Appendix G
Baggage Handling System Study

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Appendix G

Baggage Handling System Study

G.1 Inventory

The existing conditions of the baggage handling systems (BHS) at SFO were examined to determine future BHS needs at the Airport. These systems support the movement, screening, and sortation of inbound and outbound checked baggage within the landside, terminal, and apron areas of the Airport.

In general, the baggage handling systems include:

- Outbound (Departing) Baggage Systems
  - Baggage conveyors from passenger check-in facilities
  - Transfer baggage input conveyors to transport bags from one flight to another
  - Input conveyors for arriving international passengers transferring to connecting flights
  - Security screening areas (checked baggage inspection systems or “CBIS”)
  - Conveyors that sort baggage to airlines or flights within an airline
  - Baggage equipment (conveyors and carousels) for placing bags onto carts or unit load devices (ULD) used for transporting and loading baggage onto an aircraft
- Inbound (Arriving) Baggage Systems
  - Baggage input conveyors delivering baggage to the baggage claim area
  - Baggage transport conveyors
  - Baggage carousels

Table G.1-1 lists the airlines operating at each terminal and boarding area and the year of construction or the last major renovation for each boarding area. **Exhibit G.1-1** shows a diagrammatic view of the outbound baggage screening process.

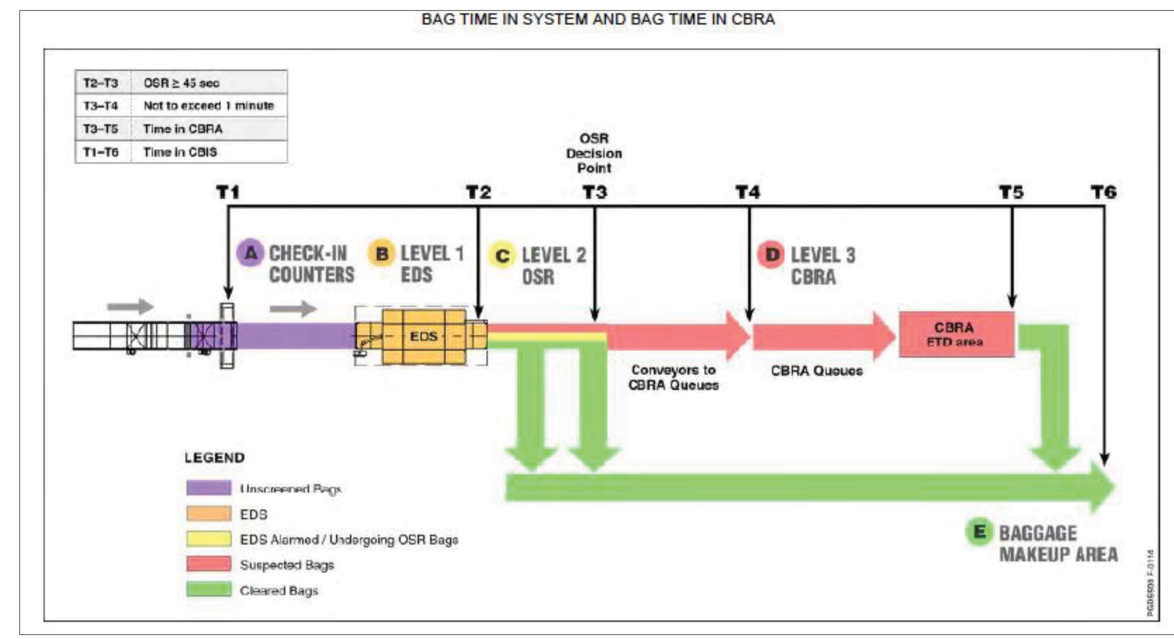
Table G.1-1 | Overview of Terminals and Boarding Areas

Terminal	B/A	Year	Gates	Airlines
International	A	2000	12	Non-Star Alliance, Star Alliance overflow, domestic overflow
	G	2000	12	United Airlines, Star Alliance
1	B	1985	9	Frontier Airlines, Southwest Airlines
	C	1987	10	Delta Air Lines, US Airways (American Airlines)
2	D	2011	14	American Airlines, Virgin America
3	E	2014	10	United Airlines
	F	1979	21	United Airlines

Note: B/A = Boarding Area

Sources: SFO Bureau of Planning and Environmental Affairs; Landrum & Brown, Inc., September 2015

Exhibit G.1-1 | Baggage Screening Process



Sources: Transportation Security Administration, Planning Guidelines and Design Standards (PGDS); BNP Associates, October 2015

Currently, each terminal operates on one or more independent baggage handling systems, each with a number of subsystems. Only the Terminal 3 and Boarding Area G systems are interconnected. All baggage handling systems include an automated explosives detection system (EDS) supplied by Safran/Morpho. The systems employee CTX-9000, CTX-9400, and CTX-9800 screening devices, which vary in age and capacity, with the CTX-9800 being the latest and fastest and the CTX-9000 being the oldest and slowest. **Exhibit G.1-2** shows an example of a CTX EDS.

Exhibit G.1-2 | CTX Explosives Detection System

Sources: SFO Site Visit by BNP, April 2015; BNP Associates, October 2015

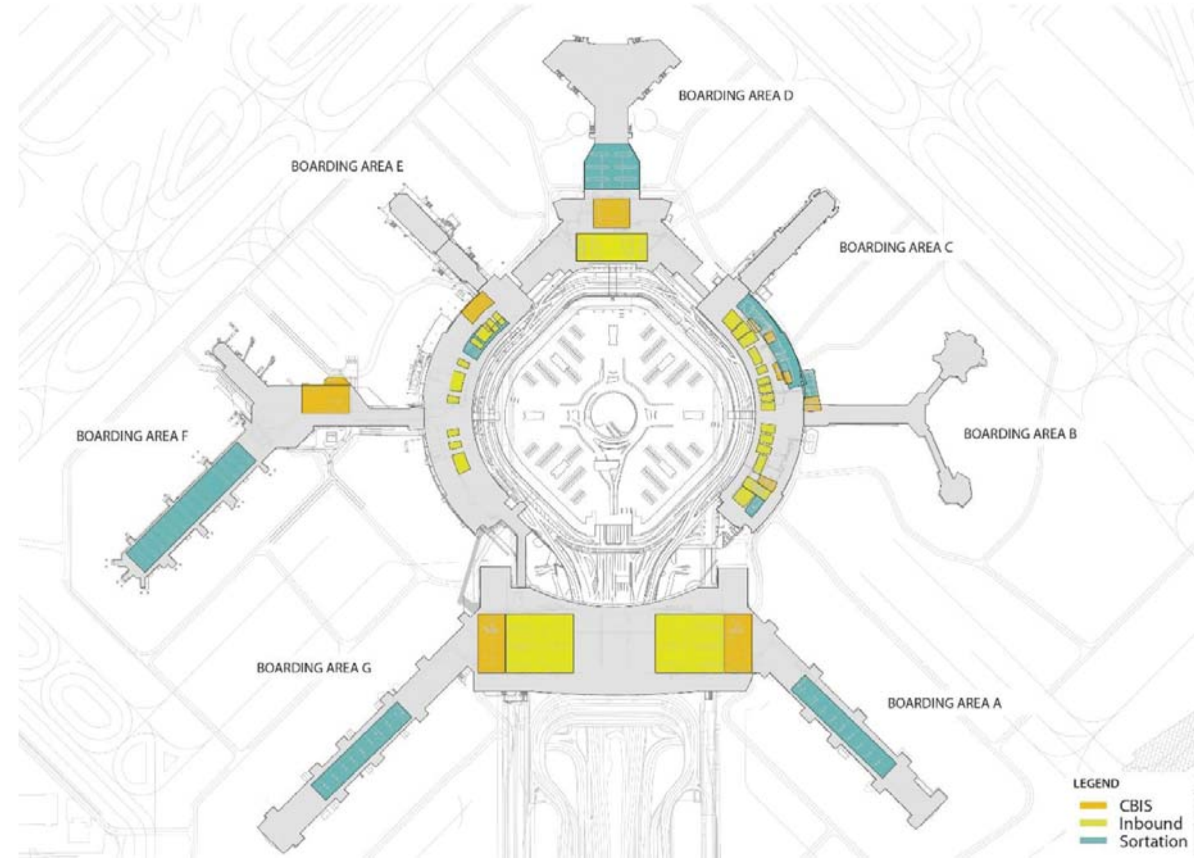
While most baggage screened through these systems is automatically cleared, some bags require viewing by a Transportation Security Administration (TSA) operator through an on-screen resolution (OSR) process. This process is conducted in a centralized location and supports all of the terminals at SFO.

In cases where baggage viewed through the OSR process cannot be resolved, the baggage is sent to a checked baggage resolution area (CBRA) for resolutions where TSA staff screen the bag manually. These CBRAs are generally located adjacent to the EDSs.

Inbound baggage is removed from an aircraft's cargo hold and driven by tug to a baggage input point for presentation on a baggage claim carousel. Each terminal contains between four and 14 claim carousels. The size of each carousel varies based on the type of aircraft it is designed to serve.

Exhibit G.1-3 illustrates the existing BHS layout within the terminal core area.

Exhibit G.1-3 | SFO Overall Existing Baggage Handling System Locations



Sources: SFO Bureau of Planning and Environmental Affairs, SFO Airport Layout Plan, 2014; SFO Site Visit by BNP, October 2014; BNP Associates, October 2015

Terminal 1 Boarding Areas B and C

The existing Terminal 1 outbound BHS consists of independent systems installed or operated by individual airlines, including Alaska Airlines, Delta Air Lines, Frontier Airlines, Southwest Airlines, and US Airways.[1] These systems, for the most part, are owned by the respective airlines. After the terrorist attacks in September 2001, the systems were modified by Airport management to provide for automated screening to meet the requirements for 100 percent screening of checked baggage by December 31, 2002.[2] The outbound baggage systems in Terminal 1 will not provide reliable service for more than a few years as their components and controls are out of date.

The inbound baggage systems in Terminal 1 are equally deficient and will require incremental upgrades in various operating areas as part of the Interim B/A B project between now and 2019, when the permanent Terminal 1 system is scheduled to be complete.

Exhibit G.1-4 shows an overview of the Terminal 1 BHS at B/As B and C and the airline users as of fall 2015.

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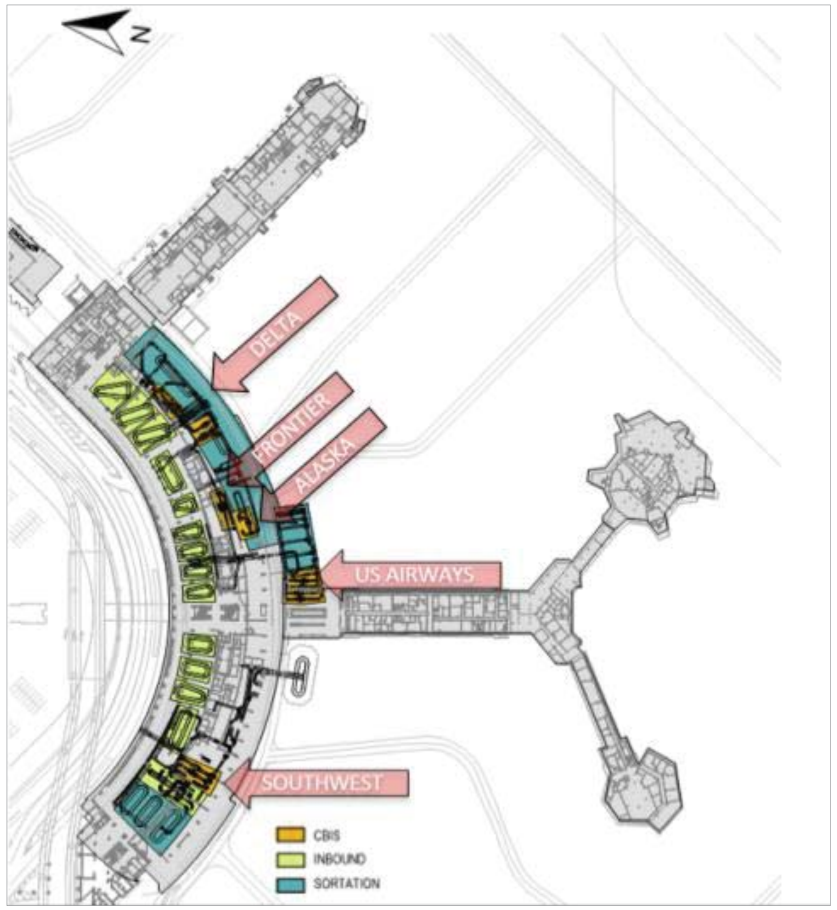
[1] Following its merger with American Airlines, US Airways vacated its T1 BHS in October 2015. For this analysis, the system is still described as the US Airways system.
[2] Public Law 107-71, *Aviation and Transportation Security Act*, 107th Congress, November 19, 2001.

Table G.1-2 presents the inventory of key elements of the existing BHS in Terminal 1. The throughput of each system is limited by its screening machines, as each CTX-9000 machine is capable of processing fewer than 400 bags per hour.

Exhibit G.1-4 | Terminal 1 Baggage Handling System



Sources: SFO Bureau of Planning and Environmental Affairs, SFO Airport Layout Plan, 2014; SFO Site Visit by BNP, October 2014; BNP Associates, October 2015

Table G.1-2 | Terminal 1 Baggage Handling Systems Inventory

ITEM	DELTA	FRONTIER	ALASKA	US AIRWAYS	SOUTHWEST
CBIS Screening Machines (CTX-9000)	3	1	1	4	2
Baggage Cart Staging	Varies by airline				
Baggage Claim Units	14				
Baggage Claim Frontage	2,086 linear feet				

Note: CBIS = Checked Baggage Inspection System

Sources: SFO Site Visit by BNP, October 2014; BNP Associates, October 2015

Terminal 2 Boarding Area D

The Terminal 2 BHS was installed in 2009 and is used by American Airlines and Virgin America.

There are two check-in counter baggage conveyors and two curbside check-in baggage conveyors that descend through the Arrivals Level ceiling into the bag room where they merge to form two main lines that feed the CBIS area. Bags are tracked through the CBIS using automatic tag readers, which read the International Air Transport Association (IATA) standard barcodes on the bag tags.

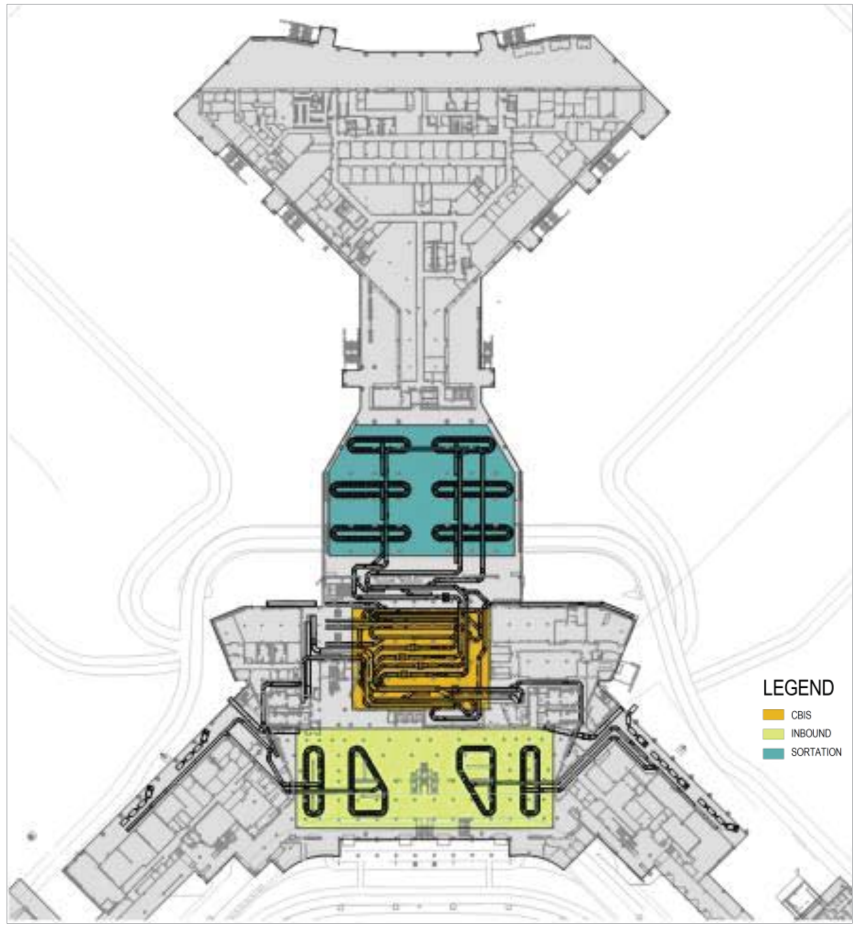
The CBRA has two input conveyors, two output conveyors, and two oversized conveyors for the delivery and removal of baggage to and from the inspection locations.

Two transfer input conveyors are also available, one to route bags directly to the sortation system (for domestic-to-domestic and domestic-to-international transfer bags that have already been screened) and one to route international-to-domestic transfer bags to the CBIS.

The BHS and the baggage room are well maintained and clean. SFO staff responsible for this area confirmed that the BHS is in good operating condition with no recent history of operational issues.

The system was designed to process originating baggage at a peak rate of 1,500 bags per hour. **Exhibit G.1-5** shows an overview of the existing Terminal 2 BHS. **Table G.1-3** presents the inventory of key elements of the existing BHS in Terminal 2.

Exhibit G.1-5 | Terminal 2 Baggage Handling System



Sources: SFO Bureau of Planning and Environmental Affairs, SFO Airport Layout Plan, 2014; SFO Site Visit by BNP, October 2014; BNP Associates, October 2015

Table G.1-3 | Terminal 2 Baggage Handling System Inventory

ITEM	QUANTITY
CBIS Screening Machines (CTX-9400)	4
Outbound Baggage Make-up Devices	6
Baggage Make-up Piers	0
Baggage Cart Staging Positions	80
Baggage Claim Units	4
Baggage Claim Frontage (linear feet)	828

Note: CBIS = Checked Baggage Inspection System

Sources: SFO Site Visit by BNP, October 2014; BNP Associates, October 2015

Terminal 3 Boarding Areas E and F

Terminal 3 has two independent CBIS and sortation systems: the B/A E basement system and the B/A F apron system

In B/A F, which is the primary operating area for United Airlines, the system includes three CTX-9800 EDS machines that feed a temporary CBRA installed outside the B/A F building. Five additional CTX-9000 EDS machines route bags to the existing CBRA inside the B/A F space. All cleared bags are transported to the existing B/A F sortation space west of the CBIS.

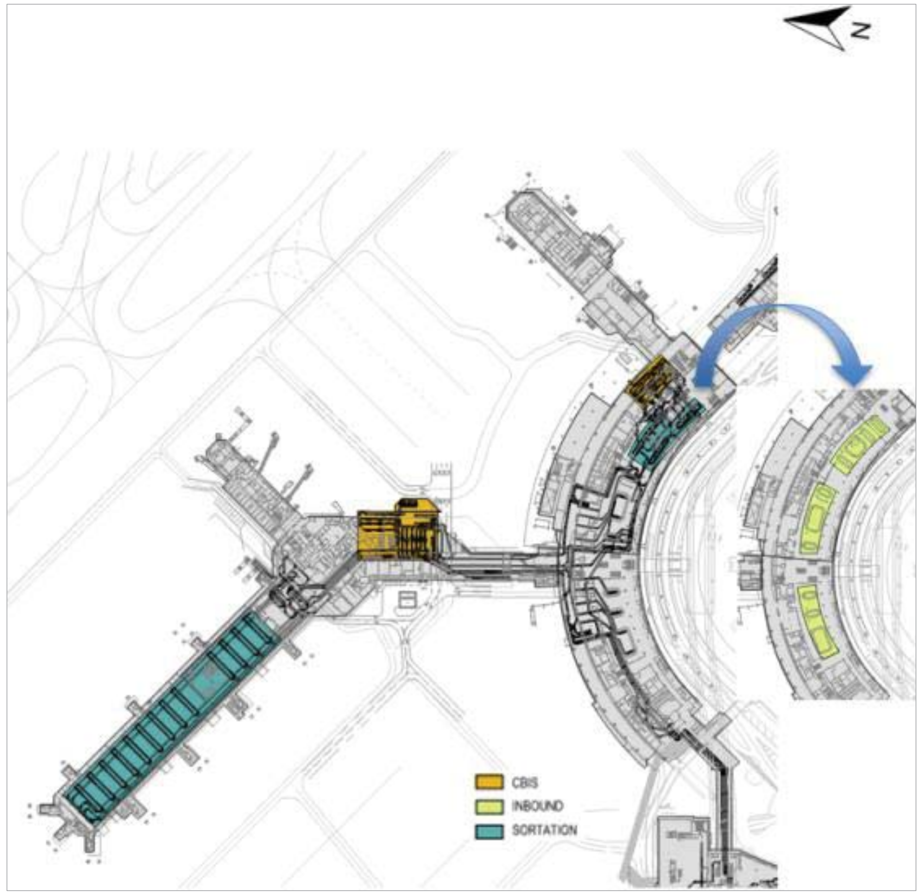
The B/A E basement CBIS consists of four CTX-9000 EDS screening machines located in the eastern Terminal 3 basement. The B/A E basement system also has three baggage make-up carousels adjacent to the CBIS.

The B/A E BHS was originally installed in 1980 and was not part of the TSA-sponsored Modernization Program. The CBIS was installed in 2004 when American Airlines operated in B/A E. Since American Airlines relocated to Terminal 2 in 2009, the B/A E CBIS was not used until United Airlines reactivated the system in 2014. The B/A E CBIS consists of four CTX-9000 EDS machines.

Crossover subsystems that link the previously independent B/As E and F BHS have been installed to provide United Airlines access to either CBIS in Terminal 3 and to allow bags to reach any make-up carousel in B/A F or in the B/A E basement. The Terminal 3 BHS is also connected to International Terminal Building (ITB) B/A G. Two conveyors for international-to-domestic recheck baggage connect from the ITB to Terminal 3. One conveyor connects from Terminal 3 to the sortation system in B/A G to handle domestic-to-international transfer baggage.

Exhibit G.1-6 shows an overview of the existing Terminal 3 BHS. **Table G.1-4** presents the inventory of key elements of the existing BHS in Terminal 3.

Exhibit G.1-6 | Terminal 3 Baggage Handling System



Sources: SFO Bureau of Planning and Environmental Affairs, SFO Airport Layout Plan, 2014; SFO Site Visit by BNP, October 2014; BNP Associates, October 2015

Table G.1-4 | Terminal 3 Baggage Handling System Inventory

ITEM	B/A E BASEMENT	B/A F APRON
CBIS Screening Machines		
CTX 9000	4	5
CTX 9800		3
Outbound Baggage Make-up Devices	3	13
Baggage Make-up Piers	3	13
Baggage Cart Staging Positions	35	228
Baggage Claim Units[1]	10	
Baggage Claim Frontage (linear feet)	1,420	

Notes: CBIS = Checked Baggage Inspection System

1: Inbound claim unit unload conveyors are located in the Terminal 3 basement and the inbound claim units are located in the Terminal 3 arrivals area. It is, therefore, not appropriate to delineate between B/A E and B/A F for the inbound claim units.

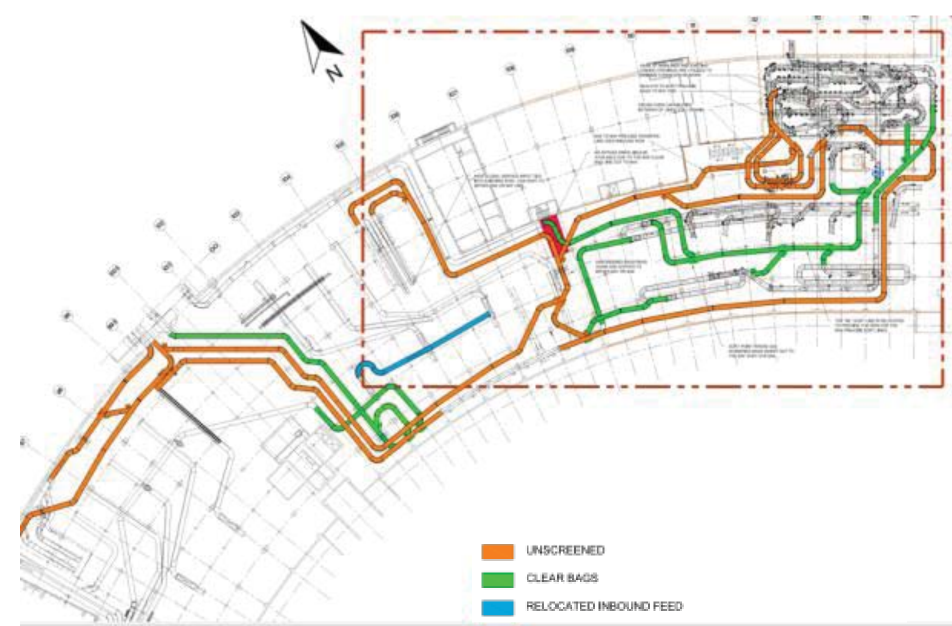
Sources: SFO Site Visit by BNP, October 2014; BNP Associates, October 2015

The outbound CBIS screening area capacity is 2,925 bags per hour at B/A F; however, the overall capacity of the outbound BHS for B/A F cannot be determined using simple calculations. It is a complex system with bags crossing over from one area to another. Originating and international-to-domestic transfer bags require screening prior to sorting while domestic-to-domestic and domestic-to-international transfer bags bypass screening and proceed directly to sorting. The final sortation system has two main lines, each theoretically rated at 50 bags per minute or 3,000 bags per hour. In operational practice, it is likely that only 75 to 80 percent of this published rate can be achieved. The capacity of the outbound system at B/A F could therefore be estimated at approximately 4,500 bags per hour, although this number is dependent on the number of transfer bags entering the system that do not require screening. It is likely that this rate cannot be achieved based on the current mix of bags requiring screening versus bags that do not require screening. A simulation would be required to determine the actual capacity of the system under varying flight schedules and transfer rates (a task that is beyond the scope of this ADP).

The outbound CBIS screening area capacity at B/A E is 987 bags per hour; however, like B/A F, the overall capacity of the outbound BHS for B/A F cannot be determined using simple calculations. It is a complex system with bags crossing over from one area to another. Based on the same assumptions as above, and with a final sortation system that has two main lines, each theoretically rated at approximately 40 bags per minute or 2,400 bags per hour, the capacity of the outbound BHS at B/A E could therefore be estimated at approximately 3,600 bags per hour.

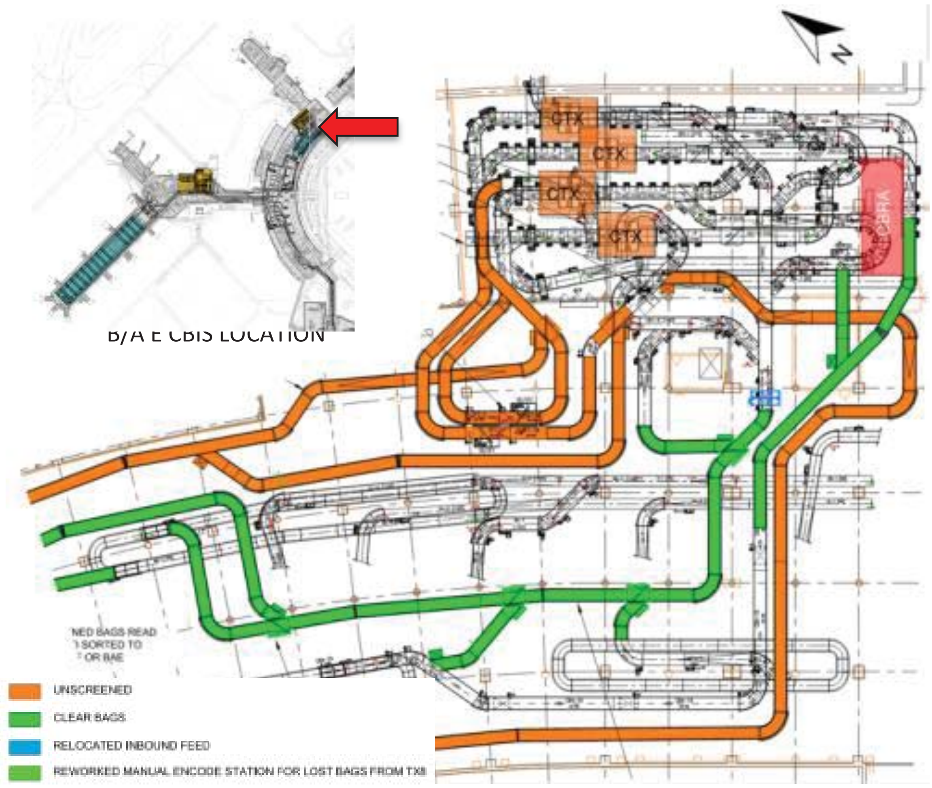
B/A E to B/A F crossover BHSs have been installed in the Terminal 3 basement. Bags can be checked in at any Terminal 3 check-in area and are then directed to either the B/A E or B/A F CBIS. Similarly, bags cleared by the B/A E or B/A F CBIS can be routed to either sortation system. **Exhibit G.1-7** shows an overview of the Terminal 3 East basement crossovers.

Exhibit G.1-7 | Terminal 3 Boarding Areas E and F (Basement)



Sources: BNP Associates, Crossover Design Drawings, 2013; BNP Associates, October 2015

Exhibit G.1-8 | Terminal 3 Boarding Area E Basement Checked Baggage Inspection System and Sortation



Sources: BNP Associates, Crossover Design Drawings, 2013; BNP Associates, October 2015

International Terminal Building

The ITB has two boarding areas, B/A A and B/A G, which currently serve both domestic and international flights. Each outbound BHS supports baggage screening, sortation, and make-up. Eight make-up carousels are located adjacent to aircraft loading and offloading operations. Inbound operations require the transport of baggage from the aircraft to areas closer to the main terminal.

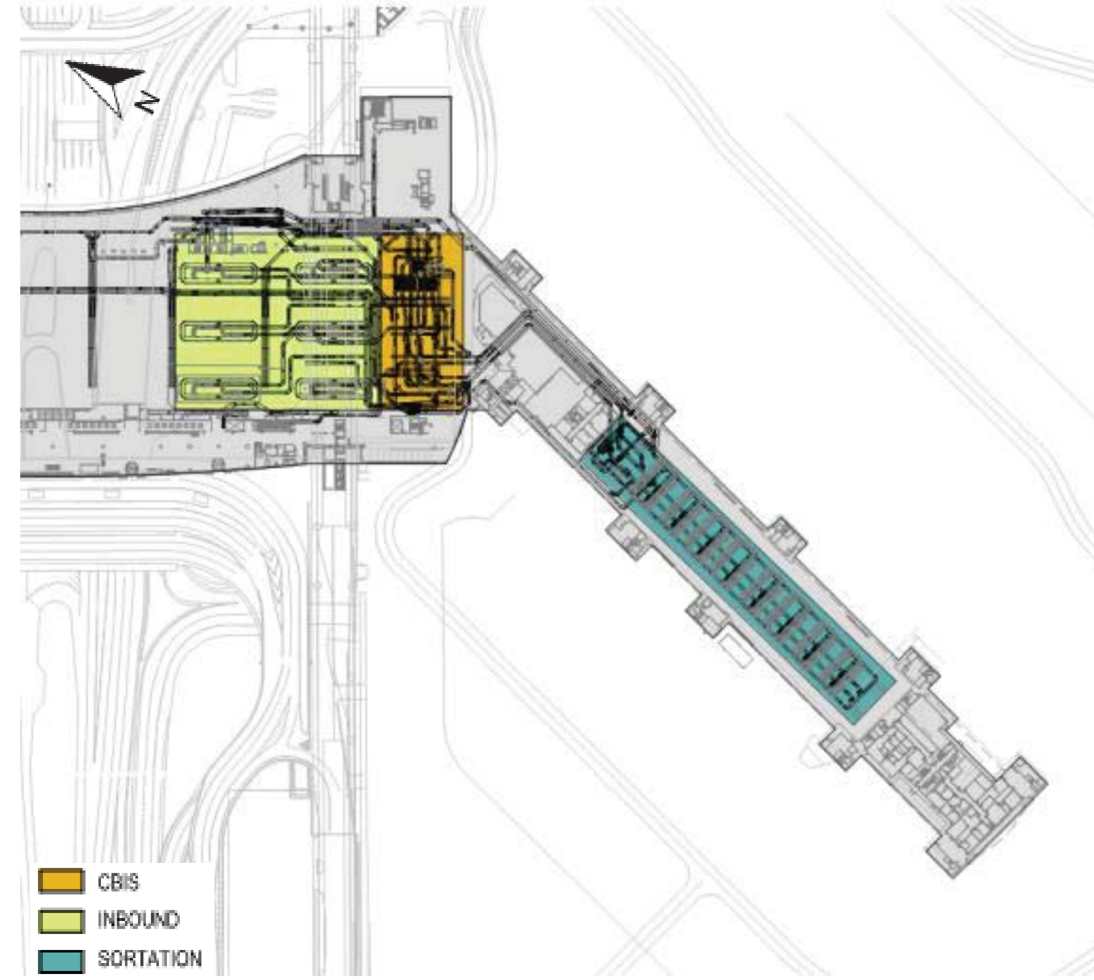
The two boarding areas provide independent baggage handling systems. Outbound baggage operations support a total of 12 check-in aisles with conveyors that distribute bags to either B/A A or B/A G. The middle four check-in rows can send bags to either boarding area CBIS while the outer four check-in rows on each side can send bags only to the nearest boarding area CBIS.

After the CBIS, crossovers allow bags to be sent to the opposite boarding area. These crossovers are not redundant/fault tolerant, as there is only one conveyor line in each direction. If a failure occurs on one of these lines, the system in each boarding area cannot exchange bags with those in the other boarding area.

Both BHSs were part of the TSA Modernization Program. One new CTX-9800 was installed at B/A G, and this single machine feeds a CBRA located on a mezzanine west of the CBIS. The remaining four EDS machines are CTX-9000s, which deliver rejected baggage to an older CBRA located directly below the CBIS mezzanine. All cleared bags are routed north to the sortation system.

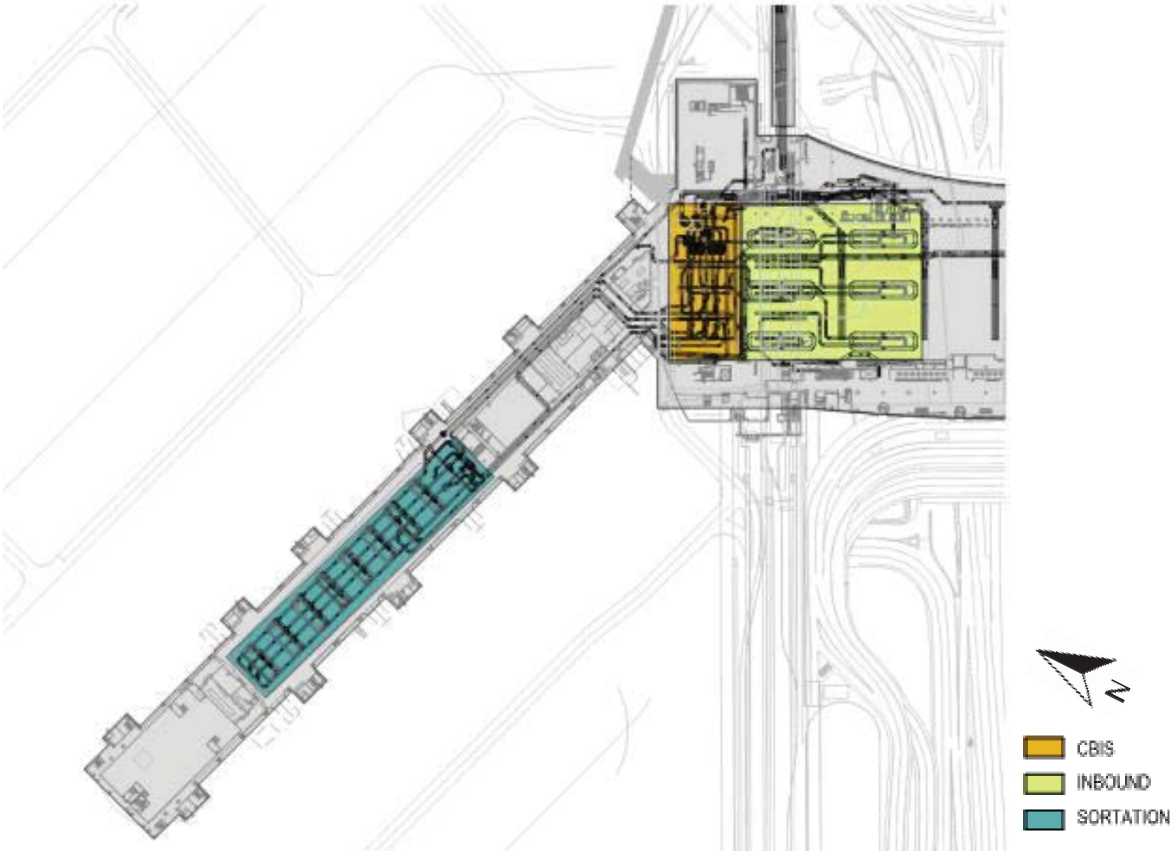
Exhibit G.1-9 shows an overview of the B/A A baggage system. **Exhibit G.1-10** shows an overview of the B/A G baggage system. **Table G.1-5** presents the inventory of key elements of the BHS in B/As A and G.

Exhibit G.1-9 | International Terminal Building Boarding Area A Baggage Handling System



Sources: SFO Bureau of Planning and Environmental Affairs, SFO Airport Layout Plan, 2014; SFO Site Visit by BNP, October 2014; BNP Associates, October 2015

Exhibit G.1-10 | International Terminal Building Boarding Area G Baggage Handling System



Sources: SFO Bureau of Planning and Environmental Affairs, SFO Airport Layout Plan, 2014; SFO Site Visit by BNP, October 2014; BNP Associates, October 2015

Table G.1-5 | International Terminal Building Boarding Areas A and G – Existing Baggage Handling System Operational Capacities

	B/A A	B/A G
CBIS Screening Machines		
CTX-9000	5	4
CTX-9800		1
Outbound Baggage Makeup Devices	8	8
Baggage Makeup Piers	12	12
Baggage Cart Staging Positions	140	140
Baggage Claim Units (incline plate)	2 Domestic, 4 International	1 Domestic, 5 International
Baggage Claim Frontage (linear feet)	1,470	1,470

Sources: SFO Site Visit by BNP, October 2014; BNP Associates, October 2015

Each ITB CBIS has a capacity of 1,316 bags per hour.[3] However, the overall capacity of the outbound baggage systems at B/As A and G cannot be determined using simple calculations (see Terminal 3, above). The final sortation system in each of the two boarding areas has three main lines, each theoretically rated at approximately 60 bags per minute or 3,600 bags per hour. The maximum practical capacity of the outbound system for both boarding areas could therefore be estimated at approximately 8,100 bags per hour.

G.2 Facility Requirements and Design Basis

The facility requirements for the baggage handling system were developed based on the ADP forecast for the 2018, Base Constrained, and High Constrained demand levels. The analysis of future flight schedules and the applicable passenger and baggage processing metrics were used to determine the BHS requirements at future development points. The key requirements in designing a BHS include:

- Outbound Baggage
  - Originating Bag Rate – the peak baggage processing demand for departing passengers whose journeys begin at SFO. The originating bag rate is measured in bags per minute (BPM).
  - Transfer Bag Rate - the peak baggage processing demand for passengers that use SFO as a transfer point within their journeys. The transfer bag rate is measured in BPM.
  - Screening Bag Rate - the peak baggage processing demand for checked baggage that must be screened at SFO. The screening bag rate includes the combined peak baggage processing demand for originating, international-to-domestic, and international-to-international transfer passengers. This screening bag rate is measured in BPM.

[3] Although B/A G includes a newer CTX-9800 which provides more practical capacity than the B/A A system, capacity assessments typically assume that the fastest screening machine has failed. If the CTX-9800 in B/A G fails, the remaining machines consist of four CTX-9000 machines, which is the same machine configuration and capability as B/A A.

- Baggage Make-up Requirement – the peak number of baggage carts that must be available at the baggage make-up area at any one time to load baggage from the BHS to the carts for transport to the appropriate departing aircraft. Depending on aircraft size, between one and eight carts per aircraft may be required during the baggage make-up period. These requirements are measured in numbers of baggage cart staging positions.
- Early Bag Storage (EBS) – if a bag arrives into the BHS before the flight's baggage make-up position is open in the bag room, the bag is considered early and must be stored within the system until the baggage make-up area for its flight is open. EBS requirements are measured in terms of the peak number of bags that must be stored in the system.

- Inbound Baggage
  - Arrival Bag Rate – the peak baggage processing demand for passengers who end their journeys at SFO. The arrival bag rate is measured in BPM.
  - Claim Presentation – the length of the baggage claim devices required to provide adequate space for passengers in the baggage claim area. Claim presentation is measured in the linear feet of claim device that needs to be accessible to passengers retrieving bags.

The data and assumptions used to generate outbound and inbound baggage requirements include:

- Design day flight schedules
- Number of bags per passenger
- Passenger check-in profile
- Screening alarm parameters
- Originating baggage requirements
- Screening requirements
- Make-up presentation requirements
- Early bag storage
- Transfer bag requirements
- Baggage claim device use
- Baggage recheck requirements

Future Design Day Flight Schedules

The 2018, Base Constrained, and High Constrained demand level design day flight schedules were used in the analysis of BHS facility requirements. These flight schedules were used to determine BHS demand to develop facility requirements. The demand is determined by passenger load factor, passenger traffic distribution, and transfer passenger distribution, all of which vary by flight.

- Passenger Load Factor: The percentage of seats occupied on a flight
- Passenger Traffic Distribution: The distribution of originating passengers and terminating passengers

- Transfer Passenger Distribution: The percentage of transferring passengers from domestic and international arriving flights and the percentage of transferring passengers from international arriving flights that recheck bags

Bags per Passenger

United Airlines was the only airline to provide detailed bags per passenger (BPP) numbers. **Table G.2-1** presents this information for all combinations of domestic and international passenger/baggage flows. Because no other airline provided BPP data, the data in Table G.2-1 applies to all SFO flights for the BHS facility requirements. The United Airlines BPP data are considered maximum values.

Table G.2-1 | Bags per Passenger Rates

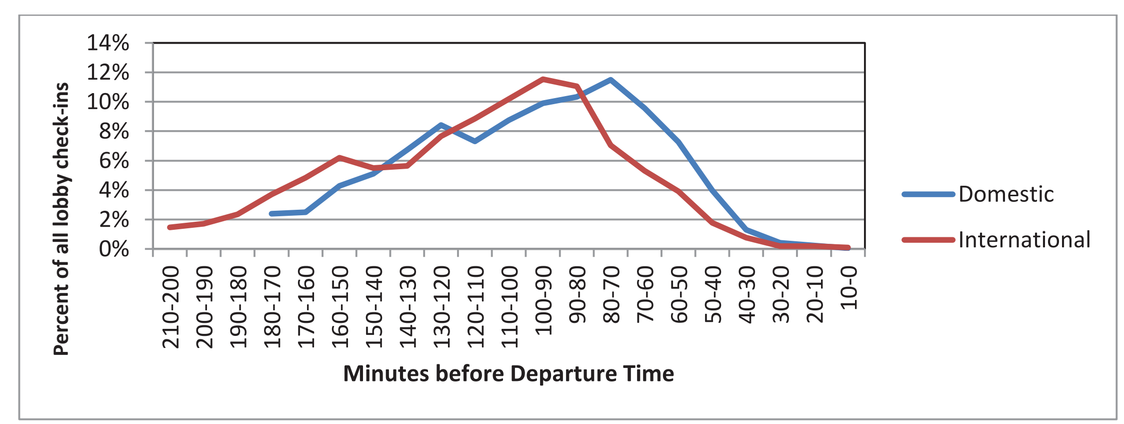
DIRECTION	TYPE	BAGS PER PASSENGER
OUTBOUND DOMESTIC	Originating	0.80
	Transfer	0.86
OUTBOUND INTERNATIONAL	Originating	1.01
	Transfer	1.07
INBOUND	Domestic	0.86
	International	0.99

Sources: United Airlines Analysis Data, October 2014; Landrum & Brown, Peak Month Average Day Flight Schedules, October 2014; BNP Associates, October 2014

Check-In Profile

The domestic and international passenger check-in profile distribution at SFO, shown on Exhibit G.2-1, indicates the percentages of passengers that arrive at the Airport by the number of minutes before departure time.

Exhibit G.2-1 | Passenger Check-in Profile



Sources: United Airlines Analysis Data, October 2014; Landrum & Brown, Peak Month Average Day Flight Schedules, October 2014; BNP Associates, October 2014

Screening Alarm Parameters

The screening alarm rates are Sensitive Security Information (SSI) and have been omitted from this report. This analysis uses historical SFO data collected during the operation of the higher throughput CTX-9800 devices installed at B/A F and B/A G. **Table G.2-2** compares the assumed throughput of the screening equipment as prescribed by the TSA with the SFO observations.

Table G.2-2 | Screening Alarm Parameters – CTX-9800 Machines

	ORIGINAL DESIGN PGDS V4.1	TSA REVISED DATA 04-09-13	REVISED OBSERVED DATA AT SFO
Level 1 Alarm Rate	SSI	SSI	SSI
Level 1 Throughput	640 Bags per Hour	640 BPH	640 BPH
Level 2 Alarm Rate	SSI	SSI	SSI
Level 2 Throughput	180 Bags per Hour	180 BPH	180 BPH
Directed Search Throughput	24.2 Bags per Hour	18.8 BPH – Domestic 13.8* BPH – International	15.0 BPH – Domestic 11.0 BPH – International
Not Directed Search Throughput (Out of Gauge/Lost In Tracking)	24.2 Bags per Hour	26.6 BPH – Domestic 19.8 BPH – International	26.6 BPH - Domestic 19.8 BPH – International
Odd Size Bag Throughput	24.2 Bags per Hour	15.2 BPH	15.2 BPH

Notes: BPH = Bags per Hour
PGDS = Planning Guidelines and Design Standards (see source below)
SSI = Sensitive Security Information (data not provided for security reasons)

Sources: Transportation Security Administration, Planning Guidelines and Design Standards for Checked Baggage Inspection Systems, Version 5.0, August 25, 2015; BNP Associates, October 2015

Originating Baggage Requirements

In developing originating baggage requirements for scheduled flights, the passenger check-in profiles by scheduled time of departure are applied to originating passenger/baggage volumes. The calculation is as follows:

$$Originating\ Baggage = (Available\ Seats)\ x\ (Load\ Factor)\ x\ (Originating\ Passenger\ Percent)\ x\ (Bags\ per\ Originating\ Passenger)$$

The originating screening bag rate is the flow of bags screened by the Level 1 screening machine. This does not include out-of-gauge (OOG) or oversized (OS) bags that bypass the screening machines and are transported directly to a checked baggage resolution area (CBRA) for screening. The originating screening bag rate is calculated by subtracting the percentage of OOG and OS bags from the previously calculated originating screening bag rate.

$$Originating\ Screening\ Bag\ Rate = Originating\ Bag\ Rate - (OOG\% + OS\%)$$

Screening Requirements

Level 1 Explosives Detection System Machine Requirements

The number of Level 1 explosives detection system (EDS) screening machines required for checked baggage screening is determined by dividing the screening bag rate by the machine processing rate.

Level 2 On-Screen Resolution Operator Requirements

In accordance with the TSA Planning Guidelines and Design Standards for Checked Baggage Inspection Systems (PGDS),4 to determine the number of on-screen resolution (OSR) operators required, the required number of Level 1 EDS machines is multiplied by the Level 1 EDS screening rate and the Level 1 alarm rate (FAEDS) and then divided by the OSR processing rate of 180 images per hour.

$$N_{OSR} = \#\ EDS\ machines\ x\ EDS\ screening\ rate\ x\ FA_{EDS} / OSR\ processing\ rate$$

Explosives Trace Detector Operator Requirements – Screened Bags

In accordance with the TSA PGDS, to determine the number of explosives trace detector (ETD) operators required, the number of required EDS machines is multiplied by the Level 1 EDS screening rate, the Level 1 alarm rate (FAEDS), and the OSR alarm rate (1-CR) OSR including Lost in Track Bags (RLIT) and OOG Bags (ROOG), and then divided by the CBRA processing rate. There are two ETD operators per work station.

$$N_{ETD} = \#\ EDS\ machines\ x\ EDS\ screening\ rate\ x\ [FA_{EDS}\ x\ (1\text{-}CR)_{OSR} + R_{LIT} + R_{OOG}] / ETD\ screening\ rate$$

Explosives Trace Detector Operators for Oversized Bags and Out of Gauge Bags

In accordance with the TSA PGDS5, to determine the required number of ETD operators for oversized bags, the EDS screening rate for oversized bags is multiplied by 60 and then divided by the ETD processing rate. There are two ETD operators per work station.

$$N_{ETD\ for\ OS} = [Originating\ Bag\ Rate\ x\ (OS\ percent)\ x\ 60] / ETD\ screening\ rate\ for\ Oversized\ Bags$$

Baggage Handling System Make-Up Presentation Requirements

The BHS make-up presentation requirements are determined using the following parameters:

- The time that carts/containers are available at the make-up devices before flight departure time.
- The number of carts/containers required per flight. This number varies based on aircraft size.

The cart/container assignments are distributed across a matrix by departure time. The number of carts is then summed for all time intervals to determine the maximum number of carts/containers required at any given time.

[4] Transportation Security Administration, *Planning Guidelines and Design Standards for Checked Baggage Inspection Systems*, Version 5.0, August 25, 2015

[5] Transportation Security Administration *Planning Guidelines and Design Standards for Checked Baggage Inspection Systems*, Version 5.0, August 25, 2015

BHS make-up periods represent the time that carts and unit load devices (ULDs) (i.e., containers) are stationed at the make-up devices before flight departure time. When this parameter changes, it changes the number of make-up positions required: the longer the make-up period, the longer the cart for a flight will be situated at the make-up device, resulting in more flights over the day overlapping at make-up. More flights that require baggage make-up simultaneously result in the need for more make-up positions and, consequently, a larger bag room. To optimize the size of the make-up area, bags can be stored in the EBS area, and the make-up duration can be shortened. Table G.2-3 illustrates the make-up start and end times used in the outbound baggage make-up analysis for both domestic and international flights.

Table G.2-3 | Baggage Handling System Outbound Baggage Make-up Periods

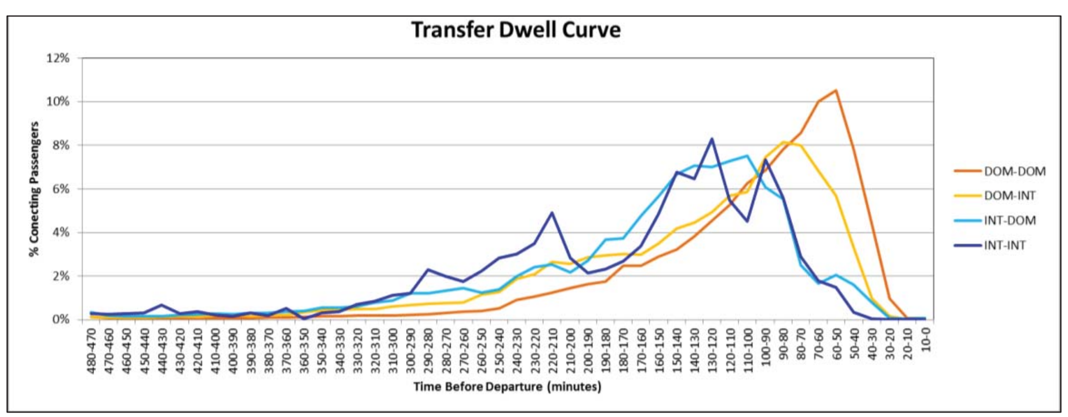
FLIGHT TYPE	MAKE-UP START BEFORE SCHEDULED TIME OF DEPARTURE (MINUTES)		MAKE-UP END BEFORE SCHEDULED TIME OF DEPARTURE (MINUTES)
	WITH EARLY BAG STORAGE	WITHOUT EARLY BAG STORAGE	
Domestic	120	180	20
International	150	210	30

Source: BNP Associates, Baggage Handling System Planning Premises, October 2015

Early Bag Storage

A bag that arrives in the BHS prior to the opening of the make-up device for the flight is considered early and must be stored somewhere in the system. Early bags come from two sources: originating passengers checking in prior to the make-up opening or transfer passengers arriving on a flight prior to the baggage make-up opening for the connecting flight. Because the time a bag is in storage has a direct effect on the capacity requirements of the storage system, a profile of storage times must be generated. For transfer baggage, the transfer dwell time profiles for the different transfer types are shown in **Exhibit G.2-2**. For originating baggage, the time period in the check-in profile (Exhibit G.1-11) that is earlier than the make-up opening time (Table G.1-8) determines the required storage time for the originating baggage.

Exhibit G.2-2 | Transfer Dwell Curve



Note: DOM = Domestic; INT = International

Sources: United Airlines Analysis Data, October 2014; Landrum & Brown, Peak Month Average Day Flight Schedules, October 2014; BNP Associates, October 2014

Transfer Bag Requirements

The transfer bag requirements are determined by multiplying the number of transfer passengers on each arriving flight (defined in the flight schedules) by the BPP number for transfer passengers to obtain the number of transfer bags. The transfer bags are then distributed by arrival flight time onto a time grid and summarized for each time period, assuming that the baggage offload rate onto the transfer input conveyor is 12 bags/minute and begins 10 minutes after aircraft arrival time. The calculation is as follows:

Transfer Bags = Arriving Passengers x Transfer Percent x Bags per Passenger

This calculation is applied to each aircraft in the flight bank, creating a transfer matrix of baggage volumes. A 20 percent peaking factor is applied to the transfer bags to account for unexpected instances, such as inbound flight delays.

Baggage Claim Frontage

Three factors determine baggage claim frontage demand: (1) the percentage of passengers per flight that will claim bags, (2) the linear footage of claim device per passenger (i.e., the passenger presentation area), and (3) the use time of the claim device for any particular flight. Passengers that claim bags include terminating passengers and any passengers required to recheck bags.

The number of passengers that arrive at baggage claim simultaneously determines the device presentation length required. Not all arriving passengers reach the baggage claim device simultaneously for a number of reasons, including the rate at which passengers disembark the aircraft and passengers travelling in groups where only one member in the group claims the bags. **Table G.2-4** provides the percentage of passengers that are simultaneously present at baggage claim per aircraft type.

Table G.2-4 | Baggage Claim Utilization Rate per Aircraft Type

SEATS	PERCENTAGE AT BAGGAGE CLAIM
Narrowbody Aircraft (<200 seats)	67%
Widebody Aircraft (200-250 seats)	55%
Widebody Aircraft (251-300 seats)	50%
Widebody Aircraft (>300 seats)	45%

Source: BNP Associates, October 2015

Based on the above information and a standard length allocation of 2 feet per passenger[6], the claim device size can be determined using the following generic formula:

Claim Size = (Aircraft Seats) x (Load Factor) x (Percent Terminating) x (Percent of Passengers @ Claim) x (Claim Utilization) x (Frontage/Passenger)

[6] International Air Transport Administration, *Aerodrome Design Reference Manual*, Edition 9, 2009, Table F9.6

The claim device utilization time is determined by the unload time of bags to the claim device plus an allowance of 10 minutes. The utilization time is determined as follows:

$$Utilization\ Time = \left(\frac{(Aircraft\ Seats)\ x\ (Load\ Factor) x\ ((Percent\ Terminating) x\ (BPP))}{(Offload\ Rate)}\right) + 10 \text{ minutes}$$

Baggage Check Rate

Table G.2-5 presents the percentage of arriving passengers that have checked bags at their originating airport.

Table G.2-5 | Baggage Claim Utilization Rate

CLAIM TYPE	UTILIZATION (%)
Domestic	67%
International	89%

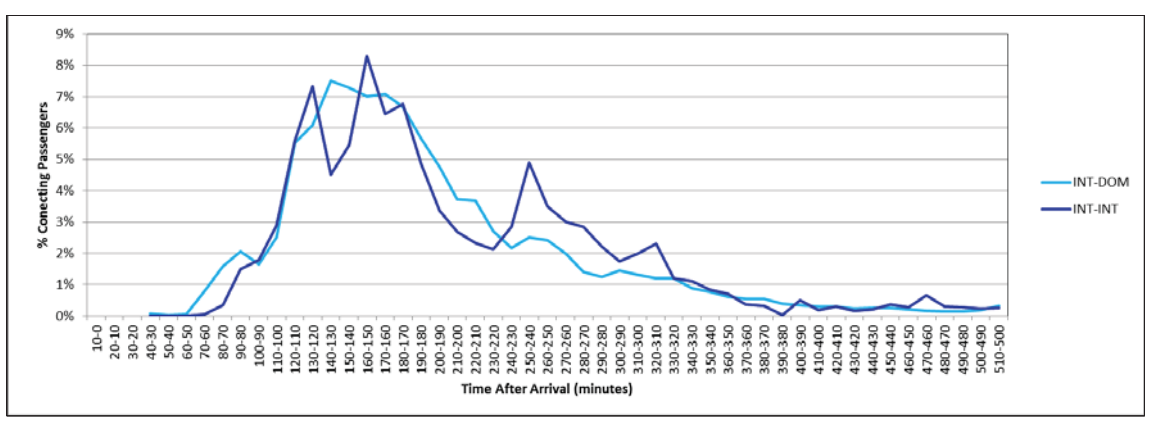
Source: BNP Associates, October 2015

Baggage Recheck Requirements

Baggage recheck requirements consist of the number of bags the belong to passengers transferring from arriving international flights to other flights. These passengers are required to claim their bags, process through U.S. CBP, and recheck their bags for their next departing flight. Specifically, the lateness distribution is applied to international recheck passengers that need to have their bags re-screened. All transfer bags arriving from international destinations (including Canada) are security screened regardless of any preclearance status. These include direct transfer bags that are input into the screening system for Canadian and other preclearance origins (i.e., passengers do not claim their bags) and include bags that have been claimed by passengers and must be rechecked after rescreening.

Exhibit G.2-3 depicts the lateness profile for international-to-domestic transfer passengers and for international-to-international transfer passengers.

Exhibit G.2-3 | Passenger Recheck Lateness Distribution



Note: DOM = Domestic; INT = International

Sources: United Airlines Analysis Data, October 2014; Landrum & Brown, Peak Month Average Day Flight Schedules, October 2014; BNP Associates, October 2014

Facility Requirements Summary

The facility requirements are based on the airline to terminal/boarding area allocations, as identified in **Table G.2-6**. The airline codes listed in that table are defined in **Table G.2-7.** The baggage requirements for each boarding area are provided in **Table G.2-8** through **Table G.2-14** and are based on the three future peak month average day flight schedules.

Table G.2-6 | Airline Terminal/Boarding Area Allocations

TERMINAL/ BOARDING AREA	2018	BASE CONSTRAINED	HIGH CONSTRAINED
A	AM, CX, TA, CI, LA, MU, NH, DL, KE, KL, UA, SQ, AF, EK, BA, SK, VS, JL, AS, VX, PR	AM, CX, TA, CI, AS, UA, NH, DL, KE, IB, KL, BA, LH, SQ, AF, JJ, EK, SK, VS, JL, VX, PR, NZ	AM, CX, TA, CI, AS, UA, NH, DL, KE, IB, KL, BA, LH, SQ, AF, JJ, EK, SK, VS, JL, VX, PR, NZ
Terminal 1	AA, DL, WN, F9, AS, B6, HA, SY	AA, DL, WN, F9, AS, B6, HA, SY	AA, DL, WN, F9, AS, B6, HA, SY, UA
Terminal 2	VX, AC, UA, WS	VX, AC, UA, WS	VX, AC, UA, WS
Terminal 3	UA	UA	UA
G & T3 SWING	SQ, BR, UA, OZ, LH, CA, LX, NZ	SQ, BR, UA, MU, CA, JJ, OZ, IB, NH, LX, LH	SQ, BR, UA, MU, CA, JJ, OZ, IB, NH, LX, LH
H	Not Operational	UA	UA

Notes: Airlines are designated by their IATA codes. See Table G.1-11.
MARS = Multiple Aircraft Ramp System

Sources: Landrum & Brown, Peak Month Average Day Flight Schedules, October 2014; BNP Associates, October 2014

Table G.2-7 | Airline IATA Codes

AIRLINE CODE	AIRLINE	AIRLINE CODE	AIRLINE
AA	American Airlines	KL	KLM
AC	Air Canada	LA	LATAM Airlines Chile
AF	Air France	LH	Lufthansa
AM	Aeromexico	LX	Swiss International Air Lines
AS	Alaska Airlines	MU	China Eastern Airlines
B6	JetBlue Airways	NH	All Nippon Airways
BA	British Airways	NZ	Air New Zealand
BR	EVA Air	OZ	Asiana Airlines
CA	Air China	PR	Philippine Airlines
CI	China Airlines	SK	Scandinavian Airlines
CX	Cathay Pacific	SQ	Singapore Airlines
DL	Delta Air Lines	SY	Sun Country Airlines
EK	Emirates	TA	Avianca El Salvador
F9	Frontier Airlines	UA	United Airlines
HA	Hawaiian Airlines	*US*	*US Airways*
IB	Iberia	VS	Virgin Atlantic Airways
JJ	LATAM Airlines Brasil	VX	Virgin America
JL	Japan Airlines	WN	Southwest Airlines
KE	Korean Air	WS	WestJet Airlines

Source: OAG, October 2015

Table G.2-8 | Boarding Area A Facility Requirements

FACILITY REQUIREMENTS	PLANNING ACTIVITY LEVEL		
	2018	BASE CONSTRAINED	HIGH CONSTRAINED
Originating Bag Rate (Bags per Minute)	15	26	28
Transfer Bag Rate (Bags per Minute)	0	0	0
Screening Bag Rate (Bags per Minute)	17	30	32
Early Bag Storage (Number of Bags)	281	491	532
Make-Up Requirements with EBS (Positions)	54	80	80
Make-Up Requirements without EBS (Positions)	70	94	94
Arrival Bag Rate (Bags per Minute)	52	87	90
Claim Presentation (Linear Feet)	1,122	2,427	2,970

Note: EBS = Early Bag Storage

Sources: Landrum & Brown, Peak Month Average Day Flight Schedules, October 2014; BNP Associates, October 2014

Table G.2-9 | Boarding Area B and C Facility Requirements

FACILITY REQUIREMENTS	PLANNING ACTIVITY LEVEL		
	2018	BASE CONSTRAINED	HIGH CONSTRAINED
Originating Bag Rate (Bags per Minute)	26	29	31
Transfer Bag Rate (Bags per Minute)	7	8	8
Screening Bag Rate (Bags per Minute)	28	30	33
Early Bag Storage (Number of Bags)	527	602	635
Make-Up Requirements with EBS (Positions)	108	108	112
Make-Up Requirements without EBS (Positions)	152	153	158
Arrival Bag Rate (Bags per Minute)	75	83	89
Claim Presentation (Linear Feet)	1,067	1,291	1,601

Note: EBS = Early Bag Storage

Sources: Landrum & Brown, Peak Month Average Day Flight Schedules, October 2014; BNP Associates, October 2014

Table G.2-10 | Boarding Area D Facility Requirements

FACILITY REQUIREMENTS	PLANNING ACTIVITY LEVEL		
	2018	BASE CONSTRAINED	HIGH CONSTRAINED
Originating Bag Rate (Bags per Minute)	10	14	17
Transfer Bag Rate (Bags per Minute)	9	11	13
Screening Bag Rate (Bags per Minute)	15	17	21
Early Bag Storage (Number of Bags)	254	335	411
Make-Up Requirements with EBS (Positions)	46	62	70
Make-Up Requirements without EBS (Positions)	63	86	97
Arrival Bag Rate (Bags per Minute)	42	52	56
Claim Presentation (Linear Feet)	460	720	924

Note: EBS = Early Bag Storage

Sources: Landrum & Brown, Peak Month Average Day Flight Schedules, October 2014; BNP Associates, October 2014

Table G.2-11 | Boarding Area D (United Airlines Only) Facility Requirements

FACILITY REQUIREMENTS	PLANNING ACTIVITY LEVEL		
	2018	BASE CONSTRAINED	HIGH CONSTRAINED
Originating Bag Rate (Bags per Minute)	2	2	3
Transfer Bag Rate (Bags per Minute)	22	15	19
Screening Bag Rate (Bags per Minute)	4	6	8
Early Bag Storage (Number of Bags)	118	119	150
Make-Up Requirements with EBS (Positions)	16	17	20
Make-Up Requirements without EBS (Positions)	21	23	29
Arrival Bag Rate (Bags per Minute)	32	21	34
Claim Presentation (Linear Feet)	265	210	275

Note: EBS = Early Bag Storage
Sources: Landrum & Brown, Peak Month Average Day Flight Schedules, October 2014; BNP Associates, October 2014

Table G.2-12 | Boarding Area E/F Facility Requirements

FACILITY REQUIREMENTS	PLANNING ACTIVITY LEVEL		
	2018	BASE CONSTRAINED	HIGH CONSTRAINED
Originating Bag Rate (Bags per Minute)	17	20	21
Transfer Bag Rate (Bags per Minute)	36	33	42
Screening Bag Rate (Bags per Minute)	21	23	25
Early Bag Storage (Number of Bags)	727	845	900
Make-Up Requirements with EBS (Positions)	116	122	127
Make-Up Requirements without EBS (Positions)	184	192	200
Arrival Bag Rate (Bags per Minute)	52	47	61
Claim Presentation (Linear Feet)	710	702	718

Note: EBS = Early Bag Storage
Sources: Landrum & Brown, Peak Month Average Day Flight Schedules, October 2014; BNP Associates, October 2014

Table G.2-13 | Boarding Area G Facility Requirements

FACILITY REQUIREMENTS			
	2018	BASE CONSTRAINED	
Originating Bag Rate (Bags per Minute)	15	22	
Transfer Bag Rate (Bags per Minute)	14	26	20
Screening Bag Rate (Bags per Minute)	20	27	
Early Bag Storage (Number of Bags)	434	591	680
Make-Up Requirements with EBS (Positions)	88	97	
Make-Up Requirements without EBS (Positions)	107	127	126
Arrival Bag Rate (Bags per Minute)	66	106	
Claim Presentation (Linear Feet)	1,508	2,016	2,212

Note: EBS = Early Bag Storage
Sources: Landrum & Brown, Peak Month Average Day Flight Schedules, October 2014; BNP Associates, October 2014

Table G.2-14 | Boarding Area H Facility Requirements

FACILITY REQUIREMENTS	PLANNING ACTIVITY LEVEL		
	2018	BASE CONSTRAINED	HIGH CONSTRAINED
Originating Bag Rate (Bags per Minute)	0	1	2
Transfer Bag Rate (Bags per Minute)	0	4	11
Screening Bag Rate (Bags per Minute)	0	2	2
Early Bag Storage (Number of Bags)	0	41	74
Make-Up Requirements with EBS (Positions)	0	5	8
Make-Up Requirements without EBS (Positions)	0	8	10
Arrival Bag Rate (Bags per Minute)	0	5	16
Claim Presentation (Linear Feet)	0	66	127

Note: EBS = Early Bag Storage
Sources: Landrum & Brown, Peak Month Average Day Flight Schedules, October 2014; BNP Associates, October 2014

G.3 Alternatives Analysis

A number of high-level BHS alternatives were developed to evaluate as many feasible concepts as possible for the final configurations of the overall BHS. With input from the stakeholders, evaluation criteria were developed to score the alternatives and determine a recommended option. This section details the drivers for alternatives development, reviews each alternative developed, describes the evaluation criteria, and identifies the scoring of each.

G.3.1 Project Drivers

For the development of the alternative configurations, several groups of project drivers were identified:

- Overall ADP goals
- Plant replacement
- Health/safety issues
- Demand/growth
- Functionality

The following ADP objectives relevant to the BHS were defined:

- Maximize gate capacity, geometry, and flexibility
- Optimize lobby and security flows to meet future needs and technology
- Maximize transfer connectivity for guests and baggage
- Maximize shared use facility and baggage claim flexibility
- Improve airline, TSA, and other stakeholder process efficiency

In order to achieve the above goals, the future BHS must have a high level of flexibility and connectivity. This design is significantly different from the existing conditions where most of the BHSs are independent systems that are not connected to each other.

The other two significant goals involve reducing energy consumption and operational costs for stakeholders including, but not limited to:

- Airport
- Airlines
- Ground handlers
- TSA

System Replacement

The existing systems at the Airport are aging. While new screening systems were implemented after September 11, 2001, the majority of the conveyor and sorting systems are from the 1990s or earlier. **Table G.3-1** and **Table G.3-2** below indicate the estimated operational life of BHS equipment as well as the screening equipment at SFO compared its expected end of life.

Table G.3-1 | Typical System Life Expectancy

SYSTEM	LIFE EXPECTANCY
Baggage Handling System Conveyors, Carousels, etc.	15 to 20 years
Screening Equipment	7 to 10 years although TSA has indicated that it may extend the life to 15 years for some systems

Source: TSA PGDS Version 5, August 2015; BNP Associates, October 2015

Table G.3-2 | System Age and Expected End of Life Dates

TERMINAL / BOARDING AREA	BHS COMMISSIONING DATE	BHS END OF LIFE	SCREENING SYSTEMS TYPE	SCREENING SYSTEM COMMISSIONING	SCREENING SYSTEM END OF LIFE
Terminal 1 B/As B and C	1975 - 2005	System being replaced	Morpho CTX 9000s	2003 6 systems	2019
Terminal 2 B/A D	2009	2029	Morpho CTX 9400s	2009	2019
Terminal 3 B/A E	1980	Beyond EOL	CTX 9000s	2004	Beyond EOL
Terminal 3 B/A F	1980 - 1992	Most beyond EOL	CTX 9000 and 9800	2003	Beyond EOL except 9800
IT B/A G	2000	2020	CTX 9000 and 9800	2002	Beyond EOL except 9800
IT B/A A	2000	2020	CTX 9000	2002	Beyond EOL

Source: Site survey and SFO Staff Interviews, October 2014; BNP Associates, October 2015

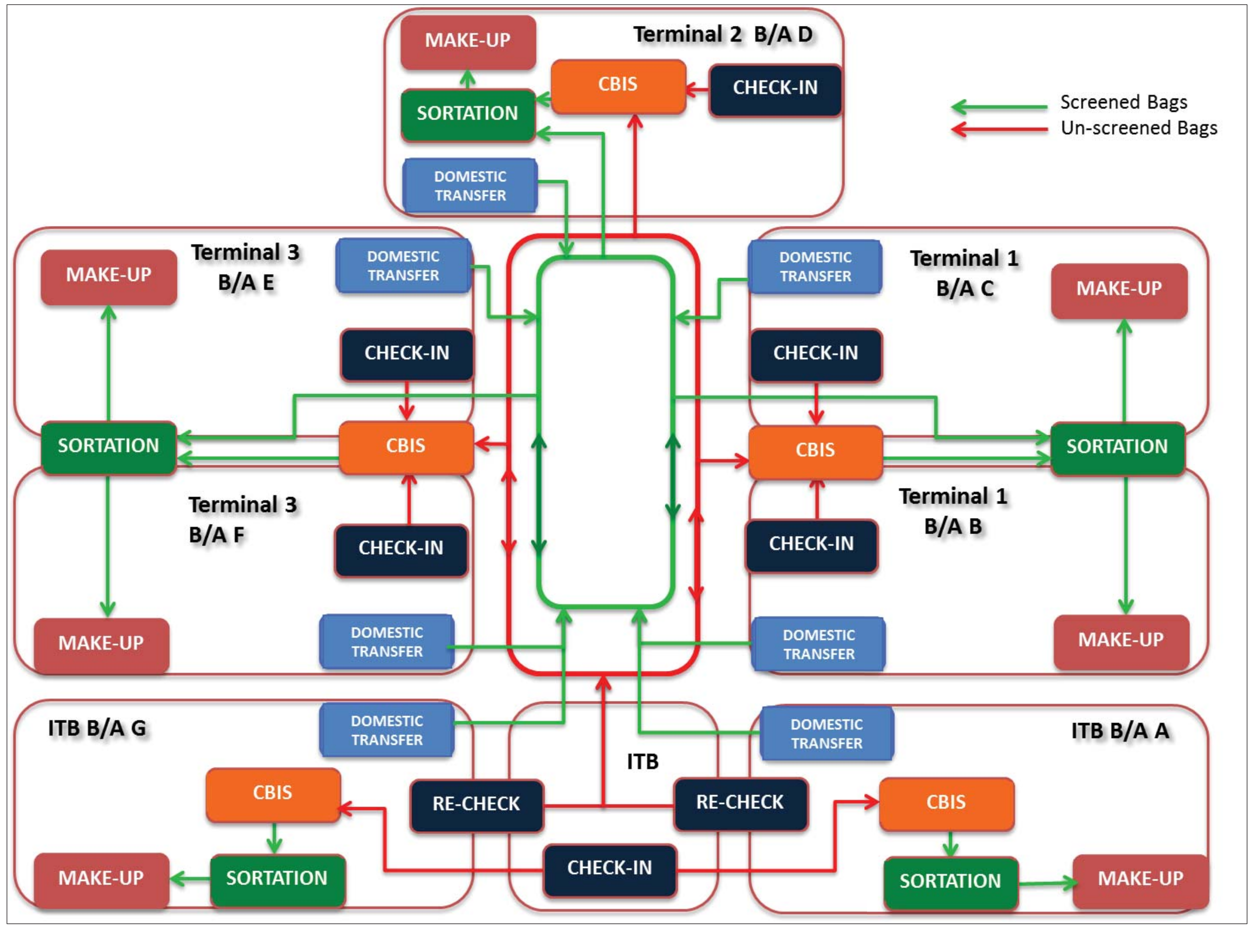
Demand Growth

The forecast growth at SFO demands additional baggage handling capability in all terminals and between terminals. As passenger movements increase and become more complicated, baggage movements need to conform to these increases and changes. Passengers will expect improved services from airports such as convenient acceptance and delivery of baggage with improved technology and automation.

Functionality

The diagram in **Exhibit G.3-1** demonstrates the existing connectivity between facilities, which only exists in the boarding areas shown. The Terminal 2 BHS is completely independent. Within the existing Terminal 1, there are multiple independent BHSs; therefore, neither terminal is shown in the connectivity diagram.

Exhibit G.3-1 | Functional Diagram of Connectivity Between Different BHSs



Source: BNP Associates, October 2015

One of the main objectives of the BHS projects is to provide connectivity between as many BHSs as possible so that check-in, security screening, and make-up can occur anywhere for any given flight. This design would allow the Airport to accommodate variability in the airline industry without making costly changes to physical systems.

Redundancy

Today, a majority of the connections for the aforementioned systems utilize single conveyors that fail to protect baggage when mechanical failures occur. In addition, manual processes in many locations reduce capacity and require higher staffing levels to handle baggage. The lack of connectivity also results in multiple handlings because bags must be sorted in one boarding area before transport to another. Although the conveyance is sometimes automated, multiple handling events reduce the effective capacity of the systems.

Outbound Baggage Output Close to Gates

Another component of the proposed BHS projects is to provide output of outbound baggage as close to the boarding gates as practical for any new outbound system (B/A H and Terminal 1 systems). Positioning bags in close proximity to their departure gates within the BHS will reduce overall processing time and ramp congestion and provide a more sustainable overall baggage process, as transporting baggage via a fixed system is more energy efficient than transporting via ramp vehicles.

G.3.2 Common Themes Among the Alternatives

Check-In

Check-in expansion is not proposed under the baggage projects of the ADP. Instead, evaluation of the check-in requirements related to the usage of home/mobile check-in and bag drops will require evaluation as baggage systems upgrades occur. It is generally believed that reduced processing times would also reduce the required space and facilities for check-in, but for the purpose of this analysis, it is assumed that the number of check-in positions currently provided is sufficient.

For Terminal 1, the check-in would be replaced as part of the general Terminal 1 project. As discussed in **Section 5.3.3**, the ITB improvements include a number of options to redevelop the ITB check-in.

Aside from the Terminal 1 redevelopment, the proposed ADP plans for the addition of some gates in B/A F, but the main expansion occurs in B/A H. Additional check-in demand for B/A H would be accommodated in the ITB. The ITB check-in is currently underutilized and can support additional capacity for B/A H. However, the increased baggage volume would require additional BHS capability to accommodate B/A H operations.

Oversize and Non-Conveyable Baggage

With conventional conveyors, it is not practical to transport and sort oversize baggage over a longer distance because they require dedicated rights-of-way and infrastructure. Additionally, fragile items, live animals, and oversize baggage cannot be transported via conveyors.

Contrary to the goals of the ADP, manual transport to a consolidated screening location and redistribution to the make-up locations would require significant additional staffing. It is therefore proposed that in all cases, some form of local screening remains at check-in for oversize and non-conveyable baggage. To obtain optimal efficiency, it is proposed that wherever possible this screening occurs near the passenger screening checkpoints because TSA staff and related support facilities are present, regardless of a check-in baggage screening requirement. The flow of oversize and non-conveyable baggage is relatively minor and non-continuous compared to the flow of normal check-in baggage. Therefore, dedicated facilities for screening of oversize and non-conveyable bags would not be efficient.

Baggage Storage and Distribution Systems

Automated bulk baggage storage and retrieval systems can substantially improve baggage processing efficiency. Making use of racking and cranes allows an item to be stored and retrieved individually according to priority. This maximizes flexibility and control. It can also reduce resource requirements by delivering bags to appropriate locations when required as opposed to when baggage is received from the passenger. Vertically stacked storage systems also reduce the footprint required to accommodate early bags, which would otherwise be routed directly to make-up areas.

Arrivals Baggage

It is assumed that the reconstruction of Terminal 1 will provide sufficient capacity to accommodate future demand; therefore, the Terminal 1 requirements are not addressed here.

The existing capacity of the arrivals claim carousels in Terminal 2 and Terminal 3 is sufficient for the calculated requirements of the future flight schedules.

The design day flight schedule uses a fixed transfer rate regardless of what time the flight operates. In reality, the amount of transfer baggage will fluctuate throughout a day (e.g., last flights arriving vs. first flights arriving). For hub carriers like United, which have a high transfer rate, these variations can cause significant differences in demand. The capacity of the arrivals carousels in Terminal 3 has been verified to be sufficient to meet demand even with 100 percent terminating passengers on incoming flights.

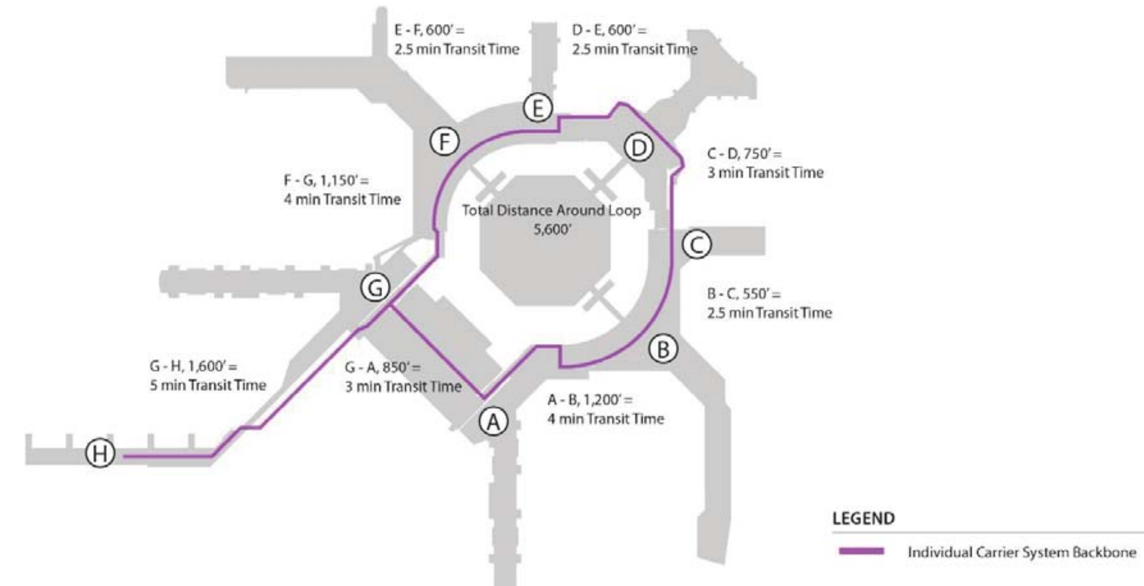
While no increase in arrivals carousel quantity or length is proposed for Terminal 3, some of the alternatives include baggage delivery improvements to these carousels such as input closer to the aircraft and transport on a common system with the outbound baggage.

For the ITB, the available BHS capacity is not sufficient to accommodate the forecast requirements. As discussed in the Inventory chapter, the ongoing ITB Arrivals Level Improvements project addresses the deficiencies in baggage claim capabilities.

Backbone

With the exception of Alternative 1, all other alternatives propose a method to interconnect the various baggage handling facilities at the airport. This design is referred to as the "backbone." A schematic diagram of one BHS backbone alternative is depicted in **Exhibit G.3-2**.

Exhibit G.3-2 | BHS Backbone Schematic

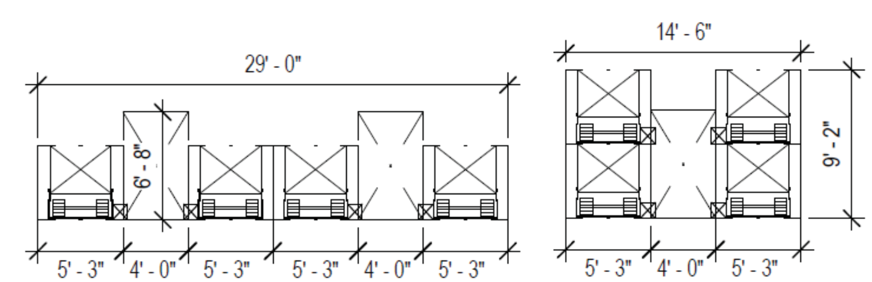


Source: SFO Bureau of Planning and Environmental Affairs; SFO Airport Layout Plan 2014; BNP Associates, October 2015

This diagram shows the end state of construction; however, the backbone would be constructed in phases during other major work on the various boarding areas and terminals.

In general, the backbone is intended to consist of a bidirectional four-conveyor system. This configuration provides a theoretical capacity of 90 bags per minute in each direction and provides for a capacity during single conveyor failure of 45 bags per minute. **Exhibit G.3-3** shows two examples of typical cross sections of this backbone including conveyor and maintenance access rights-of-way.

Exhibit G.3-3 | BHS Backbone Dimensions



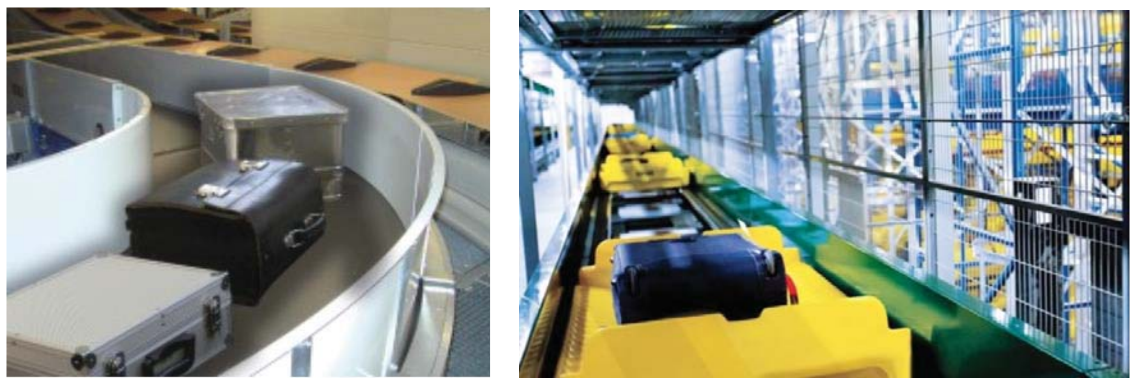
Source: BNP Associates, October 2015

Due to the travel distances and complexity of the routing, conventional conveyors are not practical for the backbone. Instead, an individual carrier system (ICS) is proposed.

Conventional conveyors transport baggage directly on a belt. The highly variable and unpredictable nature of baggage (e.g., sizes, weights, materials, trailing straps, etc.) can cause numerous issues on conventional conveyors such as baggage jams and loss of tracking (i.e., computer systems may lose track of a bag's location).

In an ICS, bags are placed in a standard carrier (i.e., tray) for transport. These carriers are predictable transport units and have a permanent identification that can be read via radio frequency identification (RFID). Once the bag is initially identified and loaded into the carrier, the control systems are able to monitor and control carrier movement throughout its journey, regardless of distance and routing. **Exhibit G.3-4** depicts an example of a conventional baggage conveyor on the left and an ICS conveyor on the right.

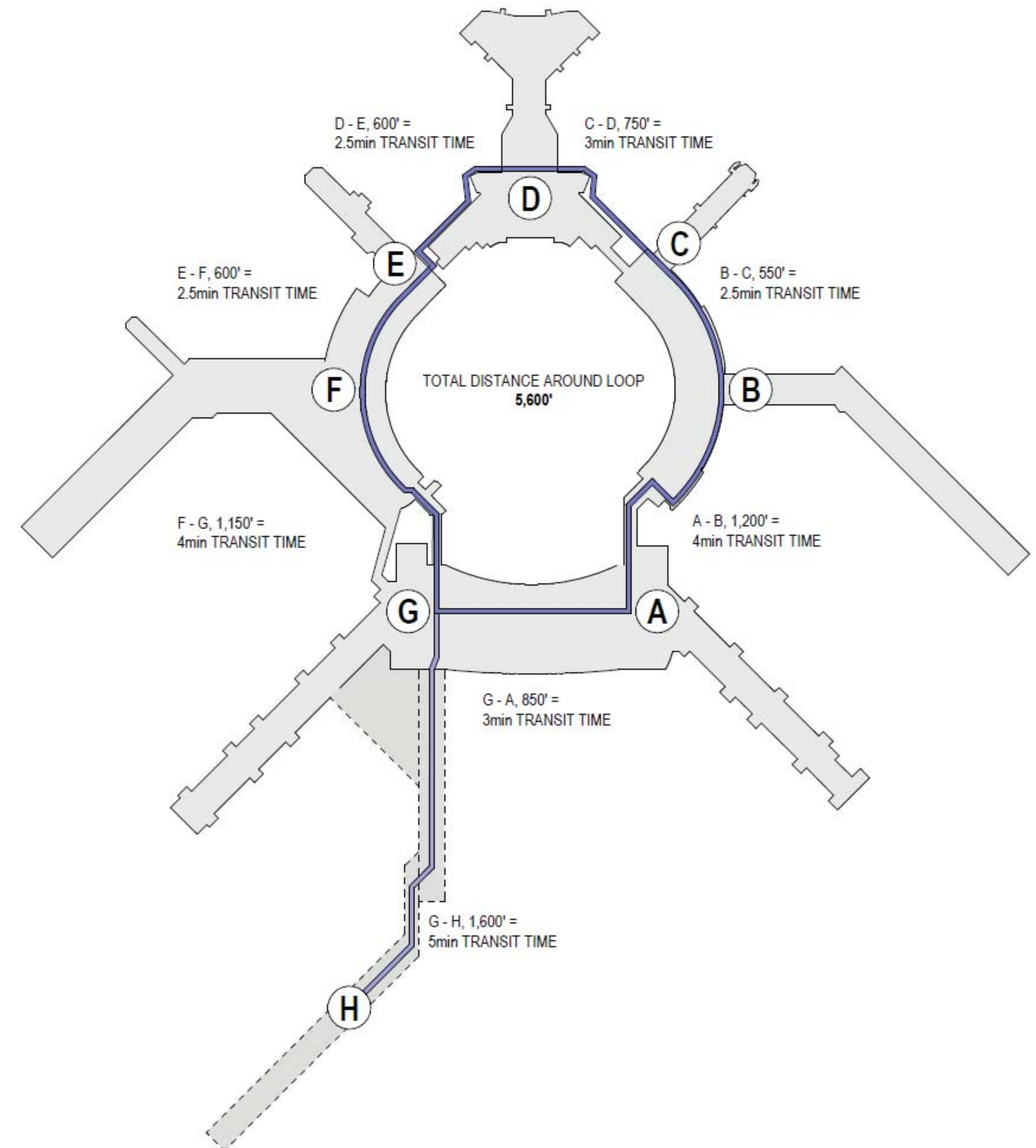
Exhibit G.3-4 | Conventional and ICS Conveyors



Source: Vanderlande Industries, 2014

The travel time on the backbone between boarding areas would be relatively constant at 2 to 4 minutes between neighboring boarding areas. A bag traveling from B/A G to B/A D would spend approximately nine minutes on the backbone as it would travel through three segments of the backbone. This travel would occur at an assumed speed of approximately 400 feet per minute plus an additional minute reservation per boarding area for local routing distances. While the technology supports speeds up to 2,000 feet per minute, the nature and curved geometry of the terminal buildings prevents the practical application of higher speeds. **Exhibit G.3-5** depicts the approximate transport time on each segment of the backbone.

Exhibit G.3-5 | Backbone Transport Times



Source: SFO Bureau of Planning and Environmental Affairs; SFO Airport Layout Plan 2014; BNP Associates, October 2015

G.3.3 Evaluation

The ADP team along with the airport stakeholders produced a set of criteria with which to evaluate each alternative. Because all criteria have varying levels of importance, a relative weight was assigned to each. Each alternative has been evaluated in each category on a scale of 1 to 5, with “1” indicating a negative score and “5” indicating a positive score.

1. Strong Negative (i.e., high impact, low feasibility, high cost, low flexibility)
2. Negative
3. Neutral
4. Positive
5. Strong Positive (i.e., low impact, high feasibility, low cost, high flexibility)

The evaluation criteria are:

1. Operational Process Control and Flexibility:
   - The ability to route and transfer bags between boarding areas to allow flexible allocation of airlines and aircraft stands across the boarding areas.
   - The degree of process control which implies knowledge of each bag’s location at any time and the ability to change the baggage route while in transit.
2. Capital Cost: The initial cost of the BHS and TSA provided screening equipment
3. Operational Cost: The relative operational cost of operation for the baggage handling systems in terms of staff (Airport, airlines, ground handler, and maintenance staff), energy usage, and material. For material, the consumption of parts and the cost of operational vehicles such as tugs are considered.
4. Achieving the Principles of R.E.A.C.H.: The degree to which the alternative achieves or contributes to R.E.A.C.H. by providing opportunities for revenue enhancement and passenger service improvements such as: remote check-in and bag drops, bag drops at BART stations, supporting shorter (later) check-in or close-out, or shorter connections.
5. Environmental Impact: The relative environmental impact of the BHS in terms of energy usage and materials of the BHS. Energy usage is primarily driven by the quantity of bags and the distance the bags need to be transported. For material, the relative quantity of material and the ability to use sustainable materials is considered.
6. Feasibility and Phasing: The feasibility of the option and the ability to construct the option in smaller steps/phases.

Table G.3-3 describes the weighing of each criterion.

Table G.3-3 | Evaluation Criteria Weighing

CRITERION	WEIGHT
1. Operational Process Control and Flexibility	20%
2. Capital Cost	15%
3. Operational Cost	30%
4. Achieving REACH	15%
5. Environmental	10%
6. Feasibility and Phasing	10%
Total	**100%**

Source: BNP Associates, October 2015

G.3.4 Alternatives

The following pages provide a graphical representation of each of the alternatives that were evaluated, including the scoring in each category. Each alternative varies in at least one of the following aspects:

1. Location of CBRA(s)
2. Number of CBRA(s)
3. Location of CBIS(s)
4. Number of CBIS(s)
5. Extent of BHS backbone

Alternative 1 – Optimization of Existing CBIS

This alternative involves the optimization of the existing BHS and CBIS in each boarding area. It is the equivalent of a no-build alternative, since screening equipment is always scheduled to be replaced at the end of its service life.

While this alternative can increase the capacity of each boarding area, it does not provide new connectivity between terminals and therefore does not support flexible assignment of airlines and aircraft across terminals.

The result would be five CBIS zones and five CBRA zones.

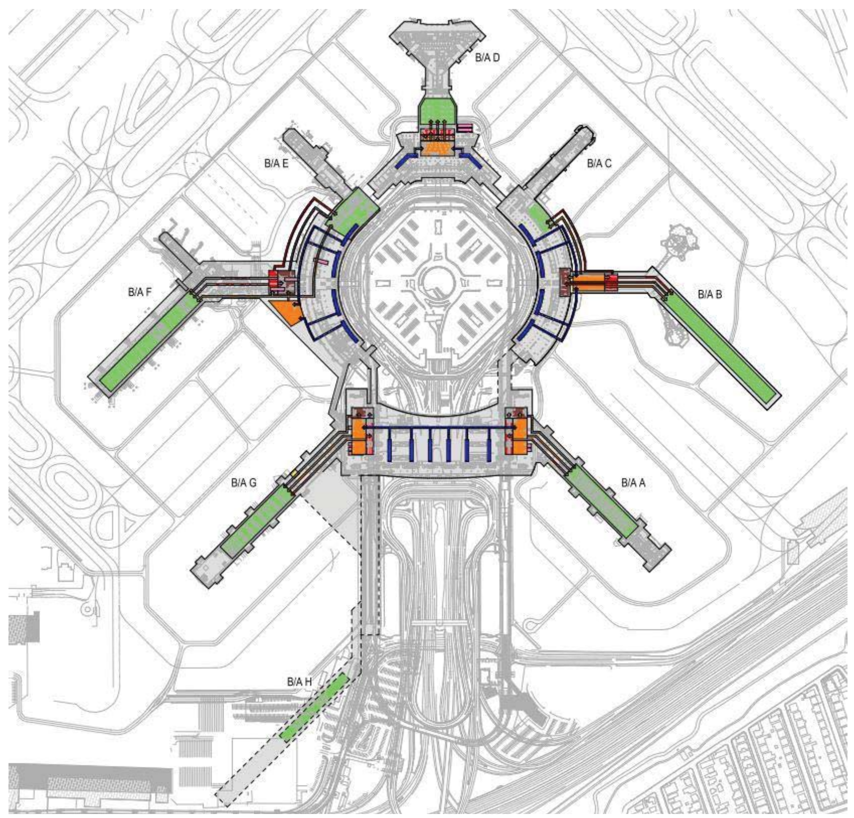
Advantages:

- Low initial investment
- Low initial impact on facilities

Disadvantages:

- Low flexibility
- Significant manual handling required for transfer baggage, increasing the potential for mishandling
- Distributed TSA staff and equipment
- Significantly higher total cost of ownership when system replacement is required
- Airline operational implications with lack of modern solution such as early bag storage

Criterion	Score
1. Operational Process Control and Flexibility	1
2. Capital Cost	4
3. Operational Cost	2
4. Achieving REACH	1
5. Environmental	1
6. Feasibility & Phasing	4



Source: SFO BPEA; SFO ALP 2014; BNP Associates, October 2015

Alternative 2 – 2-Way Split with Sort Connectivity

This alternative includes the creation of a BHS backbone that interconnects all boarding areas and consolidation of CBIS and CBRA into large facilities at Terminal 1 and Terminal 3. Terminal 2 and the ITB would not have their own screening facilities.

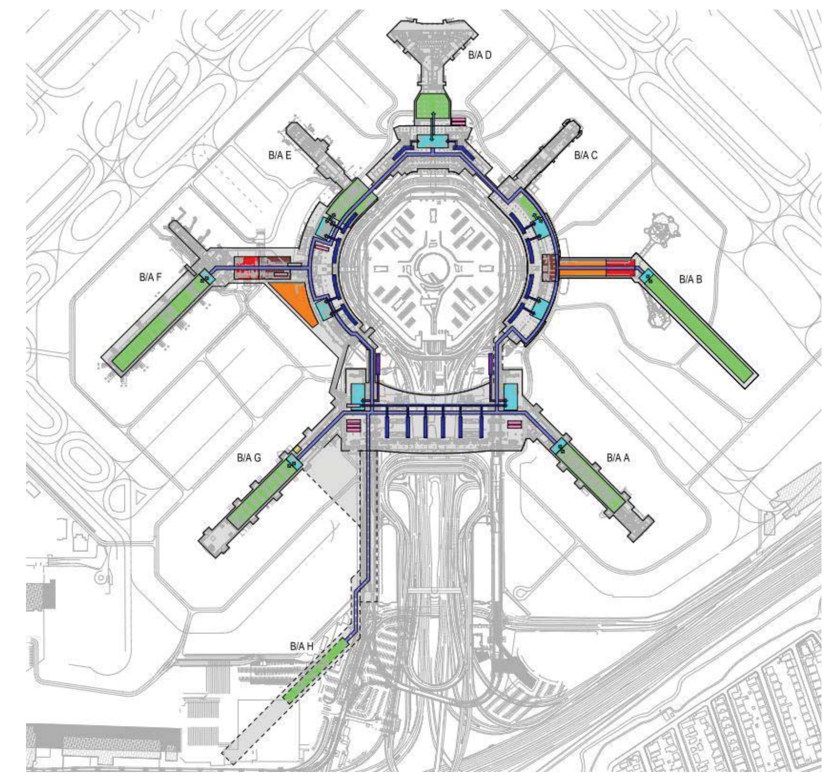
Advantages:

- Backbone connectivity provides high flexibility
- Reduced manual handling
- Consolidated TSA staff and equipment

Disadvantages:

- Higher capital investment
- Reliance on backbone for screening and transfer results in high loads and high complexity of operations during failure
- Travel time for bags that would otherwise stay in the same boarding area is increased due to transport to the consolidated CBIS zones and back
- Availability of sufficiently large spaces

Criterion	Score
1. Operational Process Control and Flexibility	5
2. Capital Cost	3
3. Operational Cost	5
4. Achieving REACH	4
5. Environmental	3
6. Feasibility & Phasing	3



Source: SFO BPEA; SFO ALP 2014; BNP Associates, October 2015

Alternative 3 – 3-Way Split with Sort Connectivity

This alternative includes the creation of a BHS backbone that interconnects all boarding areas and consolidation of CBIS and CBRA into three large facilities at Terminal 1, Terminal 2, and Terminal 3. The ITB would not have its own screening facilities.

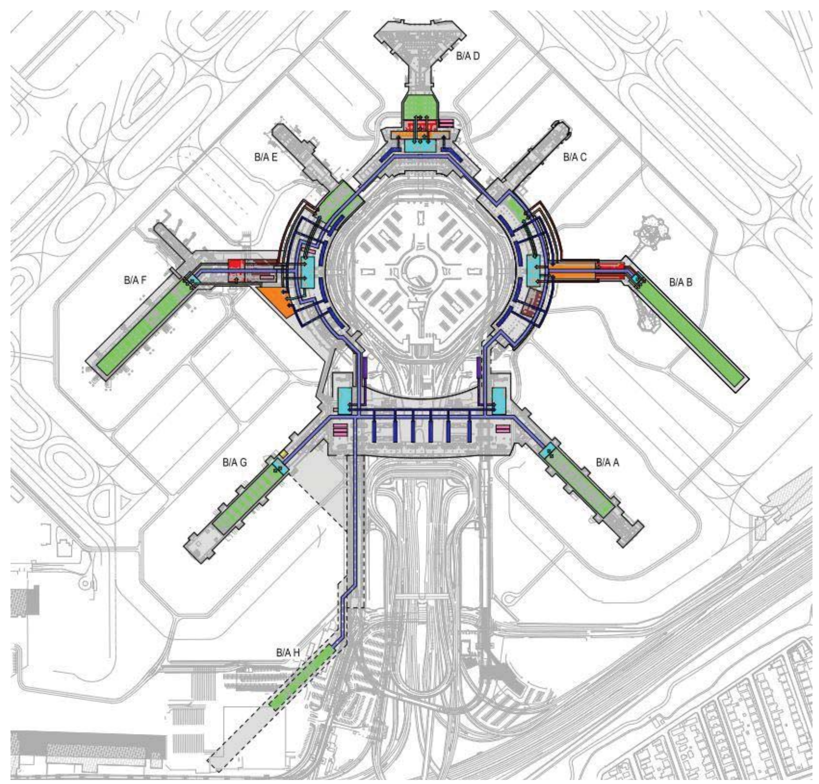
Advantages:

- Backbone connectivity provides high flexibility
- Reduced manual handling
- Consolidated TSA staff and equipment (more consolidated than Alternative 1 but less consolidated than Alternative 2)

Disadvantages:

- High investment
- Reliance on backbone for screening and transfer results in high loads and high complexity of operations during failure
- Travel time for bags that would otherwise stay in the same boarding area is increased due to transport to the consolidated CBIS zones and back
- Availability of sufficiently large spaces

Criterion	Score
1. Operational Process Control and Flexibility	5
2. Capital Cost	3
3. Operational Cost	4
4. Achieving REACH	4
5. Environmental	3
6. Feasibility & Phasing	3



Source: SFO BPEA; SFO ALP 2014; BNP Associates, October 2015

Alternative 4 – Distributed CBIS / West CBRA

This alternative includes the creation of a BHS backbone that interconnects all boarding areas and the consolidation of CBRA into one location. The ICS backbone extension to B/A H would be installed as part of the boarding area construction project. It is not shown in the exhibits for Alternatives 4 through 7.

Security screening is distributed to a CBIS in each boarding area; however, the most staff intensive TSA process (the CBRA function) is consolidated to a single location in Terminal 3.

Advantages:

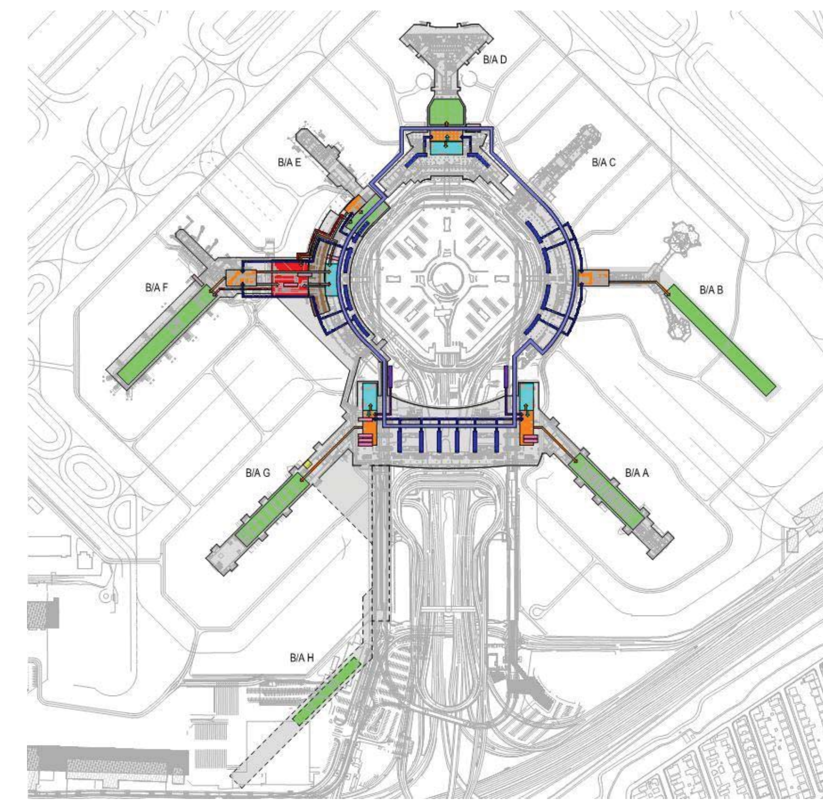
- Backbone connectivity provides high flexibility
- Reduced manual handling
- Consolidated TSA staff
- Only bags requiring CBRA processing and transfer bags require transport on the backbone (less load compared to Alternatives 2, 3, and 4)

Disadvantages:

- High investment
- Non-conveyable bags (e.g., fragile items, animals, very large items, etc.) must still be screened in each boarding area
- Distributed TSA equipment
- Single CBRA presents redundancy/disaster tolerance challenges
- Reliance on backbone for the transfer of CBRA baggage results in high complexity of operations during failure.

Due to the single CBRA location, travel time for bags requiring CBRA processing is longer compared to alternatives with multiple CBRA locations.

Criterion	Score
1. Operational Process Control and Flexibility	5
2. Capital Cost	3
3. Operational Cost	4
4. Achieving REACH	4
5. Environmental	2
6. Feasibility & Phasing	2



Source: SFO BPEA; SFO ALP 2014; BNP Associates, October 2015

Alternative 4B – Distributed CBIS / West CBRA

This alternative includes the creation of a BHS backbone that interconnects all boarding areas. The backbone is not a 'ring' as in the other alternative but rather a partial ring with a direct connection between Terminal 1 and 3.

Screening would be distributed to a CBIS in each boarding area; however, the most staff intensive TSA process (the CBRA function) would be consolidated to a single location in Terminal 1.

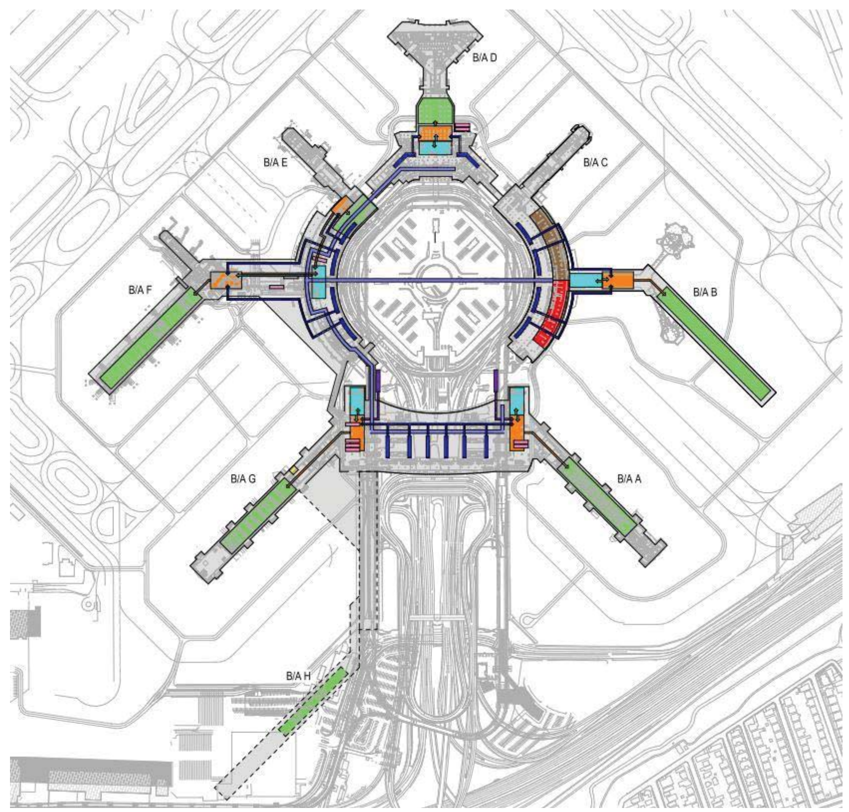
Advantages:

- Backbone connectivity provides high flexibility
- Reduced manual handling
- Consolidated TSA staff
- Only bags requiring CBRA processing and transfer bags require transport on the backbone (less load compared to Alternatives 2, 3, and 4)

Disadvantages:

- High investment
- Non-conveyable bags (e.g., fragile items, animals, very large items, etc.) must still be screened in each boarding area
- Distributed TSA equipment
- Single CBRA presents redundancy/disaster tolerance challenges
- Reliance on backbone for transfer of CBRA baggage results in high complexity of operations during failure
- Due to a single CBRA location, travel time for bags requiring CBRA processing is longer compared to alternatives with multiple CBRA locations

Criterion	Score
1. Operational Process Control and Flexibility	5
2. Capital Cost	3
3. Operational Cost	4
4. Achieving REACH	4
5. Environmental	2
6. Feasibility & Phasing	2



Source: SFO BPEA; SFO ALP 2014; BNP Associates, October 2015

Alternative 4C – Distributed CBIS / Central CBRA

This alternative includes the creation of a BHS backbone that interconnects all boarding areas.

Screening would be distributed to a CBIS in each boarding area; however, the most staff intensive TSA process (the CBRA function) would be consolidated to a single location in the parking garage. It would be connected to the backbone between Terminal 3 and the ITB.

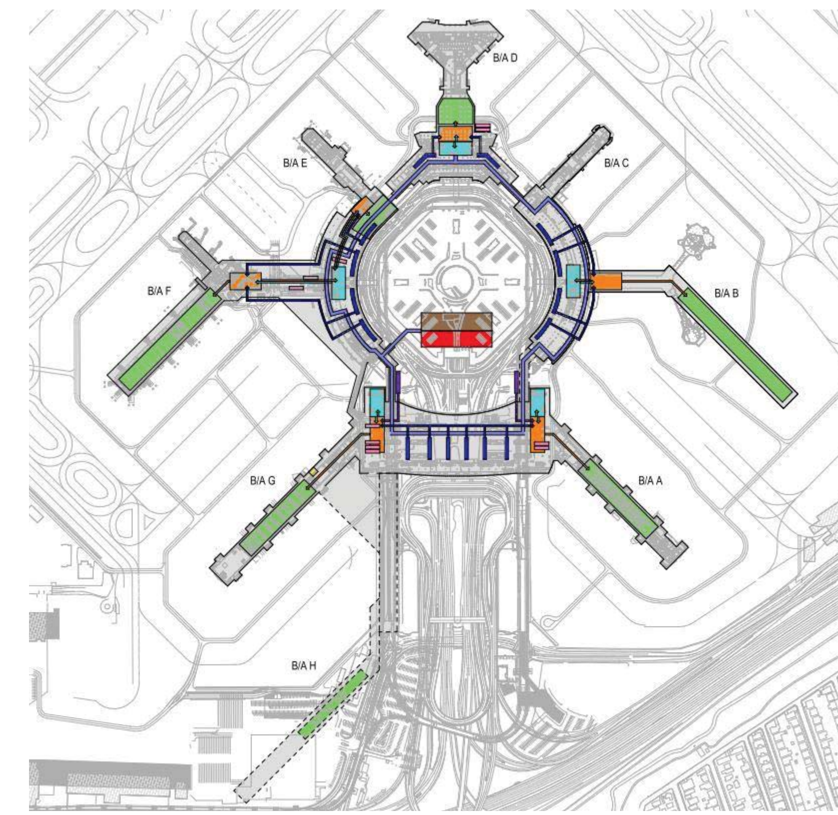
Advantages:

- Backbone connectivity provides high flexibility
- Reduced manual handling
- Consolidated TSA staff
- Only bags requiring CBRA processing and transfer bags require transport on the backbone (less load compared to Alternatives 2, 3, and 4)

Disadvantages:

- High investment
- Non-conveyable bags (e.g., fragile items, animals, very large items, etc.) must still be screened in each boarding area
- Distributed TSA equipment
- Single CBRA presents redundancy/disaster tolerance challenges
- Reliance on backbone for transfer of CBRA baggage results in high complexity of operations during failure
- Due to a single CBRA location, travel time for bags requiring CBRA processing is longer compared to alternatives with multiple CBRA locations (the longest of all options)

Criterion	Score
1. Operational Process Control and Flexibility	5
2. Capital Cost	3
3. Operational Cost	4
4. Achieving REACH	4
5. Environmental	2
6. Feasibility & Phasing	2



Source: SFO BPEA; SFO ALP 2014; BNP Associates, October 2015

Alternative 4D – Distributed CBIS / 2 CBRA

This alternative includes the creation of a BHS backbone that interconnects all boarding areas.

Security screening would be distributed to a CBIS in each boarding area; however, the most staff intensive TSA process (the CBRA function) would be consolidated to two locations (one in Terminal 1 and one in Terminal 3).

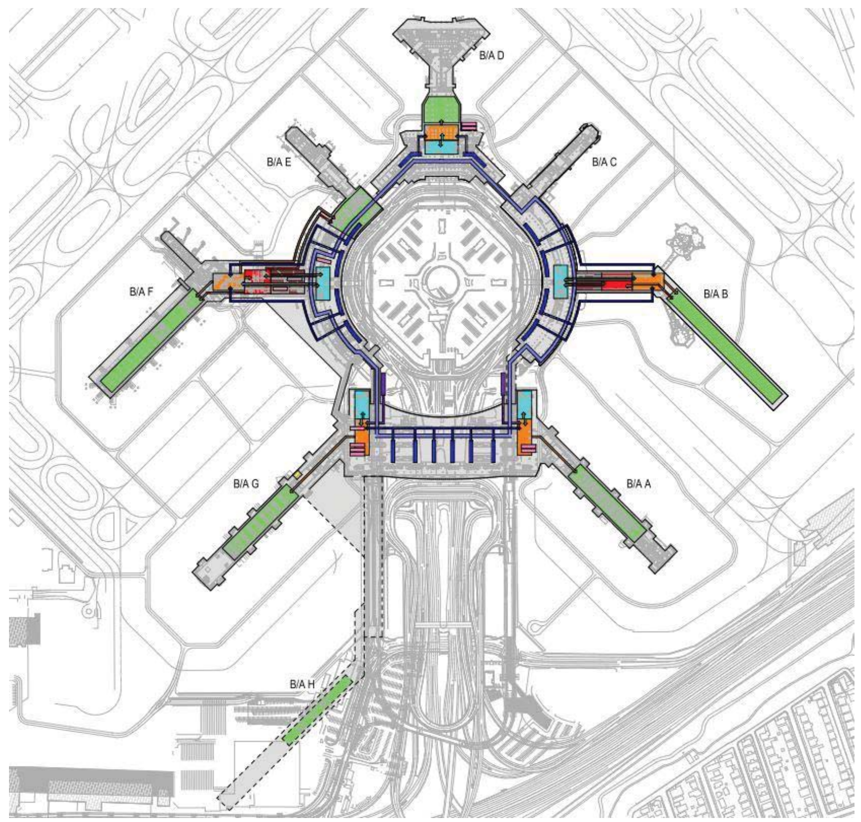
Advantages:

- Backbone connectivity provides high flexibility
- Reduced manual handling
- Consolidated TSA staff
- Only bags requiring CBRA processing and transfer bags require transport on the backbone (less load compared to Alternatives 2, 3, and 4)

Disadvantages:

- High investment
- Non-conveyable bags (e.g., fragile items, animals, very large items, etc.) must still be screened in each boarding area
- Distributed TSA equipment
- Reliance on backbone for transfer of CBRA baggage results in high complexity of operations during failure

Criterion	Score
1. Operational Process Control and Flexibility	4
2. Capital Cost	2
3. Operational Cost	5
4. Achieving REACH	5
5. Environmental	4
6. Feasibility & Phasing	3



Source: SFO BPEA; SFO ALP 2014; BNP Associates, October 2015

Alternative 4E – Distributed CBIS / 5 CBRA

This alternative includes the creation of a BHS backbone that interconnects all boarding areas. Screening would be distributed to a CBIS and CBRA in each boarding area.

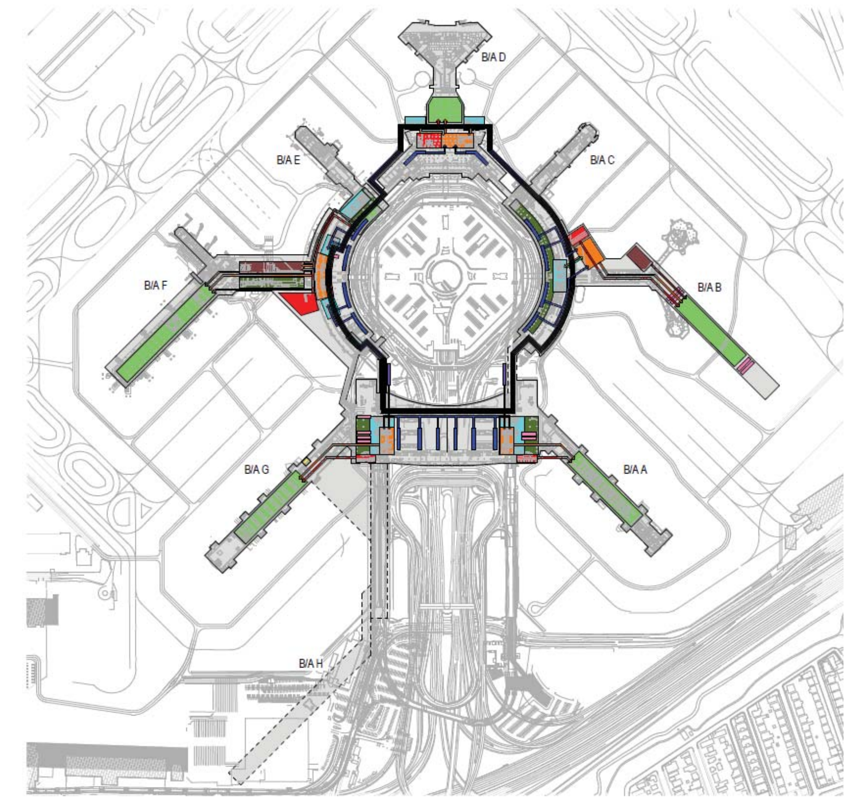
Advantages:

- Backbone connectivity provides high flexibility
- Reduced manual handling
- Only transfer bags require transport on the backbone (less load compared to Alternatives 2, 3, and 4)
- Non-conveyable bags (e.g., fragile items, animals, very large items, etc.) can be screened in each boarding area
- High disaster tolerance/redundancy because the screening functions are distributed.

Disadvantages:

- High investment
- Distributed TSA equipment
- Distributed TSA staff

Criterion	Score
1. Operational Process Control and Flexibility	5
2. Capital Cost	2
3. Operational Cost	4
4. Achieving REACH	5
5. Environmental	4
6. Feasibility & Phasing	5



Source: SFO BPEA; SFO ALP 2014; BNP Associates, October 2015

Alternative 5 – Centralized CBIS/CBRA

This alternative includes the creation of a BHS backbone that interconnects all boarding areas. All screening functions would be centralized in a new single CBIS area in the Central Parking Garage or Central Hub (see **Section 5.4**).

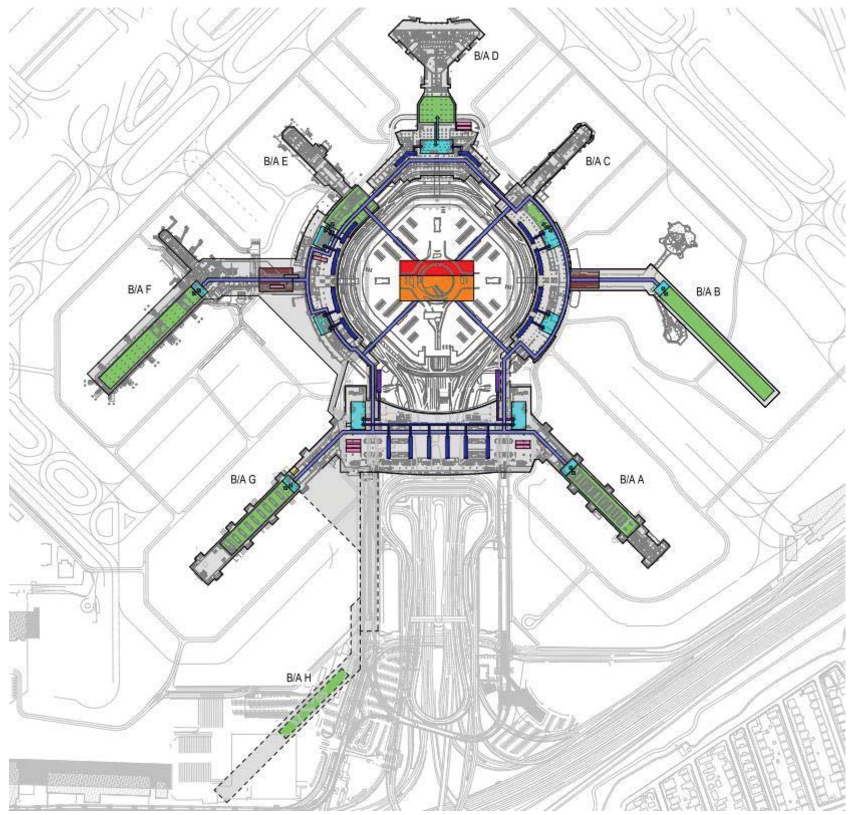
Advantages:

- Backbone connectivity provided high flexibility
- Reduced manual handling
- Consolidated TSA equipment
- Consolidated TSA staff

Disadvantages:

- High investment
- Non-conveyable bags (e.g., fragile items, animals, very large items, etc.) must still be screened in each boarding area
- Single CBIS/CBRA presents redundancy/disaster tolerance challenges
- Reliance on backbone for transfer of CBIS and CBRA baggage results in high complexity of operations during failure
- Due to a single CBRA location, travel time for bags requiring CBRA processing is longer compared to alternatives with multiple CBRA locations.

Criterion	Score
1. Operational Process Control and Flexibility	5
2. Capital Cost	1
3. Operational Cost	4
4. Achieving REACH	4
5. Environmental	2
6. Feasibility & Phasing	1



Source: SFO BPEA; SFO ALP 2014; BNP Associates, October 2015

Alternative 6 – Split CBRA / Optimized T2

In this alternative, the backbone interconnects all boarding areas except for Terminal 2 and B/A D.

Terminal 2 remains a standalone facility with its own CBIS and CBRA. All other boarding areas are interconnected via the backbone. Five CBIS zones are proposed (Terminal 1, Terminal 2, Terminal 3, B/A G, and B/A A). The CBRA in Terminal 2 is dedicated to the standalone Terminal 2 BHS. The other two CBRA zones serve the remaining terminals/boarding areas.

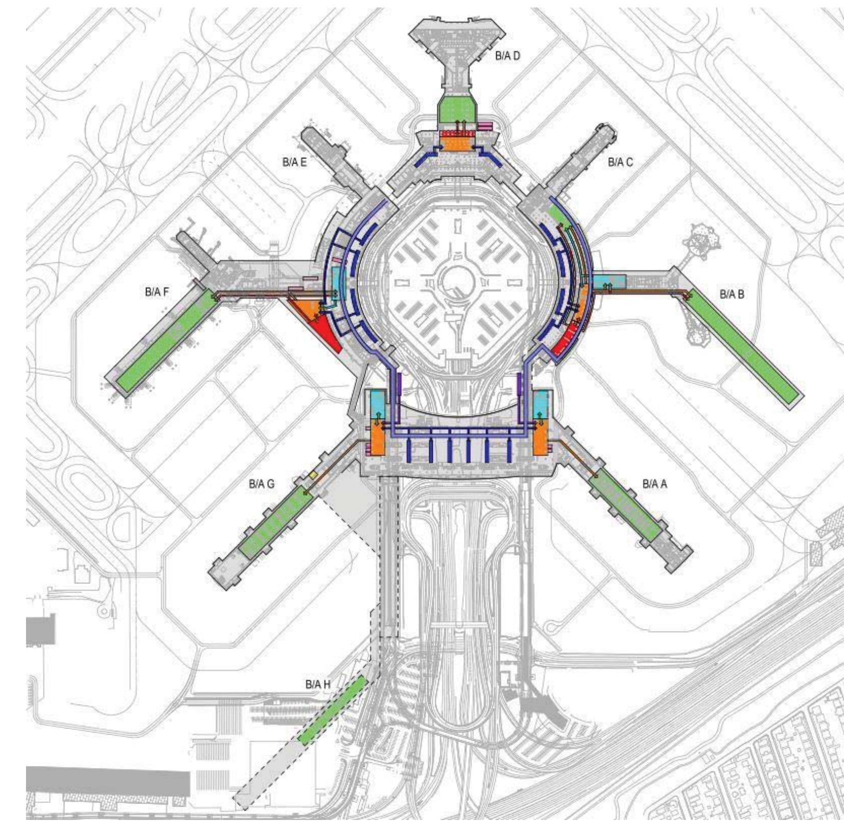
Advantages:

- Backbone connectivity provides high flexibility
- Reduced manual handling
- Consolidated TSA staff
- Only bags requiring CBRA processing and transfer bags require transport on the backbone (less load compared to Alternatives 2, 3, and 4)

Disadvantages:

- High investment
- Non-conveyable bags (e.g., fragile items, animals, very large items, etc.) must still be screened in each boarding area
- Distributed TSA equipment
- Reliance on backbone for transfer of CBRA baggage results in high complexity of operations during failure

Criterion	Score
1. Operational Process Control and Flexibility	3
2. Capital Cost	3
3. Operational Cost	3
4. Achieving REACH	3
5. Environmental	3
6. Feasibility & Phasing	2



Source: SFO BPEA; SFO ALP 2014; BNP Associates, October 2015

Alternative 7 – Split CBRA / Batching / Optimized Terminal 2

This alternative is a variation on Alternative 6 and has the same CBIS and CBRA arrangement. This alternative proposes implementation of batch building capability into B/As A, B, C, F, and G to reduce the staffing level requirements and reduce the apron level space requirements.

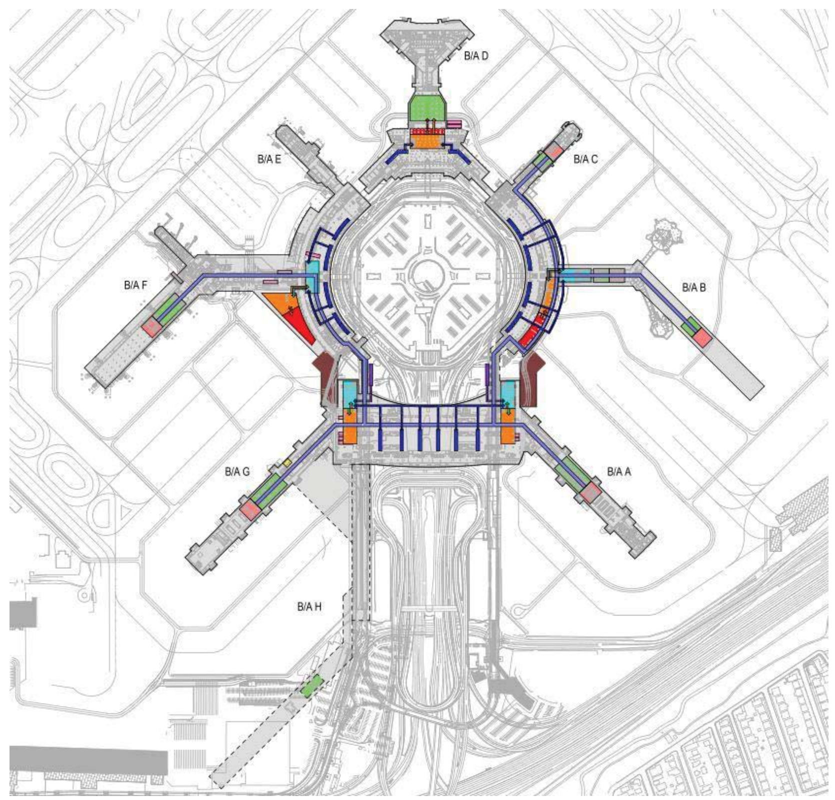
Advantages:

- Batch building automates the make-up process, thus reducing staff
- Backbone connectivity provided high flexibility
- Reduced manual handling
- Consolidated TSA staff
- Only bags requiring CBRA processing and transfer bags require transport on the backbone (less load compared to Alternatives 2, 3, and 4)

Disadvantages:

- High investment (highest amongst the alternatives)
- Non-conveyable bags (e.g., fragile items, animals, very large items, etc.) must still be screened in each boarding area.
- Distributed TSA equipment

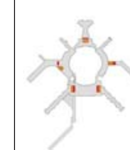
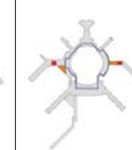
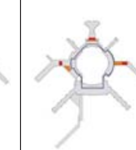
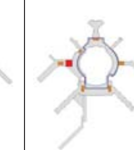
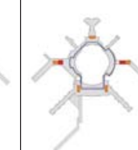
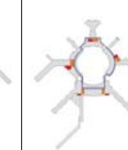
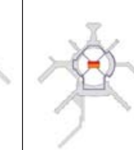
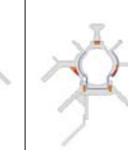
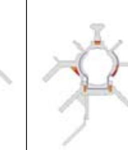
Criterion	Score
1. Operational Process Control and Flexibility	4
2. Capital Cost	1
3. Operational Cost	4
4. Achieving REACH	3
5. Environmental	3
6. Feasibility & Phasing	2



Source: SFO BPEA; SFO ALP 2014; BNP Associates, October 2015

G.3.5 Alternatives Evaluation

The matrix below shows the weighted score of each alternative. Based on the scoring, Alternative 4E is the recommended alternative.

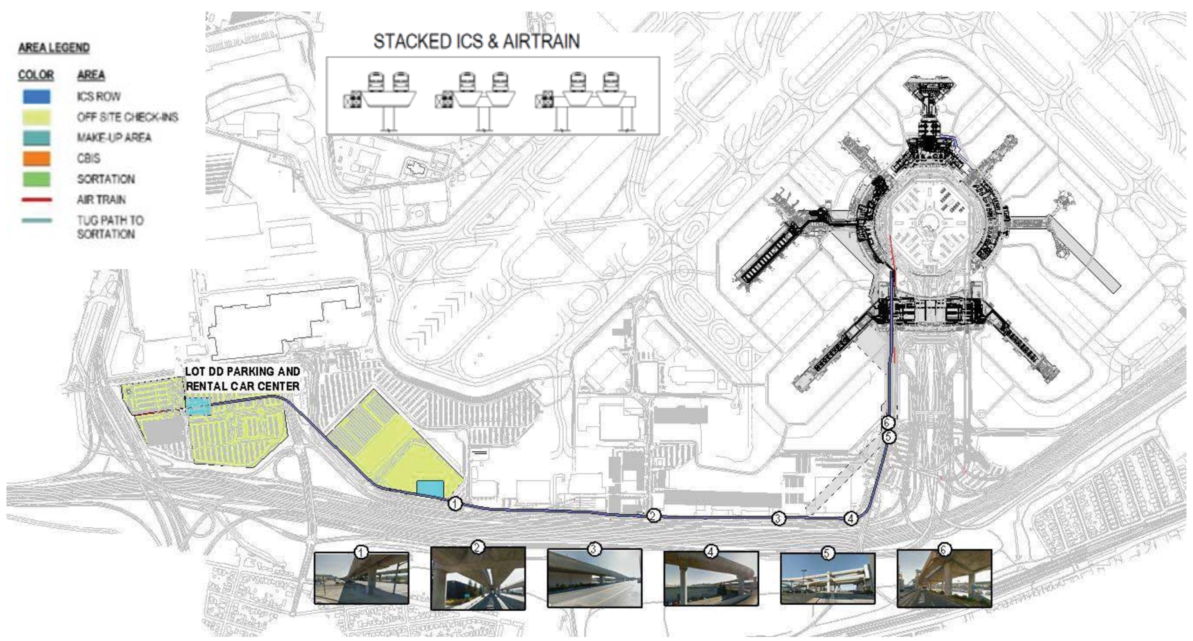
ALTERNATIVE	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3	ALTERNATIVE 4A/B/C	ALTERNATIVE 4D	ALTERNATIVE 4E	ALTERNATIVE 5	ALTERNATIVE 6	ALTERNATIVE 7
DESCRIPTION	Optimization of Existing CBIS	2-Way Split Without Sort Connectivity	3-Way Split Without Sort Connectivity	Distributed CBIS / 1 CBRA	Distributed CBIS / 2 CBRA	Distributed CBIS / 5 CBRA	Centralized CBIS/CBRA	Split CBRA / Optimized T2	Split CBRA / Batching / Optimized T2
DIAGRAM									
CRITERIA	Score	Score	Score	Score	Score	Score	Score	Score	Score
OPERATIONAL PROCESS CONTROL AND FLEXIBILITY	1	5	5	5	4	5	5	3	4
CAPITAL COST	4	3	3	3	2	2	1	3	1
OPERATIONAL COST	2	5	4	4	5	4	4	3	4
ACHIEVING REACH	1	4	4	4	5	5	4	3	3
ENVIRONMENTAL	1	3	3	2	4	4	2	3	3
FEASIBILITY and PHASING	4	3	3	2	3	5	1	2	2
WEIGHTED SCORE	2.1	4.2	3.9	3.7	4.3	4.2	3.3	2.9	3.1

G.3.6 Lot DD Parking Garages and Rental Car Center Baggage Input Options

This section discusses the BHS options to allow passengers to drop their baggage at the Long Term Parking Garages in Lot DD and/or the Rental Car Center (RCC) prior to riding the AirTrain to the terminal area. Four options were considered:

- Option 1: Baggage would be collected at remote locations and loaded into a high-speed BHS conveyor running along the AirTrain guideway. The conveyor would deposit bags into a west side CBIS at the terminal.
- Option 2: Baggage would be collected at remote locations and transported by an airside vehicle to one or more terminal area CBIS.
- Option 3: Baggage would be collected at the RCC, screened at a new remote CBIS, and transported by an airside vehicle to terminal area baggage make-up areas.
- Option 4: Baggage would be collected at remote locations and transported on by a landside vehicle to industrial bag drops in the ITB.

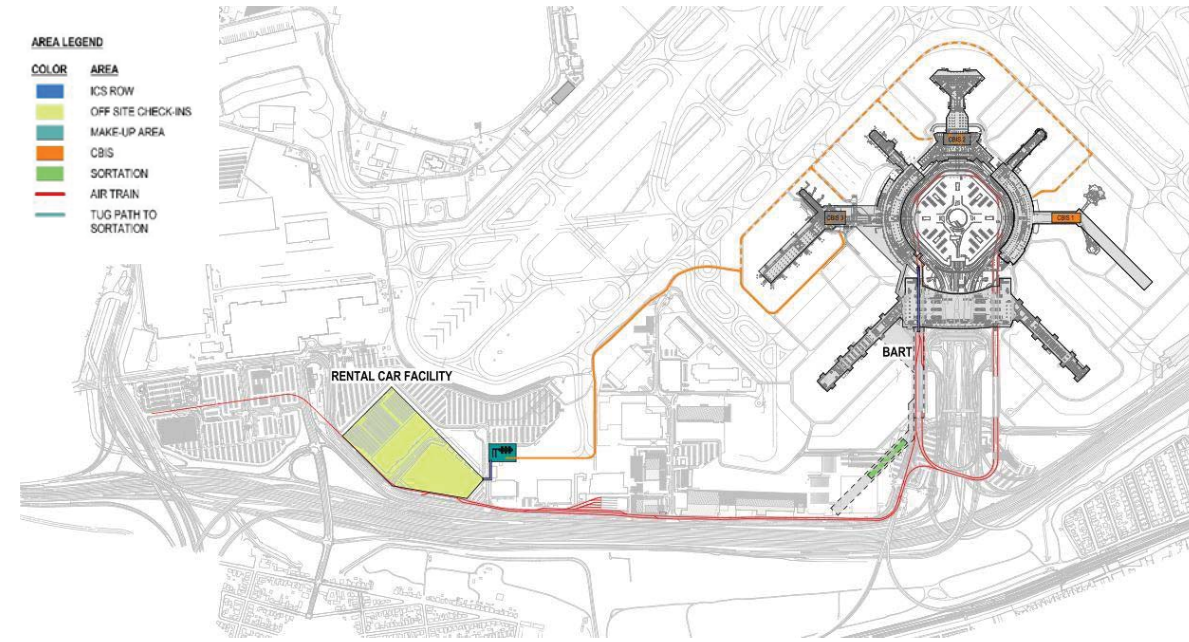
Exhibit G.3-6 | Option 1: Automated Solution



Source: SFO Bureau of Planning and Environmental Affairs; SFO Airport Layout Plan 2014; BNP Associates, October 2015

In Option 1, bags would be collected at drop points in Lot DD and the RCC and loaded onto a new conveyor running along the AirTrain guideway, as shown in **Exhibit G.3-6**. Due to the distance to the terminal area, ICS technology is proposed because of the greater speeds and control over the baggage that an ICS would provide. At the terminal area, the ICS link from the Lot DD area would connect to the backbone where the bags would be transported to one of the CBIS areas for screening and then on to sortation at the appropriate boarding area.

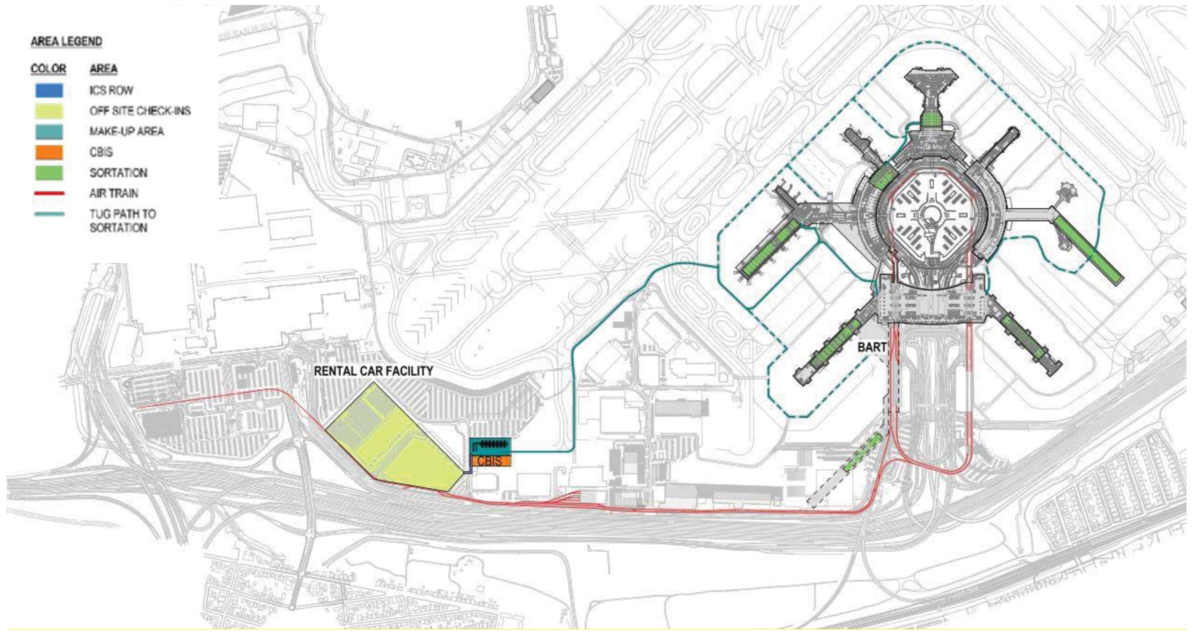
Exhibit G.3-7 | Option 2: Airside Manual Transport to Terminal Area CBIS



Source: SFO Bureau of Planning and Environmental Affairs; SFO Airport Layout Plan 2014; BNP Associates, October 2015

In Option 2, baggage checked in at the existing RCC would be sent to a sorting facility, where they would be grouped based on the terminal or boarding area of departure and then transported to input conveyors feeding the CBIS in those areas. There would be no direct connectivity from Lot DD, although landside vans could transport bags collected there to the RCC sorting facility. **Exhibit G.3-7** shows Option 2.

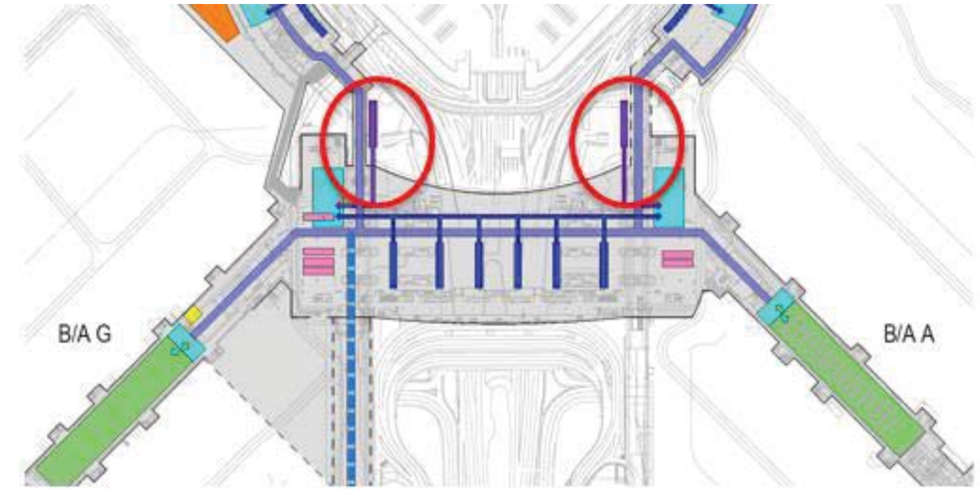
Exhibit G.3-8 | Option 3: Screening at the Rental Car Center and Airside Manual Transport to Terminal Baggage Make-up Areas



Source: SFO Bureau of Planning and Environmental Affairs; SFO Airport Layout Plan 2014; BNP Associates, October 2015

In Option 3, baggage checked in at the existing RCC would be screened at a new CBIS area near the RCC, pre-sorted based on the departure make-up area, and then transported to the appropriate make-up area or directly to the gate. There would be no direct connectivity from Lot DD, although landside vans could transport bags collected there to the RCC CBIS. **Exhibit G.2-8** shows Option 3.

Exhibit G.3-9 | Option 4: Use Industrial Bag Drops in the International Terminal Building



Source: SFO Bureau of Planning and Environmental Affairs; SFO Airport Layout Plan 2014; BNP Associates, October 2015

In Option 4, baggage would be collected manually at Lot DD and the RCC and transported on the landside to new industrial bag drops the ITB. No screening or sortation systems would be provided at Lot DD and the RCC. These bag drops could be used by for bulk induction of baggage from any source, including shuttles from area hotels, charter buses, or remote drops in city centers or the Millbrae Intermodal Station. **Exhibit G.3-9** shows Option 4.

Evaluation and Conclusion

Option 1 is expected to have a high cost, roughly estimated at $90 million for the BHS equipment only, before considering an enclosure or improvements to the AirTrain structure. While the BHS equipment could be taken into consideration in the extended AirTrain track structure, it would need to be an add-on/modification of the existing AirTrain track sections, which raises the following concerns:

- Ability to add load to the AirTrain structure
- At the AirTrain stations, the BHS conveyor would not be able to be adjacent to the AirTrain track and would require circuitous routes around the stations while maintaining vertical clearance from the vehicle roadways below
- Maintenance access to the equipment may be difficult because the equipment would be suspended alongside the AirTrain track. While access can be provided, the response time would be long given the distances and limited locations for access stairs, etc.
- Difficult to remove baggage from the elevated route if an equipment failure occurs

An additional concern is that this option can only distribute bags to all terminals/boarding areas when the BHS backbone is fully in place. Before the backbone is fully implemented, only passengers for the airlines located in the connected terminals/boarding areas would be able to use the service. This situation could be avoided if bags for the non-connected airlines were manually transferred between connected and unconnected areas. Based on the above feasibility issues, Option 1 is not recommended.

Options 2 and 3 would have a high operating cost due to the staff and vehicles required to transport the bags. Options 2 and 3 rely on adjacency to the airside and thus only work in the existing RCC location and not for the proposed Lot DD parking garages/RCC location.

Option 2 is not recommended due to its high operating cost and the security and practicality concerns of transporting unscreened bags on the airside.

Option 3 is not recommended because it would require screening equipment and TSA staffing at the RCC. Although the baggage flow at the RCC would not be particularly high, it would still require a minimum contingent of staff, leading to an inefficient use of limited staff resources. This situation is contrary to one of the ADP goals, which involves consolidating screening operations and increasing staff efficiency. Therefore, Option 3 is not recommended.

Option 4 is recommended as the most feasible option. The industrial bag drop locations can serve any off-site check-in/bag drop and is not limited to Lot DD parking garages/RCC. Other opportunities may include:

- Airport Hotel (allowing hotel guests to check out of the hotel and drop their bags at the hotel)
- Convention centers downtown and around the Peninsula (allowing convention attendees to check out of their hotel and drop their bags at the convention center)
- City check-in (ability for passengers to drop their bags in the morning upon hotel check-out and proceed to the Airport later in the day)
- Caltrain and the future high-speed rail station at Millbrae (where passengers would be able to drop their bags at the station before proceeding to the terminals)
- Drop point for limo services (driver would drop passengers at the terminal curb and then drop bags at the industrial bag drop)
- Check-in points at other major passenger population centers (e.g., large hotels, corporate campuses, etc.)

However, the industrial bag drops would only reach the adjacent baggage systems at B/As A and G or any system connected to the backbone. Any bags inducted at the drops and bound for another location would be rejected or transferred manually after screening. Therefore, the ability for baggage input at the industrial bag drops to reach any BHS automatically would be possible only when the backbone is completed.