized in Table 18. As discussed above, the inter-station running times and dwell times at intermediate stations appear to be reasonable estimates of real world performance. The inline recovery time allowance of nearly 3 minutes seems prudent, especially in light of the train control system simulation results.

Table 18. AHJV Round Trip Times

	Eastward	Westward	Total
Terminal Time	00:53	0:41	01:34
Inter-station Running Time	33:45	33:54	01:07:39
Dwell times at Intermediate Stations	10:00	07:40	17:40
Inline Recovery and Layover Time	01:28	01:30	02:58
Total	46:06	43:45	1:29:51

The terminal time necessary to turn the train between revenue trips is not explicitly discussed by AHJV in Volume 3 of the Technical Proposal. The figures presented in Table 17 are the PMOC's sum of the calculated dwell allowance at each terminal station, the AHJV recovery/layover allowance at the terminal station (4 seconds), and the ten seconds at each end of the line noted by AHJV as "extra time for turnback."

Terminal Turnback Capacity

Terminal operations are considered in more detail in AHJV's Train Control System Simulation Report[36]. This report does not entirely agree with Volume 3: Part 2. Table 19 shows the "Operational Round Trip Time" posited by the train control simulation.

Table 19. Operational Round Trip Time

	Eastward	Westward	Total
Terminal Dwell	0:00:52	0:00:40	0:01:32
Inline Time	0:44:53	0:42:33	1:27:26
Total	0:45:45	0:43:13	1:28:58

More importantly, the simulation considers how turnbacks at East Kapolei and Ala Moana Center will be accomplished. The simulation determines and illustrates that at headways of less than 240 seconds (four minutes), the following train behind any train turning at either terminal presents a conflict for its turning leader until the second train arrives at the terminal (i.e., the first train can't leave for its return trip until its follower clears the terminal interlocking that the first train needs to depart.) The operational effect of this circumstance is to set the minimum turn time at terminal stations to a value roughly equivalent to the prevailing service headway[37].

This constraint is relaxed when the follower is four or more minutes behind the turning train since the headway is long enough to allow the turning train to turn and depart before its follower seizes the interlocking for its approach to the terminal. The constraint is exacerbated by the fact

[36] AHJV, AF-902 TRAIN CONTROL SYSTEM SIMULATION REPORT, C9M HNL 2X 002 Rev. 02 Pages 25-31

[37] For more detail consult Train Control Simulation Report C9M HNL 2X 002 02 32 February 24, 2011 pages 26-31

that the end of track is close to the terminal platforms, causing the train control system to retard the train approaching the end of track to ensure that it will be able to stop in the unlikely (but theoretically possible) event that it overruns the terminal platform.

With the short (sub-three-minute) headways, the terminal configuration also constrains maximum turnback times to ensure that the third train to arrive at the terminal does not conflict with the departing first train. The first train must be out of terminal 60 to 90 seconds before the third train is due to arrive.

The time and sequencing of turnbacks at stations must be considered in determining the number of trainsets required to provide service. AHJV's tabulations showing the number of trainsets required to provide peak service in each of the ten years of full service do not appear to account for the conflict between leading and following trains at terminals. *The PMOC estimates that, when terminal time is fully considered in operations planning, one peak consist beyond AHJV estimates may be required in each year of full operation.*

None of the simulations documented in AHJV simulation report integrate line operations with terminal turnbacks. Consequently, the PMOC can only speculate how terminal turnbacks will affect peak round trip times delivered on the network. PMOC recommends that the grantee provide a simulation report showing how peak operations with dwells and turnbacks will be delivered in the last year of the proposed O&M contract (2028) or in the design year (2030).

Note: Some documents show a third (and sometimes a fourth) station track at Ala Moana terminal. However, no operations planning document describes any use for the additional tracks.

The March 2012 O&M plan update is silent on the issue concerning times to turn back trains at terminals and potential conflicts between trains arriving and departing terminal stations. These considerations might increase running times, recovery times and peak vehicle requirements.

2.5 Maximum Line Capacity

Line capacity is a function of track configuration, passenger activity, station characteristics, vehicle characteristics (performance and length), and the minimum following distance between trains.

AHJV train control simulations purport to demonstrate a Safe Separation Headway of less than 90 seconds with minimal 20-second dwell times in conformity with grantee specifications.[38] No analysis is specifically provided by the grantee or AHJV showing how terminal turnbacks or dwell times at busy stations affect line throughput and capacity maximums.

AHJV did conduct simulations that it interpreted to indicate that the "**Non-Interference Headway"** with AW2 passenger loads and nominal peak dwell times is "about 133.9 seconds." At headways tighter than 133.9 seconds,[39] commercial velocity is compromised as trains are retarded enroute by conflicts with preceding trains. The grantee sets the "**Minimum Operating**

[38] AHJV Train Control Simulation Report C9M HNL 2X 002 02 February 24, 2011 Page 12
[39] AHJV Train Control Simulation Report C9M HNL 2X 002 02 February 24, 2011 Page 25

Headway" at 115% of the Non-Interference Headway to allow "multiple trains, station stops, normal disturbances, passenger interference, etc." and to "ensure" smooth normal operations without train bunching and unscheduled stopping on the guideway.[40] This works out to 154 seconds during peak operations on the system.

Using the methodology specified in TCRP 100 and TCRP 8 Reports with parameters derived from the AHJV proposal, the PMOC was able to independently estimate the minimum sustainable headway along the line at **89** seconds. This methodology is described in an earlier PMOC report. Parameters employed are listed in Table 20. Note: This headway assumes substantial interference between trains.

Table 20. Minimum Headway Calculation Input Variables

Term	Units	Description	Source	Value
L	meters	length of the longest train	AHJV Spec	78.2
D	meters	distance—front of train to exit block	TCRP Default	10
K	constant	% service braking rate	TCRP Default	75
B *moving block signaling*		train detection uncertainty constant	TCRP Default	1
t_{os}	seconds	overspeed governor operating time	TCRP Default	3
t_{jl}	seconds	time lost to braking jerk limitation	TCRP Default	0.5
a_s	m/s^2	service acceleration rate	AHJV Spec	1.19
d_s	m/s^2	service deceleration rate	AHJV Sped	1.32
t_{br}	seconds	brake system reaction time	TCRP Default	1.5
v_{max}	km/h	maximum line velocity	Grantee Spec	88.5
P_e	meters	Positioning error (moving block only)	TCRP Default	6.25
v_l	%	% of normal line voltage	TCRP Default	90
G	%	Grade into headway critical station	Grantee Spec	0.0
Margin	seconds	Operating Margin	TCRP Default	20
Max Dwell	Seconds	Estimated dwell at busiest non-terminal station	AHJV Calculations	46

The PMOC could not determine whether the terminals pose a more severe headway constraint than 89 seconds. The question of terminal turnback impacts on minimum headways should be explored with the grantee.

Based on the discussion above, it is possible to report several minimum headways for the proposed infrastructure.

[40] HHCTC. TP-3 OPERATIONS & MAINTENANCE PERFORMANCE REQUIREMENTS October 2010 Page 25

Table 21. Minimum Headway Estimates

Headway	Seconds	Comment
Minimum Operating Headway	154	Provides capacity to avoid interference between trains under a range of normal operating conditions
Non Interference Headway	133.9	Theoretical minimum headway avoiding interference between trains
Minimum Sustainable Headway	89	Based on TCRP formulae and PMOC calculations. Presumes substantial interference between trains. Does not consider the possibility of more severe conflicts at terminals

2.6 Maximum Person Capacity

Person capacity is the product of car capacity and line capacity. AHJV proposes to supply cars that will carry 32 seated and 127 standing passengers. The Project is designed to allow trains up to four cars in length for a "Comfort Load" of 636 passengers per train. Based on the minimum headways reviewed above and a peak load factor of 0.9, the maximum unidirectional person capacity of the Project as proposed is summarized in Table 22.

Table 22. Maximum Persons Per Hour Per Direction

Headway	Trains per Hour	Comfort Load per Train	Peak Hour Factor	Hourly Person Capacity
Minimum Operating Headway	23.4	636	0.9	13,381
Non Interference Headway	26.9	636	0.9	15,389
Min Sustainable Headway	40.4	636	0.9	23,153

From a practical perspective, the capacity estimate based on Minimum Operating Headway is the most realistic of the three figures since it provides the most substantial allowance to avoid interference between trains following one another down the line.

Should AHJV chose to operate four-car trains at a rate of 23.4 trains per hour, the service could accommodate up to 50% growth in peak ridership above the design year (2030) forecast peak flow of 8,982[41].

2.7 Staffing

Per the requirements specified in OP 32A, this document also reviews the sufficiency of staffing proposed for the Project. The review summarizes and compares the staffing levels proposed by the grantee's vendor of O&M services (AHJV) with the universe of other "metro" systems operated in the United States. Separate benchmarks are reviewed for vehicle operations, vehicle maintenance, non-vehicle maintenance and administration. Since the 2011 review, the PMOC has had the opportunity to attend a UITP (International Association of Public Transport) seminar on Automated Metros. One session of the seminar was devoted to Operations and Maintenance

[41] Based on 8,084 peak hour passengers adjusted with a PHF of 0.9.

with an emphasis on staffing. This update to the PMOC reflects new insights and information from that seminar.

2.7.1 Grantee Staffing Overview

During the sixth through tenth years of full operation of the system, AHJV proposes to operate the service with a staff of 289 full time employees, supplemented with a subcontracted cleaning force of unspecified size and a variety specialty contract support staff employed on an as-needed basis.

Table 23. AHJV Staffing Summary (2028)

Function	FTEs
AHJV Staff	
Operations	121
Vehicle Maintenance	67
Non Vehicle Maintenance	62
Management and Administration	39
Subtotal	**289**
Cleaning Contractors (PMOC Estimates)	
Vehicles	9.5
Stations and Facilities	22.5
Subtotal	**32**
Grand Total	**321**

2.7.2 Operations

Operations staff will be responsible for train control from the Operations Control Center (OCC) and customer service/vigilance in stations and on board trains. AHJV will assign 35 of the 121 operations staff to the OCC, to be responsible for oversight of train operations, support of the OCC functions, and dissemination of public information. Another 85 members of the operations staff will deliver or manage "steward" services. "*Stewards will … provide customer service to passengers on-board and on station platforms, report errors, defects, failures and irregularities to the control room, provide assistance to the police and fire personnel in case of incidents or emergencies, rescuing and driving trains, if needed, provide monitoring of the cleanliness of trains and stations, open and close stations. Assistance to passengers includes, conflict management and crowd-control.*[42]"

Grantee specifications call for two field functions: service attendants (onboard trains) and station attendants (in stations) with minimum staffing levels for both functions. AHJV has combined the two job functions into a single roving job while adhering to the minimum staffing levels.

The typical heavy rail metro operation uses several more classes of personnel to provide onboard and station services. Operators run each train. (The system is "driverless".) On many systems guards/conductors are responsible for train door operation and onboard announcements. Station attendants/fare collectors are usually responsible for station oversight and fare collection.

[42] AHJV Proposal C9M HNL 00003 2 February 24, 2011 Page 3 – 184

Inspectors rove to provide supervision and respond to emergencies and unusual circumstances as station attendants are often "tied" to their fare collection posts. With the level of automation proposed for the line (driverless trains, automatic fare vending and proof of payment), many of these job functions are superfluous. Most of the remaining functions are combined in the steward's job description, which is roughly analogous to the typical rapid transit inspector.

The assignment of 85 staff to cover and manage steward functions for a network that covers 21 stations is consistent with the staffing practices of other UTO metros for which data are available. Vancouver's SkyTrain deploys 1.2 attendants for every station. The Nuremburg Metro works with a thinner staffing plan of one attendant for every three stations. (In contrast to Vancouver, Nuremberg is also quite new and may find it needs to add stewards to achieve an acceptable level of service.) 85 total staff will not provide the level of coverage provided in Vancouver but it should exceed 0.33 stewards per station.

A staff of 35 at the OCC should provide adequate coverage and oversight averaging seven staff per shift. Vancouver, which has a much more extensive network, deploys nine per shift.

It is notable that neither the grantee's specifications nor AHJV's proposal specifically mention the essential fare inspection/enforcement role that is critical to stem fare evasion with the proof of payment fare regime. Fare inspection/enforcement is not included in the steward's job description. It is implied that fare inspection and enforcement may be handled by the municipal police force. Information concerning the fare inspection/ enforcement process should be developed and supplied by the grantee. It is notable that assistance with the fare control process is integral to the steward job descriptions for UTO systems in Vancouver and Nuremberg.

Table 24. Operations Staffing Benchmarks

State	System	Number of Trains in Operation (Average Weekday)	Annual Train Miles (x1000)	Annual Vehicle Revenue Miles (x1000)	Annual Vehicle Operations Staff Hours	Train Miles per Operating Staff Hour	Revenue Vehicle Miles per Operating Staff Hour
MA	MBTA	58	3,976	22,475	2,209,553	1.80	10.17
NY	NYCT	589	40,266	352,524	20,475,891	1.97	17.22
NJ	PATCO	14	1,064	4,432	157,393	6.77	28.16
NJ	PATH	38	1,840	12,203	868,099	2.12	14.06
NY	SIRR	11	675	2,336	176,704	3.82	13.22
PA	SEPTA	50	3,296	16,887	1,382,599	2.38	12.21
DC	WMATA	131	12,228	71,803	3,727,978	3.28	19.26
MD	MD MTA	9	1,150	5,285	279,147	4.12	18.93
GA	MARTA	33	4,500	24,565	1,904,028	2.36	12.90
FL	Miami Dade	14	1,270	6,691	232,633	5.46	28.76
OH	GCRTA	11	1,125	1,789	174,811	6.44	10.23
IL	CTA	138	12,348	68,592	3,041,751	4.06	22.55
CA	BART	62	9,772	67,843	2,250,024	4.34	30.15
CA	LA MTA	11	1,373	6,077	297,936	4.61	20.40
HI	**HRTP**	**37**	**4,411**	**8,402**	**251,680**	**17.53**	**33.38**

Notwithstanding the omitted revenue protection functions, the proposed staffing of the system heavily leverages the labor saving economies of automatic train operation, modern surveillance technologies and communication tools to field a very lean transport operation. Table 24 benchmarks the proposed staffing levels against the universe of other US heavy rail systems operating on the mainland. Data concerning existing operations are derived from National Transit Database Reports for 2009. Staffing for system is based on the year 2028 staffing plan provided by AHJV. All system staff members were presumed to work 2,080 hours per year.

The system will be the nation's first driverless metro. Owing to a combination of the staffing economies available from automated operations (vehicles and fare vending) and the very short two-car trains proposed by the system, the ratio of train miles to operating staff hours is forecast to be an order of magnitude more favorable than the most labor intensive operations. See Figure 10.

Figure 10. Train Miles per Operating Staff Hour

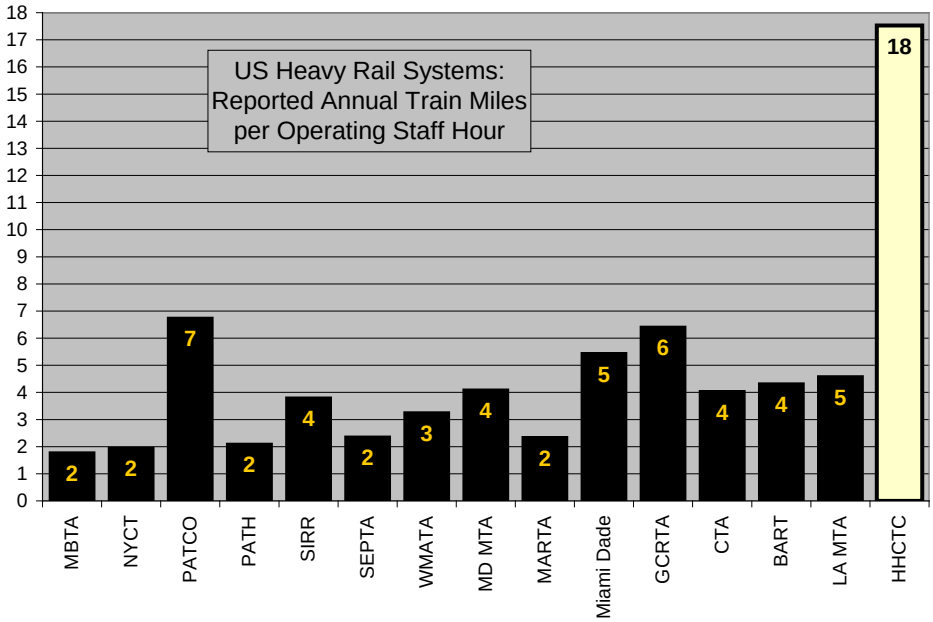
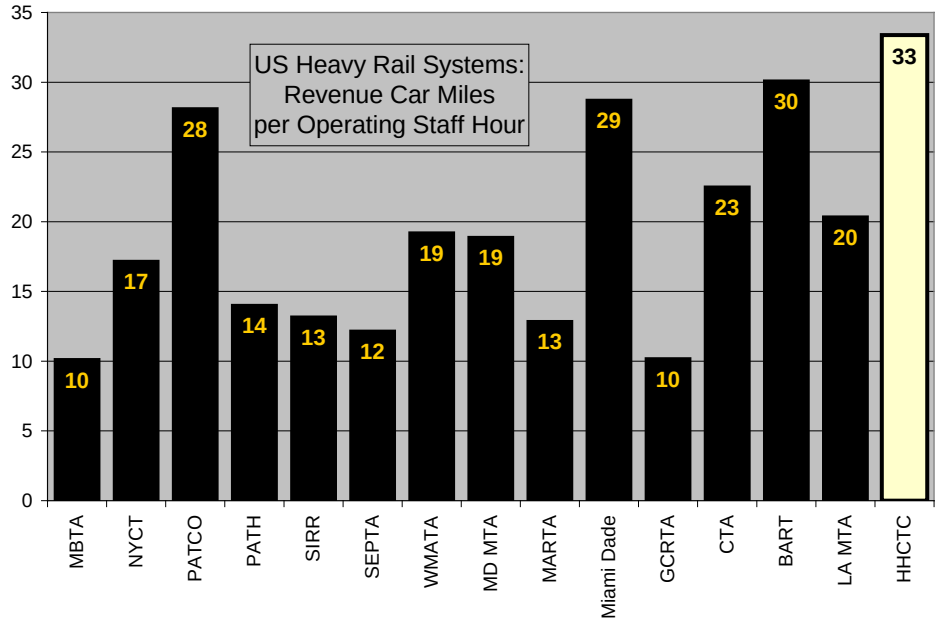


Figure 11 controls for train length by comparing the systems in terms of vehicle miles per staff hour. With this control in place, the comparison between Honolulu system and legacy systems is less stark. The Honolulu system is projected to be comparable to some of the other more heavily automated systems including BART, PATCO, Miami Dade, WMATA and MD MTA.

Figure 11. Vehicle Miles per Operating Staff Hour



When plans and staffing responsible for fare inspection and enforcement are finalized and included in the staffing estimates, it is expected that the benchmark forecasts for system will be reduced but remain favorable. This benchmark could be revisited when the fare enforcement questions are resolved.

2.7.3 Vehicle Maintenance

AHJV proposes a staff of 67.5 directly responsible for maintaining the 80-car fleet. The CSC expects to contract for vehicle cleaning services with an as-yet unidentified firm. Based on review of cleaning contracts and operations for other rapid transit operations, the PMOC estimates that nine (9) managers, supervisors, and cleaners will be employed for vehicle cleaning[43]. This yields an estimated 76.5 staff members assigned to vehicle maintenance and cleaning.

The staff estimates do not include specialty subcontractors and out-sourced services included on AHJV's preliminary list of vehicle maintenance activities that may be sub-contracted[44] including:

- Support Vehicle Maintenance: Service of Cars, Trucks, Forklifts
- Overhaul of Rolling Stock Components & Assemblies
- Vehicle Glass Replacement

[43] Jacobs Engineering, Management Audit of Contract Cleaning Services, prepared for Massachusetts Bay Transportation Authority, Boston, MA 2007

[44] AHJV Proposal C9M HNL 00003 2 February 24, 2011 Page 3 – 275

Component overhauls and support vehicle maintenance are commonly outsourced, especially at smaller and newer systems. The PMOC is not aware of any rail transit operation that makes special arrangements for vehicle glass replacement.

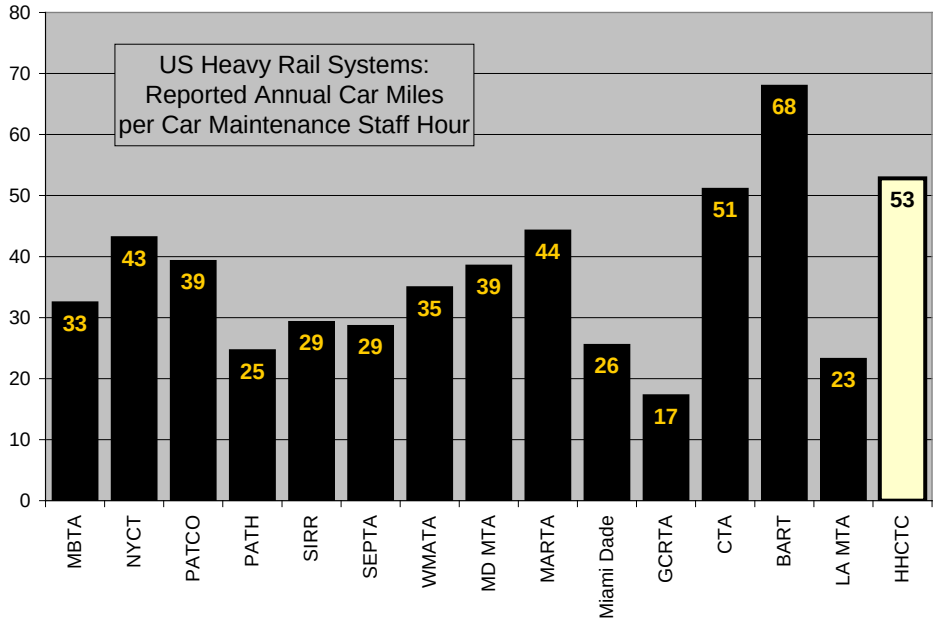
Compared with US rapid transit properties, this represents an ambitious, but potentially achievable maintenance staffing program. Table 25 benchmarks that Honolulu system against mainland metro operations.

Table 25. Vehicle Maintenance Staffing Benchmarks

State	System	Vehicles in Maximum Service	Total Fleet	Annual Revenue Vehicle Miles (x1000)	Annual Vehicle Maintenance Staff Hours	Vehicle Miles per Maint. Hour	Thousands of Maintenance Hours per Fleet Vehicle	Thousands of Maintenance Hours per Peak Vehicle
MA	MBTA	334	440	22,475.0	690,567.0	32.55	1.57	2.07
NY	NYCT	5,388	6,317	352,524.6	8,155,918.0	43.22	1.29	1.51
NJ	PATCO	84	96	4,432.5	112,732.0	39.32	1.17	1.34
NJ	PATH	266	383	12,203.0	493,961.0	24.70	1.29	1.86
NY	SIRR	46	63	2,336.8	79,672.0	29.33	1.26	1.73
PA	SEPTA	278	369	16,887.3	588,504.0	28.70	1.59	2.12
DC	WMATA	850	1,128	71,803.3	2,050,283.0	35.02	1.82	2.41
MD	MD MTA	54	100	5,285.4	137,028.0	38.57	1.37	2.54
GA	MARTA	182	338	24,565.8	554,317.0	44.32	1.64	3.05
FL	Miami Dade	84	130	6,691.5	261,554.0	25.58	2.01	3.11
OH	GCRTA	22	60	1,789.0	103,338.0	17.31	1.72	4.70
IL	CTA	1,002	1,190	68,592.2	1,341,169.0	51.14	1.13	1.34
CA	BART	534	669	67,843.1	996,934.0	68.05	1.49	1.87
CA	LA MTA	70	104	6,077.7	261,111.0	23.28	2.51	3.73
HI	**HRTP**	**74**	**86**	**8,402.2**	**159,120.0**	**52.80**	**1.85**	**2.15**

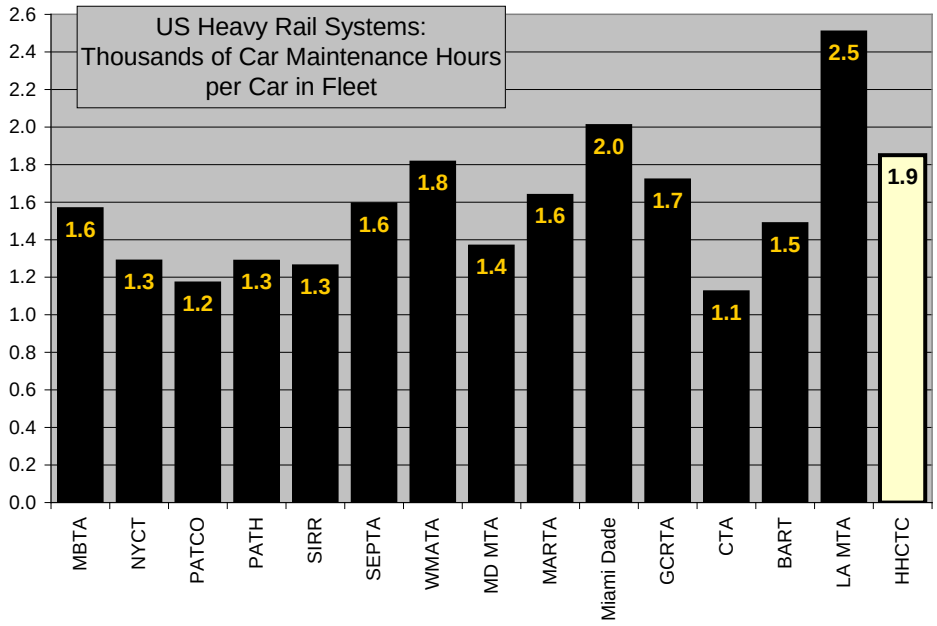
AHJV expects to be among the most efficient US rapid transit car maintenance operations, getting 53 miles of car operation per hour of maintenance and cleaning services. This level of performance is comparable to Chicago's CTA and the Bay Area's BART system.

Figure 12. Car Miles per Car Maintenance Staff Hour



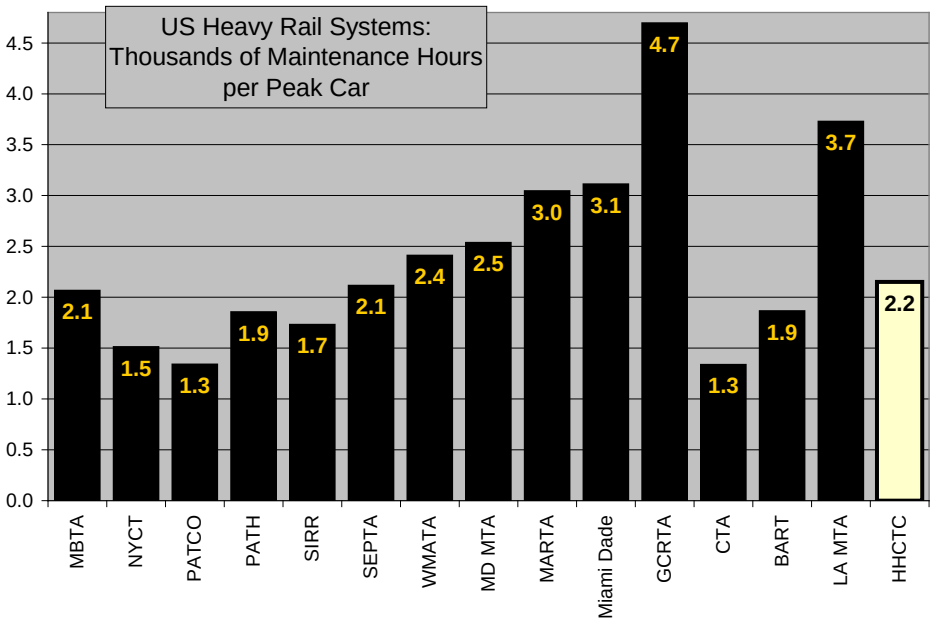
Some of AHJV's planned efficiency for the system reflects a "right sized fleet" with a minimum of number of vehicles requiring periodic maintenance and inspection. Figure 13 shows that AHJV actually plans to deliver more maintenance staff hours per vehicle in the fleet than most US heavy rail properties.

Figure 13. Maintenance Staff Hours per Fleet Vehicle



When maintenance hours per peak vehicle are benchmarked, the system falls near the industry norm. PATCO and CTA are the industry leaders, closely followed by NYCT. Cleveland and Los Angeles are unfavorable outliers (See Figure 14).

Figure 14. Maintenance Hours per Peak Vehicle



At this stage in the project development process, the PMOC is satisfied with grantee's proposed car maintenance staffing levels.

2.7.4 Infrastructure Maintenance

AHJV proposes 62.5 staff members directly responsible for maintaining the 20-mile, 21-station infrastructure network necessary to operate the system. The CSC expects to contract for station and facilities cleaning services. AHJV envisions four teams of station cleaners and a special projects cleaning team. Based on review of cleaning contracts and operations for other rapid transit operations, the PMOC estimates that 22 managers, supervisors and cleaners will be employed to clean stations, parking lots and other facilities. This yields an estimated staff of 84.5 assigned to infrastructure maintenance and cleaning.

The staff estimates do not include specialty subcontractors and out-sourced services included on AHJV's preliminary list of infrastructure maintenance activities that may be sub-contracted,[45] including:

- Heavy Track Maintenance: Possible expertise support from track maintenance companies
- Rail Grinding
- Geometrical Survey: Gauging, vertical and horizontal alignment
- Rail Welding
- Maintenance of Lifts, Escalators and other safety related devices such as cranes and fire alarm system in the Maintenance and Storage Facility (MSF)
- Maintenance of MSF Specialized Equipment (e.g. Wheel Truing Machine, Under floor Lifts)

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- MSF Facility's maintenance, such as emptying and cleaning of water treatment tanks, painting
- Specialist Civil Works Inspections and Maintenance

Most of these functions are commonly outsourced, especially at smaller and newer systems. Systems with extensive investment in vertical circulation equipment have tended to find that in-sourcing escalator and elevator maintenance produces superior system availability and higher customer satisfaction. With large numbers of elevators and escalators, in house maintenance can also be more cost effective. Given the lack of other rail systems on Oahu, it is possible that the grantee may find that the use of specialty rail firms for functions such as welding, grinding and testing may not be as cost effective as it is on the mainland.

Compared with other US rapid transit properties, the grantee's infrastructure staffing plans are very ambitious, especially given the proposed hours of operation. With 20 hours of service each weekday and a patrol train required each day before the start of service, it may be especially difficult to reconcile system availability goals with track outages required for some maintenance operations. Additional staff may be necessary to provide the resources for high levels of availability over the long haul. With the passage of time, the O&M contractor (and the grantee) may realize that it has underestimated the magnitude of the infrastructure maintenance workload. Table 26 benchmarks the Honolulu system against mainland metro operations.

Table 26. Infrastructure Maintenance Staffing Benchmarks

State	System	Directional Route Miles	Total Track Miles	Annual Non Vehicle Maintenance Staff Hours	Thousands of Maintenance Staff Hours per Directional Route Mile	Thousands of Maintenance Staff Hours per Track Mile
MA	MBTA	76.3	108.0	1,276,822	16.73	11.82
NY	NYCT	493.8	829.9	15,194,468	30.77	18.31
NJ	PATCO	31.5	38.4	197,850	6.28	5.15
NJ	PATH	28.6	43.1	807,838	28.25	18.74
NY	SIRR	28.6	32.7	174,199	6.09	5.33
PA	SEPTA	74.9	99.8	612,602	8.18	6.14
DC	WMATA	211.8	269.8	3,201,928	15.12	11.87
MD	MD MTA	29.4	34.0	284,868	9.69	8.38
GA	MARTA	96.1	103.7	987,486	10.28	9.52
FL	Miami Dade	45.0	55.9	437,269	9.71	7.82
OH	GCRTA	38.1	41.9	185,786	4.88	4.43
IL	CTA	207.8	287.8	1,647,338	7.93	5.72
CA	BART	209.0	267.6	1,283,648	6.14	4.80
CA	LA MTA	31.9	34.1	301,337	9.45	8.84
HI	**HRTP**	**39.9**	**45.6**	**175,760**	**4.40**	**3.86**

Figure 15 illustrates how AHJV's infrastructure staffing plans call for it to be the most parsimonious of all US rapid transit operations. This may be unrealistic in the long run, especially in light of the system's high reliance on precision automation tools to replace operating manpower.

Figure 15. Thousands of Infrastructure Maintenance Hours per Route Mile

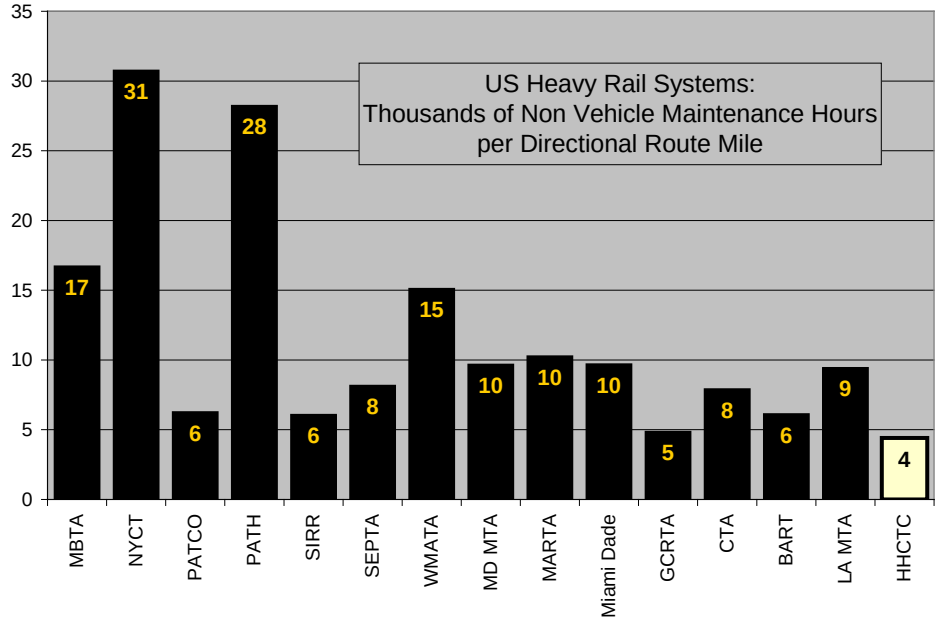
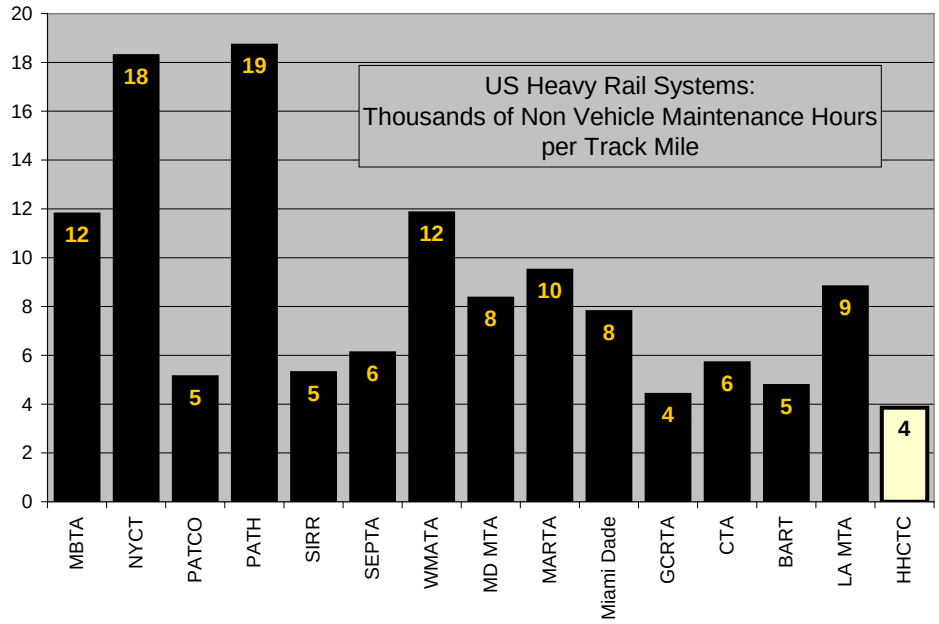


Figure 16 reinforces the suspicion that AHJV and the grantee may be underestimating the maintenance workload required to sustain the system infrastructure and operation.

Figure 16. Thousands of Infrastructure Maintenance Hours per Track Mile



The PMOC suggests that the grantee may wish to review infrastructure maintenance staffing assumptions with AHJV to ensure that expectations are realistically aligned with service availability and customer service goals.

Information relayed at the recent (March 2012) UITP Seminar on Automated Metros echoes the infrastructure maintenance staffing concerns noted above. Seminar participants responsible for operating many of the world's 41 existing UTO lines generally agreed that maintenance needed to be more intense on a UTO system because the system relies on machines to do jobs that had been traditionally done by staff. Quotes from the seminar include:

- "Maintenance must be very robust"
- "UTO allows you to save on operations but you need to spend a little more for maintenance"
- "With UTO, maintenance is more critical because it takes time to get a qualified person on site to troubleshoot."
- "Eventually all of operations will be maintenance"
- "With very short headways a larger fraction of physical wayside work needs to done overnight because it can't be done under traffic."

2.7.5 Management and Administration

AHJV proposes a staff of 39 responsible for management and administration of the O&M contract.

Table 27. O&M Management and Administration Staffing

Function	Staff
General Management	3
Safety and Security	4
Safety, Quality Assurance and Environment	4
Human Resources	6
Customer Service	6
Public Relations	1
Finance	8
Engineering	3
Information Technology	4
Total	**39**

The proposed organization chart is confusing in one detail: Two sub-departments are identified as responsible for Safety. AHJV and the grantee may wish to revisit the organization structure to eliminate the potential for confusion, rivalry, overlap, and duplicative effort concerning this critical dimension of service provision.

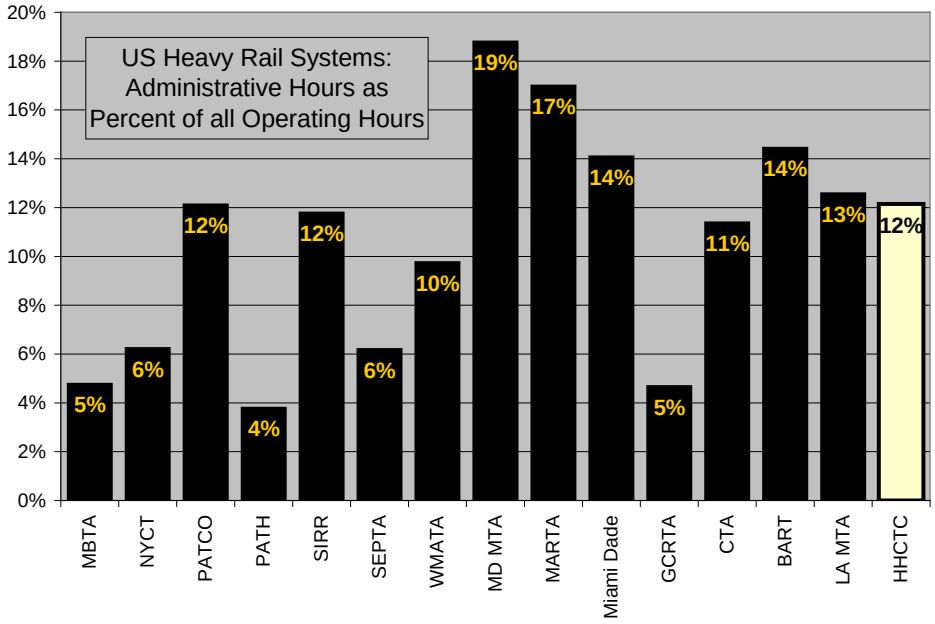
AHJV's proposal indicates that it is considering outsourcing two administrative functions: Maintenance of information technology hardware, and security at the maintenance and storage facility. These functions are routinely outsourced by transit agencies.

The grantee's specifications imply that the grantee will be responsible for crime fighting and fare enforcement on the system. Staffing levels for these functions are not identified in the grantee's plans. The grantee should not underestimate the staffing and diligence necessary to administer an effective fare evasion prevention program.

The grantee and AHJV plan to share revenue management responsibilities in a relatively unique and potentially awkward way. Grantee forces will service the TVMs, lifting cash and replenishing ticket stock. AHJV will be responsible for TVM maintenance and repair. AHJV will be responsible for preparing revenue reports from the TVM system. The grantee will hold and deposit all revenue. The parties should obviously pay close attention to the process of coordinating revenue processing and accounting functions to avoid embarrassing opportunities for leakage and resultant finger pointing.

Notwithstanding the omission of passenger security and revenue management from the administrative functions, the aggregate level of staffing planned for management and administration seems reasonable in comparison with peer agencies, as shown in Figure 17. Approximately 12% of the staff and full time contractors to be hired by AHJV will be responsible for management and administrative functions. This is generally in line with other US rapid transit properties. It is especially notable that AHJV's 12% is quite close to its two closest peers, BART and PATCO, which are also uni-modal "rail-only" transit operations. Most other peers are generally part of much larger transportation agencies that generally run related bus operations. (Although RTD runs Honolulu's The Bus operation, the grantee will not be involved in that mode of transportation.) The larger multi-modal agencies tend to enjoy economies of scale that are not available to smaller and single-mode operations.

Figure 17. Administrative Staff as Percent of Total Staff



2.7.6 Key Findings and Recommendations

Operations - With 121 full time staff, AHJV plans to heavily leverage the labor saving economies of automatic driverless train operation, ticket vending machines, modern surveillance technologies, and communication tools to field a very lean transport operation. One oversight of no small concern is the failure to mention the essential fare enforcement role that is critical to stem fare evasion. When plans and staffing responsible for fare inspection and enforcement are

finalized and included in the staffing estimates, it is expected that the forecast staffing benchmarks for system will be reduced but remain favorable. This benchmark could be revisited when the fare enforcement questions are resolved. It is notable that assistance with the fare control process is integral to the steward job descriptions for UTO systems in Vancouver and Nuremberg.

The assignment of 85 staff to cover and manage steward functions for a network that covers 21 stations is consistent with the staffing practices of other UTO metros for which data are available. A staff of 35 at the OCC should provide adequate coverage and oversight averaging seven staff per shift. Vancouver, with a more extensive network, deploys nine per shift.

Vehicle Maintenance - AHJV proposes 67.5 staff members directly responsible for maintaining the 86 car fleet. The PMOC estimates another nine (9) managers will be employed for vehicle cleaning, for a total staff of 76.5 assigned to vehicle maintenance and cleaning. Comparing this with mainland rapid transit operations, the PMOC is satisfied with grantee's proposed car maintenance staffing levels at this stage in the project development process.

Infrastructure Maintenance - Including cleaning contractors, the PMOC estimates that 84.5 staff members will be assigned to infrastructure maintenance and cleaning. Compared with other US rapid transit properties, the infrastructure staffing plans are very ambitious. With the passage of time, the O&M contractor (and the grantee) may realize that it has underestimated the magnitude of the infrastructure maintenance workload. The PMOC suggests that the grantee review infrastructure maintenance staffing assumptions with AHJV to ensure that expectations are realistically aligned with service availability and customer service goals.

Management and Administration - AHJV proposes a staff of 39 for management and administration of the O&M contract. The proposed organization chart is confusing in one detail. Two sub-departments are identified as responsible for Safety. AHJV and the grantee may wish to revisit the organization structure to eliminate the potential for confusion concerning this critical dimension of service.

The grantee's specifications imply that the grantee will be responsible for crime fighting and fare enforcement. Staffing levels for that function are not identified in the grantee's plans. The grantee should not underestimate the staffing and diligence necessary to administer an effective fare-evasion prevention program.

The grantee and AHJV plan to share revenue management responsibilities in a relatively unique and potentially awkward way. The parties should closely coordinate shared revenue processing and accounting functions to avoid embarrassing opportunities for leakage and resultant finger pointing.

Notwithstanding the omission of passenger security and revenue management from the administrative functions, the aggregate level of staffing planned for management and administration seems reasonable in comparison with peer agencies. Approximately 12% of the staff and full time contractors to be hired by AHJV will be responsible for management and administrative functions. This is generally in line with other transit systems.

2.8 Other Capacity Topics

FTA's OP 32A guidance raises a number of other transit capacity topics, not all of which are discussed in detail within this report. Although some of these topics are not applicable to this Project, beyond the purview of the PMOC, or applicable only to other project phases, this report section attempts to address them.

2.8.1 Capital versus Operating Cost and Service Trade-offs

Federal Guidance

Assess long-term vs. short-term capital and operating cost and service trade-offs inherent in capacity choices.

Findings

The grantee's decision regarding trade-offs between capital costs and operating costs and level-of-service was made early in the project, when the grantee decided to proceed with design of a grade-separated, rail-on-rail, driverless system. In making that decision, the grantee assured that the finished project would not be subject to the same traffic problems that it was attempting to alleviate, as sometimes happens in lesser-cost capital programs. That decision being well thought out and firmly entrenched in the environmental documents, it is no longer subject to discussion.

The grantee has also made a long-term capital cost investment in building platforms that are already long enough for the eventual use of four-car trains, thus assuring capacity beyond its currently-projected needs.

2.8.2 Impact upon the Capacity of the Existing Transit System

Federal Guidance

If the project will become part of an existing transit system, assess the project's impact upon the capacity of the existing transit system, for example, will the project boost the carrying capacity of the entire system, overload the system or create bottlenecks. Consider whether the grantee can build, operate, and maintain its entire system without reducing existing public transportation services or level of service to operate the proposed project. Consider the grantee's financial and staffing capabilities to operate and maintain the project in addition to its existing system.

Findings

Since this is the first rail system to be implemented by the grantee, there are no adverse effects on the "existing transit system," which consists only of rubber tired road vehicles (buses and paratransit services). The rail line will actually boost the capacity of the bus network by providing express service along the service network's main east-west trunk. The project is not causing any physical obstacles to the grantee's ability to maintain or even expand its bus system.

Staffing capabilities to operate and maintain the project are the subject of Section 3.6 ("Staffing") of this report.

The grantee's financial capabilities are more properly the subject of the FMOC's oversight. While the PMOC does not know of any reason to doubt the grantee's financial strength, it nevertheless defers to the FMOC's judgment in those matters.

2.8.3 Guideway Route and Station Design

Federal Guidance

The PMOC shall gain an understanding of the following with respect to the project:

- *Route information*
  - *Selection*
  - *Route and station coordination for ease of transferring among passenger transport agencies*
  - *Requests and requirements by customers, public officials, other departments, or the general public*
  - *Paratransit operations*
- *Schedule and Staffing*
  - *Headways*
  - *Schedule adherence*
    - *During construction*
    - *During full revenue service*
    - *Due to weather-related emergencies and other unexpected occurrences*
    - *Sufficiency of staffing*
    - *Sufficiency of funding for operations considering agency finances*
- *Station design*
  - *Pedestrian access from public way; intermodalism or connectivity with other passenger transport*
  - *Fire exiting design criteria for public areas, platforms, and stairways*
  - *Capacity of escalators, elevators, stairs,*
  - *Dimensional and clearance requirements of ADA*

The PMOC shall evaluate grantee's documentation for route information, schedule and staffing for proposed operations and station design.

Findings

The selection of the route was essentially complete, except for a couple of later adjustments, at the end of Alternatives Analysis. The PMOC has certainly made itself aware of most of the route's features, which are described in Chapter 2. Section 3.3 of this report discusses the issues of the scheduling of trains and headways and Section 3.6 deals with staffing. While issues with station design have been and will continue to be a constant subject of PMOC scrutiny, they are not addressed in this report, since the stations are not expected to be a controlling factor in this project's transit capacity. If

constraints to capacity become apparent as station designs progress, they will be addressed by the grantee and its designers, with oversight provided by the PMOC.

2.8.4 Maintenance Infrastructure

Federal Guidance

The PMOC's evaluation shall include capacity of the project's maintenance infrastructure (as-built) such as shops, yards, secondary maintenance, component rebuilds or capital inventory requirements using a structured and methodical approach that makes maximum use of previous TRB work and other existing engineering data.

Findings

In the course of its ongoing Project reviews, PMOC has given consideration to the MSF complex and found it to be reasonably sized and efficiently organized. The MSF and the CSC are now under contract. However, there is a potential that the currently planned MSF configuration may undergo some changes as the DB and DBOM contracts move into Final Design. The CSC has, for example, expressed its desire to convert some of the yard to unmanned operations, which will likely lead to other changes in the complex. In short, PMOC expects the DB and DBOM contractors, who have the contractual responsibility to do so, to address and resolve shop, yard, and maintenance issues as they arise.

2.8.5 Build Out Approach

Federal Guidance

Assess for cost effectiveness the proposed "build out" approach for the transit project given the revenue operations date, and the 20-year, 50-year, and 100-year horizons. Recommendations should account for the time value of money as well as the costs associated with various construction approaches.

Findings

The PMOC has not received much information on the grantee's proposed build out approach beyond the current project. It is known that the grantee intends to eventually extend the rail system to Kapolei on the 'Ewa end and to UH Manoa and Waikiki on the Koko Head end, although neither the routing nor the mode for those extensions has been finalized. The Stations VE team and the PMOC offered suggestions in how the grantee could reconfigure its Ala Moana Station to allow more flexibility in design for the UH Manoa and Waikiki extensions, but the grantee will not pursue that idea further until grantee Center Segment designers are under contract.

PMOC would prefer that at least the two high demand Koko Head extensions be given consideration at this time, but understands the grantee's plans to postpone them, likely to at least the 20-year horizon. Any planned build out beyond those discussed would likely fall into the 50-year or 100-year horizon.

2.9 Conclusion and Recommendations

The PMOC recommends that HART issue an updated O&M plan after the current draft plan has been reviewed and validated by AHJV. The PMOC suggests a joint HART/AHJV review of the O&M plan where the partners address the several discrepancies and oversights that have concerned the PMOC since the Fall of 2011. Addressing these concerns should strengthen and improve this valuable and important project.

PMOC looks forward to reviewing a revised O&M plan that addresses concerns relative to car capacity and seating; minimum headways, dwell times with platform screen gates, times to turn back trains at terminals, and staffing and management plans for infrastructure maintenance, fare control, revenue processing, and safety management.

2.9.1 Car Capacity

The newest update to the O&M does not address the PMOC's previous concerns about car capacity. The grantee's peak hour capacity specifications, as stipulated to vendors, fall considerably short of the capacity that had been contemplated and discussed when the 2009 Fleet Sizing Report was prepared. The hourly passenger capacities specified by the grantee were calculated in a manner that eliminated virtually all capacity for peak-of-the-peak surges in ridership. AHJV's proposal to offer service with an annually increasing frequency in response to annually increasing peak demand is very attractive until it is realized that the proposed frequency is not supported by the proposed train control system. Close inspection of the pattern of boardings and alighting raises concerns regarding passenger trip duration and comfort standards.

- Despite assurances to the contrary, the operating plan provides no capacity for any surge in peak ridership after the fifth year of operations and falls well short of the surge that would have been accommodated by the 2009 Fleet Sizing Report. The level of forecast peak crowding fails to meet AHJV's stated standards but lies within a range that is generally considered acceptable for peak rapid transit passenger comfort for a typical rapid transit system.

- AHJV's proposal to provide required capacity for 2026 and subsequent years calls for it to operate service at less than its reported minimum operating headway. Since the minimum headway includes a 15% cushion above the non-interference headway, it is possible that service could be operated without degradation on some days. But on many days service would be degraded with longer trip times and more uneven service than had been specified as acceptable.

- The PMOC's final car capacity concern is more qualitative. When fully operational, the Project is forecast to carry some of the longest average passenger trips of any US rapid transit system. The vehicles planned for the service do not seem to offer a degree of comfort suitable for the journey length. Thus, while the capacity of the proposed system falls within the average range for typical rapid transit systems, it falls well short of the seating capacity offered by the transit lines that carry passengers for journeys of similar length and duration. The expectation that passengers in Honolulu would be willing to endure such long trips standing on crowded trains may not be realistic. Significant

fractions of the forecast ridership base may chose to avoid the system under such conditions. Further analyses by the PMOC in this area indicate that crowded conditions where standees greatly outnumber seated passengers will persist during most hours of the day.

It is recommended that the grantee and AHJV confer regarding plans to operate at frequencies that violate the minimum operating headway. A possible response would be to offer service with longer trains operating at four-minute headways. The change in overall fleet size necessary to operate with three-car trains at slightly longer headways should be negligible. The fleet would also include a number of presumably less expensive middle cars and the level of comfort (seats/passenger) afforded passengers that are not riding in the peak of the peak would be increased. Operating at four-minute peak headways would also provide more capacity for surges in demand during the first several years of the contract. Changes in the proposed consist size may, however, require modification to the vehicle order if some middle cars would have to be substituted for an equivalent number of end cars in the final contract.

2.9.2 Dwell Times

In the aggregate, HART and the PMOC agree on estimated dwell times for peak trips. However, it is understood that HART has decided to add platform screen gates to the Project. AHJV and HART should review how this addition may impact the time for door operation and the possible cascade impacts on overall running times and car requirements

2.9.3 Round Trip Time and Terminal Turnback Time

Estimates of station-to-station running times vary among the AHJV's O&M proposal, vehicle performance simulations, and train control simulations reviewed in 2011. HART should be congratulated for using the most conservative estimates in its O&M plan. The combination of running time and forecast dwell times necessary for the operation of doors and service of peak passengers sums to 88:58. HART's O&M plan calls for a round trip time of 89:36. This allows only 38 seconds over a run of 5,376 seconds (0.7%) for unforeseen events. This seems like a small cushion. But with automated operations where movements are scheduled and controlled to the second it is conceivable that this small allowance might be sufficient to avoid cascading delays if not for the PMOC's concerns about turnback time at the both ends of the line.

AHJV's Train Control Simulation Report illustrates that, at headways of less than 240 seconds the following train behind any train turning at either terminal presents a conflict for its turning leader until the second train arrives at the terminal. Operationally, this sets the minimum turn time at terminal stations to a value roughly equivalent to the prevailing service headway. This margin of time is much greater than had been considered in the O&M proposal and its resulting fleet size estimates. None of the simulations documented in the AHJV simulation reports integrate line operations with terminal turnbacks. Moreover, the PMOC has found no evidence that the timing and sequencing of turnbacks at terminal stations were considered in making fleet size calculations. HART's O&M plan must show how the time required to turn back trains without retarding other revenue trains was factored into fleet size calculations.

For capacity planning purposes, PMOC recommends that the grantee and AHJV prepare a simulation report showing how peak operations with dwells and turnbacks will be delivered in the last year of the proposed O&M contract (2028) or the design year (2030).

2.9.4 Maximum Line and Person Capacity

The Minimum Operating Headway of 154 or 155 seconds represents the most frequent service that could be reliably offered within the grantee's 45-minute end-to-end travel time goals. A four-car train is the longest consist that can be accommodated by the station design. Using a Comfort Load capacity of 32 seated and 127 standing passengers and the grantee-specified Peak Hour Factor of 0.9, the maximum person capacity of the system is 13,381. This provides for 50% growth over the design-year peak flow of 8,982 passengers. Once 50% growth in peak ridership has been reached, it will likely be necessary for the grantee to extend station platforms to accept longer trains.

2.9.5 Staffing Capacity

The staffing review found areas of concern with respect to fare enforcement, infrastructure maintenance staffing, safety management, and revenue processing. It also suggests that further benchmarking of operations relative to the universe of 25 established driverless metros operating in locations such as Denmark, Canada, France, Japan, Malaysia, and Singapore may be warranted. The PMOC was able to assemble some international information benchmarking in March 2012 and plans to assemble further information from systems in Denmark and France in May 2012.

2.9.6 Final Observations

- The Project meets its stated purposes and goals, to provide safe and reliable transit service to the Honolulu community.
- The project is both "right-sized" and justifiable in its choice of technology.
- The project has rightly taken advantage of its substantial scale as evidenced by its obtaining bids that are favorable in relation to expectations.
- By locking in operating and maintenance costs with the CSC and by using a driverless vehicle, the grantee has assured reasonable operating and maintenance costs.
- Rebuild costs could be another issue, as the track structure would be difficult to replace under traffic.
- The grantee needs to resolve a number of issues with its Car Builder/Systems Designer and Builder/Operator, the CSC, particularly as they relate to
    - Seating capacity
    - Train Headways in the Peak Period and the Maximum Operating Headway
    - 2-car versus 3-car or 4-car trains
    - Possible substitution of M-cars (middle cars) for some of the E-cars (end cars) in the vehicle order
    - Terminal operations and efficient turnbacks.
    - Adequacy of maintenance staffing.

APPENDICES

Appendix A: List of Acronyms

A	Amperes
AC	Alternating Current
AHJV	Ansaldo Honolulu Joint Venture
APTA	American Public Transportation Association
ATC	Automatic Train Control
ATO	Automatic Train Operation
BAFO	Best and Final Offers
CC	Community College
CSC	Core Systems Contract
DB	Design-Build
DBOM	Design-Build-Operate-Maintain
DC	Direct Current
FEIS	Final Environmental Impact Statement
FFGA	Full Funding Grant Agreement
ft	Foot
FTA	Federal Transit Administration
GBS	Gap Breaker Station
HART	Honolulu Authority for Rapid Transportation
HHCTCP	Honolulu High-Capacity Transit Corridor Project
HRTP	Honolulu Rail Transit Project
Kw	Kilowatt
LV	Low Voltage
mph	Miles Per Hour
mphps	Miles Per Hour Per Second
MSF	Maintenance and Storage Facility
NGD	Negative Grounding Device
O&M	Operations and Maintenance
OCC	Operations Control Center
OP	Oversight Procedure
PHF	Peak Hour Factor
PMOC	Project Management Oversight Contractor
PMP	Project Management Plan
pphpd	Passengers per hour per direction
RFMP	Rail Fleet Management Plan
RFP	Request for Proposals
rms	Root mean square
RSD	Revenue Service Date
s	second
TCRP	Transit Cooperative Research Program
TP	Technical Provision
TPSS	Traction Power Substation
TRB	Transportation Research Board
TVM	Ticket Vending Machine
UITP	International Association of Public Transport
UP	Uninterruptible Power
UTO	Unattended Train Operation
V	Volt
VDC	Volts, Direct Current

Appendix B: Documents Reviewed

Document	Rev. No.	Date
Management Plans/Administrative		
Final Environmental Impact Statement (FEIS)	-	25-Jun-10
Programmatic Agreement (PA)	-	18-Jan-11
Record of Decision (ROD)	-	18-Jan-11
Project Management Plan (PMP)	5.0	29-Jun-12
Quality Management Plan (QMP)	1	05-Feb-12
Real Estate Acquisition and Management Plan (RAMP)	5	31-Jan-12
Bus Fleet Management Plan (BFMP)	3	Mar-12
Rail Fleet Management Plan (RFMP)	0.1	Mar-12
Safety and Security Management Plan (SSMP)	3A	28-Feb-12
Safety and Security Certification Plan (SSCP)	2A	01-Mar-12
Configuration Management Plan	0.2	07-eb-12
Staffing and Succession Plan	5	25-May-12
Operating Plan	0.2	29-Jun-12
Force Account Plan	0.3	05-Jan-12
Mitigation Monitoring Program	0	15-Mar-12
Interface Management Plan	0.1	17-Jan-12
Risk Contingency Management Plan	0	29-Jun-12
Contract Packaging Plan	3	30-Mar-12
Claims Avoidance Plan	0.1	24-Jan-12
Construction Management Plan (CMP)	0.1	03-Feb-12
Contract Resident Engineer Manuals (DB & DBOM)	0.1	Feb-12
Contract Resident Engineer Manual (DBB)	A	15-Feb-12
1.PP-01 – Procedures Index	0	15-Mar-12
1.PP-02 – Procedure Development Process	0.1	12-Mar-12
1.PP-03 – Standard Terms, definitions, and Acronyms	0.1	12-Mar-12
1.PP-04– Baseline Documents Revision and Control	0.1	12-Mar-12
1.PP-05 – Identification of Badge Policy	0.1	15-Mar-12
2.PA-01 – Security Sensitive Information (SSI)	0.1	12-Mar-12
2.PA-02 – Procurement Control	0.1	12-Mar-12
2.PA-03 – Email Management	0.1	12-Mar-12
2.PA- 04- Project Wide Document Control	0.1	12-Mar-12
2.PA-05 – Project Library	0.1	12-Mar-12
2.PA-06 – Community Relations and Media Contacts	0.1	12-Mar-12
2.PA-07 – RTD Training Procedure	0.1	12-Mar-12
2.PA-08 – Policy for Safeguarding Protected Information	0.1	12-Mar-12
2.PA-09 – Permit Procedures	0	15-May-12
3.PM-01 – Contract Management System	1.1	14-Mar-12
3.PM-04 – Public Information Communication	0.1	15-Mar-12
3.PM-05 Meeting/Minutes	2.1	12-Mar-12
4.PC-02 – Project Management Control	0.1	15-Mar-12
4.PC-03 – Project Progress Reports	0.1	15-Mar-12
4.PC-04 – Program Scheduling	0.1	15-Mar-12
4.PC-05 – Project Accounting	0.1	12-Mar-12
4.PC-06 – Cost Estimating	0.1	12-Mar-12
4.PC-07 – Cost Control	0.1	12-Mar-12
4.PC-08 – Risk Management	0.1	12-Mar-12
4.PC-09 – Contingency Management	1	15-Mar-12
5.CA-01 – Contract Administration	0.1	15-Mar-12
5.CA-02 – Contract Change Management	0.1	14-Mar-12

Document	Rev. No.	Date
5.CA-03 – Contractor Progress Payments	0.1	13-Mar-12
5.CA-04 – Contractor Progress Reports	0.1	13-Mar-12
5.CA-05 – Contract Change Orders	0.1	13-Mar-12
5.CA-06 – Contract Closeout	0.1	13-Mar-12
5.CA-07 – Claims and Disputes Resolution	0.2	14-Mar-12
5.CA-08 – CACO and Contract Amendment Procedure	0	14-Mar-12
6.CM-01 – Submittal Procedure	1.1	14-Mar-12
6.CM-02 – RFI Procedure	2.1	14-Mar-12
6.CM-03 – RFC Procedure	0.2	14-Mar-12
6.CM-05 – Interface Management and Coordination Procedure	0.1	12-Mar-12
7.GA-01 – Board – Staff Interaction	0	17-July-11
7.GA-04 – Petty Cash Fund	0	17-July-11
7.GA-06 - Travel	0	17-July-11
7.GA-07 – Preparation of Board Materials	0	20-July-11
Technical		
Design Criteria		
Chapter 1 – General		15-Mar-12
Chapter 2 – Operations		15-Mar-12
Chapter 3 – Environmental Considerations		15-Mar-12
Chapter 4 – Track Alignment and Vehicle Clearances		14-Feb-12
Chapter 5 – Trackwork		15-Mar-12
Chapter 6 – Civil		15-Mar-12
Chapter 7 – Traffic		15-Mar-12
Chapter 8 – Utilities		15-Mar-12
Chapter 9 – Structural		15-Mar-12
Chapter 10 – Architecture		10-Feb-12
Chapter 11 – Landscape Architecture		15-Mar-12
Chapter 12 – Passenger Vehicles		10-Feb-12
Chapter 13 – Traction Electrification		15-Mar-12
Chapter 14 – Train Control		15-Mar-12
Chapter 15 – Communications and Control		15-Mar-12
Chapter 16 – Fare Vending		15-Mar-12
Chapter 17 – Corrosion Control		15-Mar-12
Chapter 18 – Maintenance & Storage Facilities (MSF)		14-Feb-12
Chapter 19 – Facilities Mechanical		15-Mar-12
Chapter 20 – Facilities Electrical		15-Mar-12
Chapter 21 – Fire and Intrusion Alarm Systems		15-Mar-12
Chapter 22 – Elevators and Escalators		15-Mar-12
Chapter 23 – Fire/Life Safety		15-Mar-12
Chapter 24 – Systems Assurance		10-Feb-12
Chapter 25 – System Safety and Security		15-Mar-12
Chapter 26 – Sustainability		14-Feb-12
HART Directive Drawings		3-Nov-10
HRTP Standard Specifications		15-Feb-12
West Oahu/Farrington Station Highway Final Design Drawings		Various
Geotechnical Data Report (WOFH)		27-Mar-09
Supplement to Geotechnical Data Report (WOFH)		15-May-09
Geotechnical Baseline Report (WOFH)	2.0	Aug-09
Kamehameha Highway Interim Design, Advanced Interim Design, and Final Design Drawings		Various
Kamehameha Highway Segment Geotechnical Baseline Report	1.1	07-May-10
Kamehameha Highway Geotechnical Data Report		16-Feb-10

Document	Rev. No.	Date
Kamehameha Highway Geotechnical Data Report Addendum		7-May-10
Airport Preliminary Engineering Drawings, Volumes 1-3		1-Oct-10
Airport Geotechnical Data Report		8-Feb-10
Airport Fixed-Guideway Foundation Technical Memorandum		6-Feb-10
City Center Preliminary Engineering Drawings, Volumes 1-4		6-Oct-10
City Center Geotechnical Data Report		26-Feb-10
City Center Fixed-Guideway Foundation Technical Memorandum		26-Feb-10
East Kapolei Station Updated Design Plans		9-Mar-12
UH West Oahu Station Updated Design Plans		9-Mar-12
Ho-opili Station Updated Design Plans		9-Mar-12
West Loch Station In-Progress Submission		29-Feb-12
Waipahu Transit Center Station In-Progress Submission		29-Feb-12
Leeward Community College Station In-Progress Submission		29-Feb-12
Pearl Highlands Station Updated Design Plans		9-Mar-12
Pearlridge Station Updated Design Plans		9-Mar-12
Aloha Stadium Station Updated Design Plans		9-Mar-12
Airport Station Group Updated Design Plans		9-Mar-12
Dillingham Station Group Undated Design Plans		9-Mar-12
Kaka'ako Station Group Updated Design Plans		9-Mar-12
Ala Moana Station Updated Design Plans		9-Mar-12
Guideway Superstructure Study – Summary Report		22-May-08
Structures Workshop Summary Report		7-10-Jan-08
Systems Workshop Presentation		22-Aug-08
Transportation Technical Report		1-Aug-08
Construction Workshop Frequently Asked Questions (FAQ)		12-Jun-08
Construction Workshop Presentation		12-Jun-08
Environment Condition of Property, NAVFAC (Navy Drum Site)		Mar-09
Final Evaluation of Project Delivery Options		2-Nov-06
Fixed Guideway Fleet Sizing Report		Jun-09
Value Engineering – Stations Report		Sep-10
Value Enhancement Summary Report		Sep-10
Contracts		
West Oahu/Farrington Highway Design-Build – RFP, Addenda, Proposal and Contract Documents		Various
Kamehameha Highway Design-Build – RFP, Addenda, Proposal and Contract Documents		Various
Maintenance and Storage Facility Design-Build – RFP, Addenda, Proposal and Contract Documents		Various
Core Systems DBOM – RFP, Addenda, Proposal and Contract Documents		Various
General Conditions of Design-Build Contracts, Honolulu		Feb-09
Financial/Cost		
FFGA Capital Cost Estimate Basis and Assumptions		9-May-12
FFGA Main Worksheet – Build Alternative		14-May-12
FFGA Cash Flows Worksheet		14-May-12
FFGA HRTP SCC Cost Workbook		14-May-12
HART Capital Cost by Contract by SCC Workbook		20-Mar-12
Price Proposals (post bid) Kiewit WOFH		11-Nov-09
Price Proposals (post bid) Kiewit MSF		16-Mar-11
Price Proposals (post bid) Kiewit Kamehameha		16-Mar-11
Price Proposals (post bid) Ansaldo Core Systems		16-Mar-11
General Excise and Use Tax in Hawaii		16-Feb-06
Schedule		

Document	Rev. No.	Date
HRTP Baseline Progress Schedule REV.04.xer		13-Jun-12
HART FFGA BASELINE PMOC Review.plf		13-Jun-12
Basis of Schedule 062012.pdf (Rev 3.0)	3.0	20-Jun-12

Note: The above list includes all key documents reviewed by the PMOC for preparation of the various OP deliverables.