WASHINGTON UNION STATION
STATION EXPANSION

Draft Environmental Impact Statement for Washington Union Station Expansion Project

Appendix A5d –

Action Alternatives Refinement Report

Appendix C – Pedestrian Circulation

U.S. Department of Transportation
Federal Railroad Administration

January 2020

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WASHINGTON
UNION STATION
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Washington Union Station Expansion Project

Appendix C: Pedestrian Circulation

JANUARY 2020

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Contents

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Executive Summary

The following section provides a summary of the pedestrian circulation analyses that were completed for the Washington Union Station (WUS) expansion project. The analyses were performed to understand how the station may perform from the perspective of passengers in the design year of 2040 with increased passenger demand and design and operational modifications.

Passenger flows were analyzed throughout the station using MassMotion software. Key access points within the station were scrutinized and, through coordination with the design team, optimized to handle expected flows and demand during the AM peak hour. The AM peak hour was identified for study since it features some of the highest magnitude passenger volumes associated with train arrivals.

The figure below diagrammatically summarizes a simplified set of findings for the station. Much of the circulation analysis was focused on pinch points such as Vertical Circulation Elements (VCEs) that, if not adequately sized, can act as bottlenecks, restricting flows, creating congestion and delay, and impacting one's overall experience of the station.

Overall flows and desire lines (the routes that people would hypothetically want to travel if unconstrained) were also studied to understand if the design will facilitate primary movements in the future.

The circulation analyses determined the following:

- There is adequate overall circulation space throughout the station. Corridors, platforms, and concourses appear to be of sufficient size to accommodate future volumes and allow ease of movement.
- On platforms that primarily serve Amtrak trains under the 2040 operating plan (Tracks 9-12),* Amtrak performance guidelines for pedestrian level of service (LOS) are being met. These guidelines state that LOS C is acceptable for 15-minute peak periods (Source: Amtrak Station Program and Planning Guidelines, 2013). The guidelines are met if both "Walkway" LOS and "Queue" LOS are applied.
- In the absence of pedestrian LOS guidelines for commuter services and infrastructure, Amtrak LOS guidelines were applied to all other platforms serving mainly VRE and MARC trains under the 2040 operating plan (Source: LTK). Even though these platforms generally have higher passenger volumes and more frequent train service than Amtrak given the commuter services, the LOS C guidelines are generally met if appropriately applied to the circulation conditions: "Walkway" LOS standards applied to areas where passengers are mainly walking/ambulating and "Queue" LOS standards applied to areas where passengers are queueing for a VCE.
- The quantity of VCEs such as stairs and escalators have been optimized to accommodate demand and limit times spent in queue.

As the design is advanced beyond the 10% Design stage, it is strongly recommended that pedestrian circulation continue to be studied to ensure a station that functions as intended for the people it is ultimately being designed and built for.

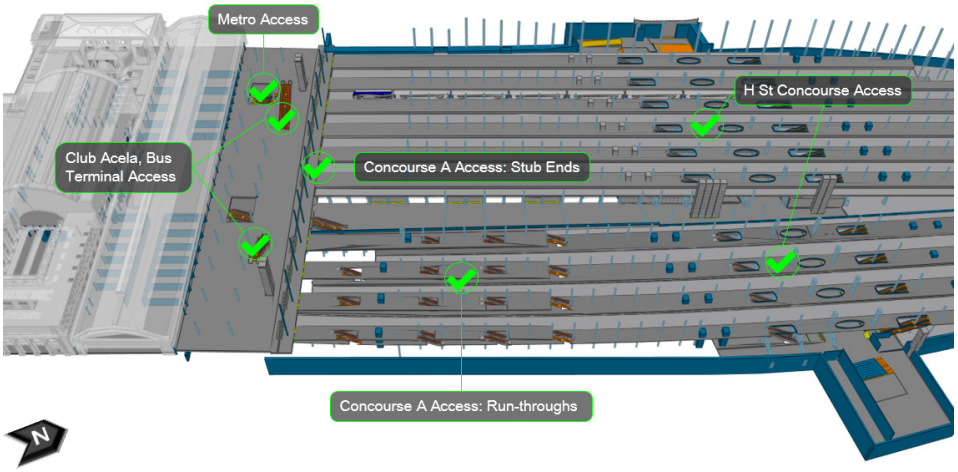

Figure 1: Diagram summarizing key analytical outcomes for Washington Union Station expansion.

* It is noted that all upper level platforms serving Tracks 1-12 can accommodate Amtrak or MARC trains.

1. Analysis Software, Inputs, and Functionality

The software used to technically evaluate pedestrian circulation within the station is called MassMotion. MassMotion is inherently 3D which delivers an intuitive environment through which to view pedestrians moving through space. The software is used to a) visualize a space with pedestrians flowing through it, b) understand building performance, and c) influence design and operations. As analytical outputs, MassMotion is capable of producing various metrics including Level Of Service (LOS) "heat maps," journey times, or volume counts.

To build and program models in MassMotion, three general sets of inputs are required as illustrated in the following Venn diagram. More information on each can be found below and in the following sections.

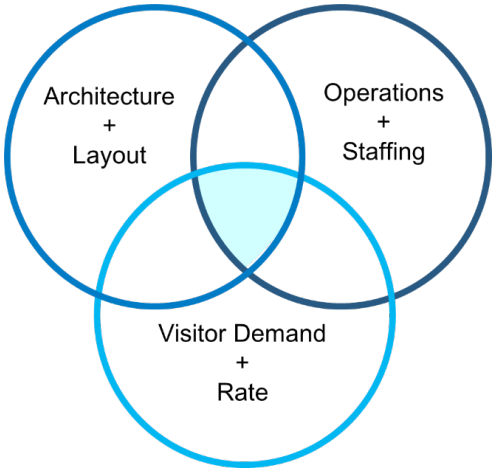

Figure 2: Inputs required for MassMotion model programming. These are also areas that can be influenced through analyses.

Architecture and Layout: This represents the planning and design of the space.

Operations and Staffing: This represents the various operational aspects of the space which may include train movements or scheduling, points of interaction or service like retail or ticketing, or the operational parameters of vertical circulation (e.g., escalator speeds).

Passenger Demand and Rate: This represents the model population and the rate at which people are entering or departing the model environment.

Through analyses, these are also areas that can be influenced. For instance, if a bottleneck is observed at a point of vertical circulation, additional stairs, escalators, or elevators can be tested at that location.

More information on each area can be found in the following sections.

1.1 Station Design

The design that was evaluated is Alternative E where:

- the Bus Facility and Club Acela are located directly above Concourse A, and
- parking is located below the lower concourses.

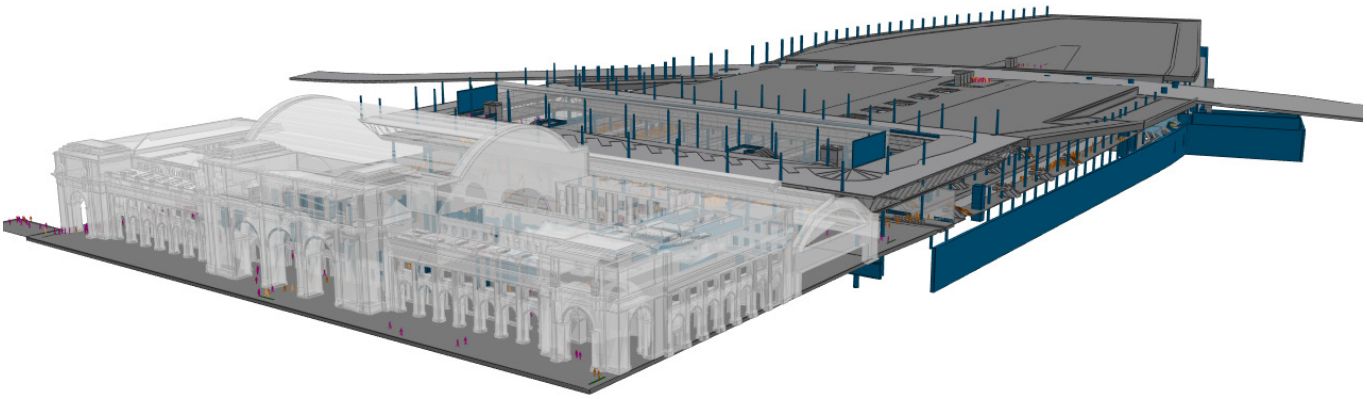

Figure 3: Overview of the Washington Union Station model.

Alternative E was selected for study due its layout which has most multimodal connections—Metro, commuter rail, Amtrak, and buses—accessible via Concourse A. This design alternative therefore puts the most pressure on this area of the station.

According to the trip generation model, pedestrian demand to/from the Bus Facility, Club Acela, and parking is fairly low when compared to the overall station population, so presumably relocating these components will have little impact on other areas of the station.

1.2 Station Operations

The modeled time period is a representative weekday morning peak hour between 8:00 and 9:00 AM.

The 2040 rail operating plan developed by LTK was used to simulate train arrivals and departures on Tracks 1-28. All trains within the AM peak period are single berthed; the operating plan does not call for double-berthed trains in either the AM or PM peak periods.

The pedestrian circulation models have been calibrated to reflect the number of coaches stipulated in the 2040 operating plan as well as train positioning on the platforms per arrival/departure.

1.3 Passenger Demand and Rate

A model population of approximately 39,000 people represents the total AM peak hour "demand" and includes all station users: transit riders (i.e., train/bus/Metro passengers) and those not using transit (e.g., people moving between the street and the private air-rights development).

People in the model—called "agents"—move in predefined numbers between the specific origins and destinations established in the trip generation spreadsheet model. This was developed in coordination with the NEPA consultant team, FRA, Amtrak and other transport agencies. The train schedule for the design year (2040) was provided along with passenger capacity and load factors generated by the spreadsheet model (see Table 1).

Load factors were derived from the NEC FUTURE analysis of future ridership and service patterns that envisioned substantial growth on the corridor due to new MARC/VRE through-running service, the overall growth in the commuter rail program, and the emergence of the Metropolitan service. However the NEC FUTURE ridership falls short of projected maximum peak hour capacity per the operating plan, capable of moving approximately 40,000 riders per peak period. Load factors were therefore adjusted accordingly (Source: VHB).

Model agents are inherently programmed to move between origins and destinations using the shortest and/or "lowest cost" route available. In this way, they are responsive to potential obstacles like congestion or vertical circulation.

For the analyses, agents have been given simple itineraries often consisting of a single origin and single destination, and they navigate their route in the most efficient manner possible as a commuter would do on a regular basis. Route detours can also be programmed by adding stopping points or points of interaction between origin and destination. The key detour added to some agent itineraries was a stop at retail.

Three distinct arrival rates were developed for different train services to simulate "boarding" passengers arriving at the station over a defined period of time prior to their train departure. These rates are illustrated in Figure 4 and Figure 5. Amtrak passengers arrive at the station over a one-hour period. Arrival rates for more frequent train services such as the Metropolitan, VRE, and MARC services span a 20-minute period.

Assumptions around passenger activities before train departures are linked to the passenger arrival profiles. At defined time intervals during arrival periods, some passengers visit retail or the Club Acela lounge, stop at designated waiting areas near the departing train platform or proceed directly to their platform. The agents complete these activities prior to their train's track announcement, assumed to be 10 minutes before departure. For instance, when Amtrak customers arrive in the model 30-35 minutes before their train departs they can visit Club Acela (if eligible) or retail or wait at a designated waiting area near their assigned platform. MARC passengers that enter the model with less than 10 minutes prior to their departure proceed directly to their platform. All pre-departure activity assumptions for boarding passengers are defined in the following tables.

Alternative E retail spaces are shown in Figure 6. It is assumed that passengers visiting retail will proceed to a retail destination within reasonable proximity to their origin. However, the food court and in the Central Concourse can be visited by agents irrespective of origin due to their central locations and/or unique offerings.

Table 1: Proposed 2040 AM peak period (8-9am) train timetable at Washington Union Station. Trains that do not have either an arrival or departure within the 8-9am peak hour are shaded in blue. Source: LTK (schedule), VHB (load factors & totals).

Service	Arriving Train #	Departing Train #	Arrive	Depart	Track	Passenger Capacity	Alighting Load Factor	Total Alighting	Boarding Load Factor	Total Boarding
HSR	A2001	A2026		8:23	12	425	0.5	0	0.5	213
HSR	AEQ 1022	A1022		8:19	11	425	0.5	0	0.5	213
IC	A122	A122		8:06	25	1008	0.3	0	0.3	302
MARC	M119	M116		8:08	1	852	0.75	0	0.25	213
MARC	M219	M216		8:04	6	1136	0.75	0	0.25	284
VRE	V410	V410		8:03	27	1320	0.3	0	0.15	198
MET	T605	T522		8:16	5	1368	0.3	0	0.3	410
MARC	M013	MEQ 013		8:11	3	1136	0.75	0	0.25	0
MV	V512	M512	8:00	8:16	24	1136	0.5	568	0.25	284
MARC	M121	M118	8:00	8:38	2	852	0.75	639	0.25	213
MV	M507	V507	8:01	8:20	22	1136	0.5	568	0.25	284
MARC	M221	MEQ 221	8:04	8:16	8	1136	0.75	852	0.25	0
HSR	A2003	A1024	8:06	8:49	10	425	0.5	213	0.5	213
MV	V412	M412	8:08	8:21	25	852	0.5	426	0.25	213
HSR	A1003	A2028	8:10	8:53	9	425	0.5	213	0.5	213
MARC	M223	MEQ 223	8:11	8:23	1	568	0.75	426	0.25	0
IC	A124	A124	8:12	8:36	23	1008	0.3	302	0.3	302
MARC	M015	MEQ 015	8:14	8:26	3	1136	0.75	852	0.25	0
VRE	V514	V514	8:15	8:25	28	924	0.3	277	0.15	139
MARC	M123	MEQ 123	8:15	8:27	6	852	0.75	639	0.25	0
MV	M407	V407	8:19	8:28	24	852	0.5	426	0.25	213
IC	A101	A101	8:22	8:46	22	1008	0.3	302	0.3	302
VRE	V414	V414	8:23	8:33	27	792	0.3	238	0.15	119
MARC	M225	MEQ 225	8:25	8:37	1	1136	0.75	852	0.25	0
MET	T607	T632	8:26	8:46	4	1368	0.3	410	0.3	410
MARC	M017	MEQ 017	8:29	8:41	6	1136	0.75	852	0.25	0
MV	V516	M516	8:30	8:41	24	994	0.5	497	0.25	249
MARC	M125	M120	8:30		3	852	0.75	639	0.25	0
MV	M509	V509	8:31	8:50	25	994	0.5	497	0.25	249
MARC	M227	M222	8:34	8:49	7	1136	0.75	852	0.25	284
MET	T503	T524	8:34	8:54	5	1368	0.3	410	0.3	410
HSR	A2005	A1026	8:36		11	425	0.5	213	0	0
MV	V416	M416	8:38	8:51	23	994	0.5	497	0.25	249
HSR	A1005	A2030	8:40		12	425	0.5	213	0	0
MARC	M229	MEQ 229	8:41	8:53	2	1136	0.75	852	0.25	0
IC	A126	A126	8:42		24	1008	0.3	302	0.3	0
VRE	V518	V518	8:45	8:55	28	924	0.3	277	0.15	139
MARC	M127	MEQ 127	8:45	8:57	6	852	0.75	639	0.25	0
MV	M409	V409	8:46	8:58	27	994	0.5	497	0.25	249
MARC	M231	M226	8:49		1	1136	0.75	852	0.25	0
IC	A103	A103	8:52		22	1008	0.3	302	0.3	0
VRE	V418	V418	8:53		26	1320	0.3	396	0.15	0
MET	T609	T634	8:56		5	1368	0.3	410	0.3	0
VRE	V520	V511	9:00		28	924	0.3	277	0.15	0

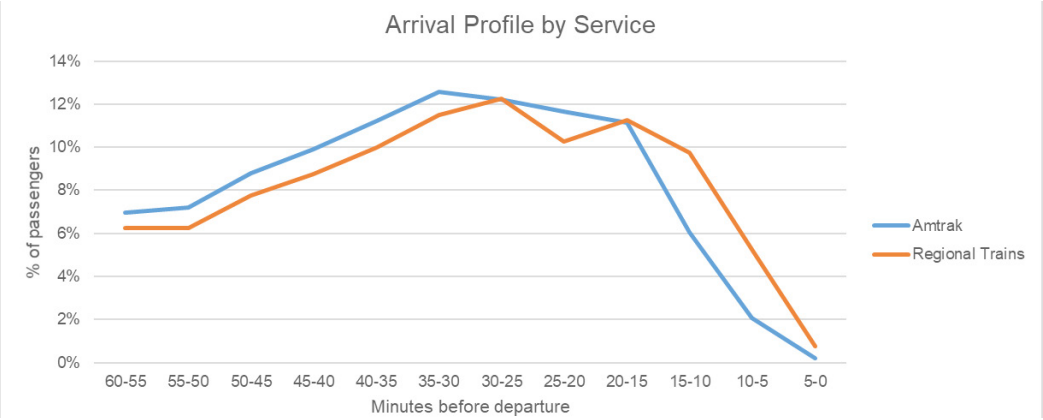

Figure 4: Amtrak and Regional train service passenger arrival profile.

Figure 5: MARC, VRE and Metropolitan train services passenger arrival profile.

Table 2: Amtrak pre-departure passenger activities undertaken by agents at the time they enter the model.

AMTRAK	
Minutes prior to departure	Pre-departure activities
60-55	10% to Retail, then Club Acela, then Platform. 56% to Retail, then Waiting Room, then Platform. 10% to Club Acela then Platform. 24% to Waiting Room, then Platform.
55-50	10% to Retail, then Club Acela, then Platform. 56% to Retail, then Waiting Room, then Platform. 10% to Club Acela then Platform. 24% to Waiting Room, then Platform.
50-45	10% to Retail, then Club Acela, then Platform. 56% to Retail, then Waiting Room, then Platform. 10% to Club Acela then Platform. 24% to Waiting Room, then Platform.
45-40	10% to Retail, then Club Acela, then Platform. 56% to Retail, then Waiting Room, then Platform. 10% to Club Acela then Platform. 24% to Waiting Room, then Platform.
40-35	10% to Retail, then Club Acela, then Platform. 56% to Retail, then Waiting Room, then Platform. 10% to Club Acela then Platform. 24% to Waiting Room, then Platform.
35-30	20% to Club Acela, then Platform. 30% to Retail, then Waiting Room, then Platform. 50% to Waiting Room, then Platform.
30-25	20% to Club Acela, then Platform. 30% to Retail, then Waiting Room, then Platform. 50% to Waiting Room, then Platform.
25-20	20% to Club Acela, then Platform. 30% to Retail, then Waiting Room, then Platform. 50% to Waiting Room, then Platform.
20-15	20% to Club Acela, then Platform. 10% to Retail, then Waiting Room, then Platform. 70% to Waiting Room, then Platform.
15-10	20% to Club Acela, then Platform. 80% to Waiting Room, then Platform.
10-5	Platform
5-0	Platform

Table 3: Regional pre-departure passenger activities undertaken by agents at the time they enter the model.

Regional	
Minutes prior to departure	Pre-departure activities
60-55	66% to Retail, then Waiting Room, then Platform. 33% to Waiting Room, then Platform
55-50	66% to Retail, then Waiting Room, then Platform. 33% to Waiting Room, then Platform
50-45	66% to Retail, then Waiting Room, then Platform. 33% to Waiting Room, then Platform
45-40	66% to Retail, then Waiting Room, then Platform. 33% to Waiting Room, then Platform
40-35	66% to Retail, then Waiting Room, then Platform. 33% to Waiting Room, then Platform
35-30	50% to Retail, then Waiting Room, then Platform. 50% to Waiting Room, then Platform
30-25	50% to Retail, then Waiting Room, then Platform. 50% to Waiting Room, then Platform
25-20	50% to Retail, then Waiting Room, then Platform. 50% to Waiting Room, then Platform
20-15	10% to Retail, then Waiting Room, then Platform. 90% to Waiting Room, then Platform
15-10	Waiting Room, then Platform
10-5	Platform
5-0	Platform

Table 4: MARC/VRE/Metropolitan pre-departure passenger activities undertaken by agents at the time they enter the model.

MARC/VRE/Metropolitan	
Minutes prior to departure	Pre-departure activities
20-15	20% to Retail, then Waiting Area then Platform. 80% to Waiting Area then Platform
15-10	10% to Retail, then Waiting Area then Platform. 90% to Waiting Area then Platform
10-5	Platform
5-0	Platform

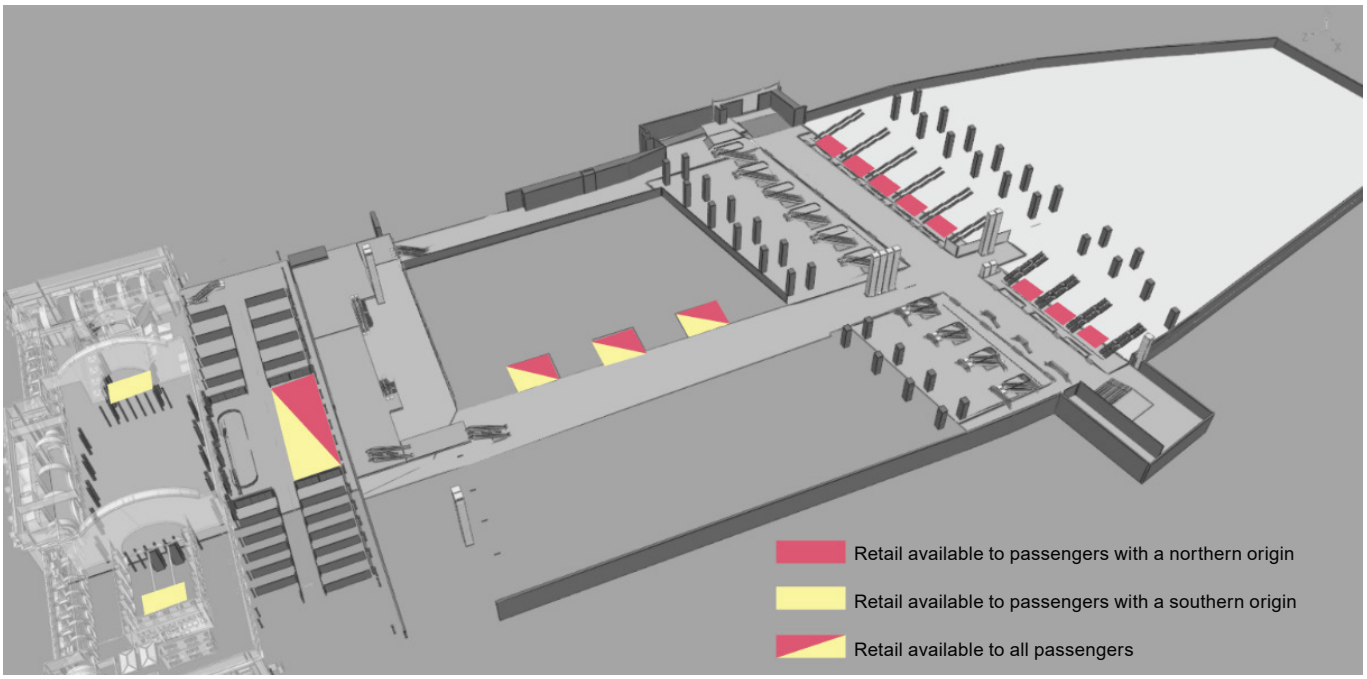

Figure 6: Indicative locations of WUS retail options. Yellow indicates retail destinations eligible to agents originating in the south; Red indicates retail destinations eligible to agents originating in the north.

2. Findings

2.1 Platform Connections

The WUS train platforms connect to Concourse A at the south and the H Street Concourse at the north. As indicated previously, agents move between origins and destinations using the shortest and/or "lowest cost" route available. As it relates to the platforms, this behavior results in 78% of all passengers moving to and from Concourse A with the balance, 22% moving to and from the H Street Concourse during the AM peak hour. These connections between the platforms and the station's main east-west concourses have been assessed to understand how future flows are accommodated.

2.1.1 CONCOURSE A CONNECTION VIA STUB-END TRACKS

For passengers **alighting** trains and moving south to Concourse A, congestion/bottlenecking is not anticipated. The stub-end connections to Concourse A consist of a set of platform doors and turnstile banks (see Figure 7).

To evaluate circulation at the connection of the southern stub-end tracks with Concourse A, maximum passenger demand was compared to the maximum throughput capacity of the doors and turnstiles.

From the pedestrian model, a maximum passenger flow rate from the trains to the doorways was observed to be 307 ppl/min. This was the maximum per-minute rate for all platforms during the AM peak hour.

The platform/Concourse A threshold features two ~6' wide doorways and two ~3' wide doorways for one platform. This arrangement provides six pedestrian travel "lanes" at ~3' each with a maximum one-way throughput of ~360 ppl/min.

The bank of nine turnstiles has an assumed maximum outbound processing rate of 40 ppl/min each and a maximum combined outbound throughput of 360 ppl/min.

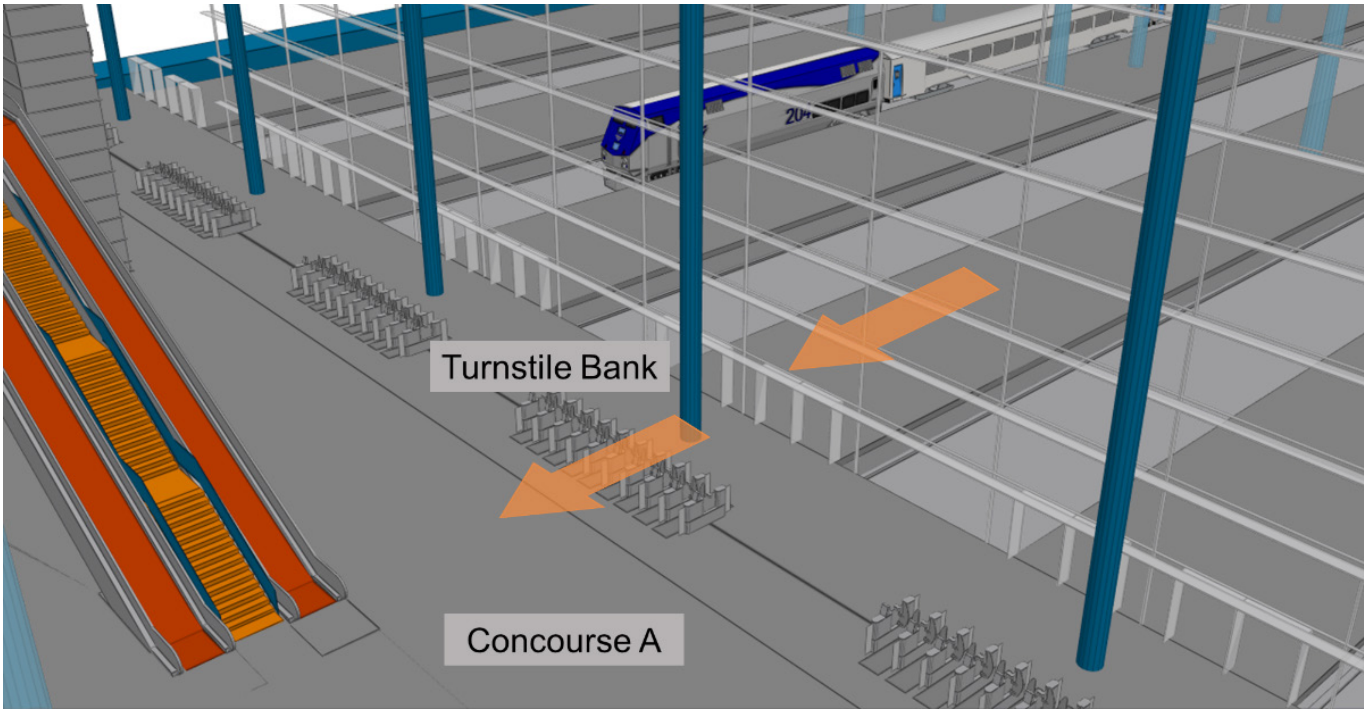

Figure 7: A sample alighting route from stub end platform to Concourse A.

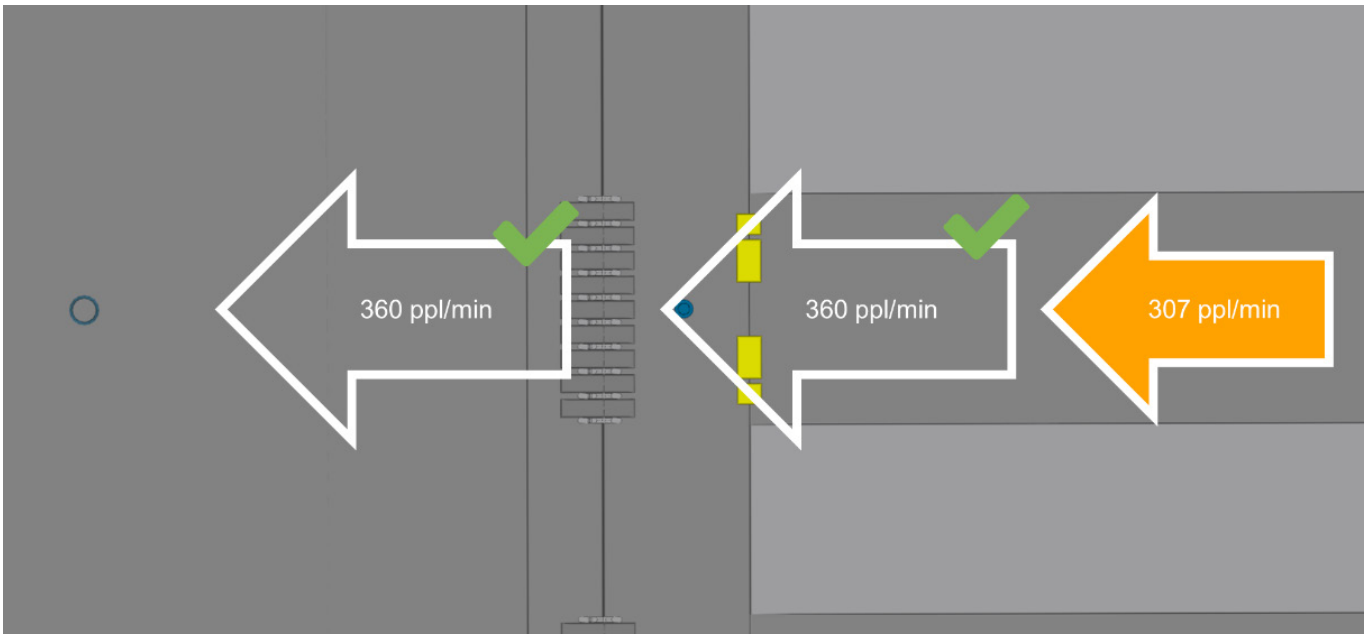

Figure 8: Flow and capacity diagram for alighting passengers.

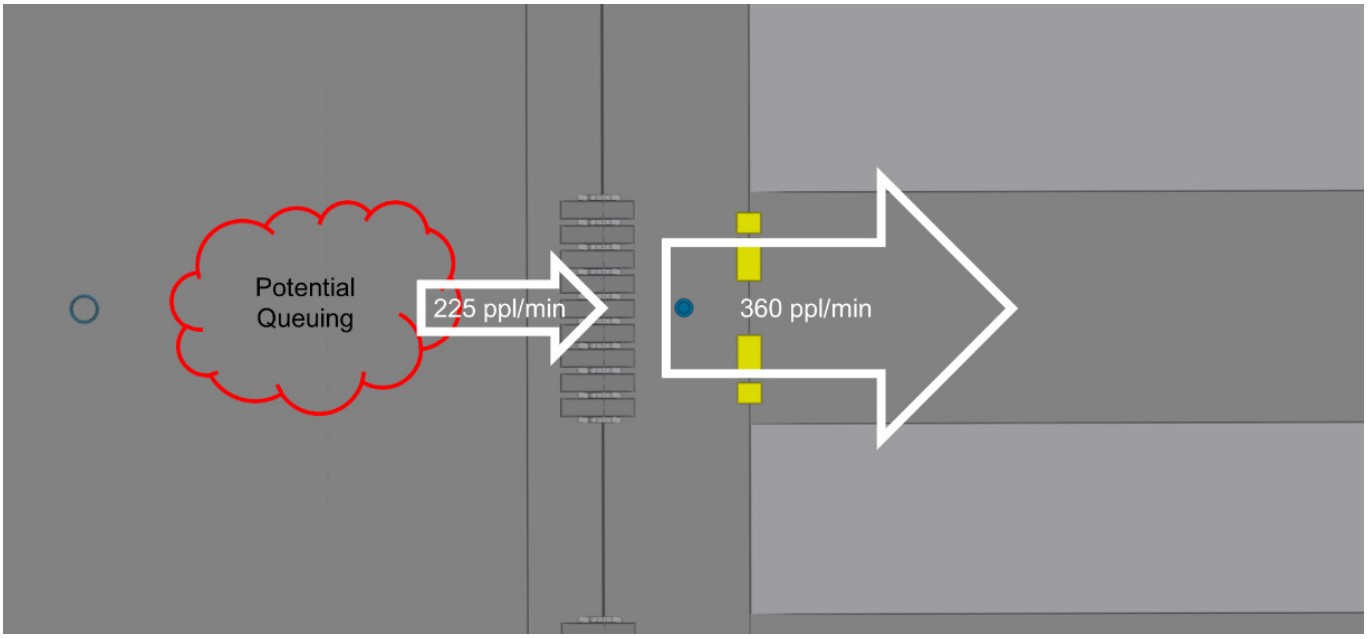

Figure 9: Flow and capacity diagram for boarding passengers.

Figure 8 diagrammatically illustrates the system as a whole. The platform doorways have enough capacity to receive the maximum passenger flow rate from the platforms. The turnstiles, with the same handling capacity as the doors, can then receive the passenger demand as well. Together this system ensures that potential queueing may occur on the platforms and not in the limited interstitial space between the platform doors and the turnstiles.

For passengers **boarding** trains from Concourse A, congestion/ bottlenecking is also not anticipated.

The maximum inbound passenger flow rates at the turnstiles is assumed to be 25 ppl/min per individual turnstile and 225 ppl/min for each bank of nine turnstiles. The maximum throughput of ~360 ppl/min at the doors remains unchanged.

Figure 9 diagrammatically illustrates the system as a whole. The platform doorways have enough capacity to receive the maximum passenger flow rate from the turnstiles, ensuring that potential queueing may occur in Concourse A and not in the limited interstitial space between the platform doors and the turnstiles.

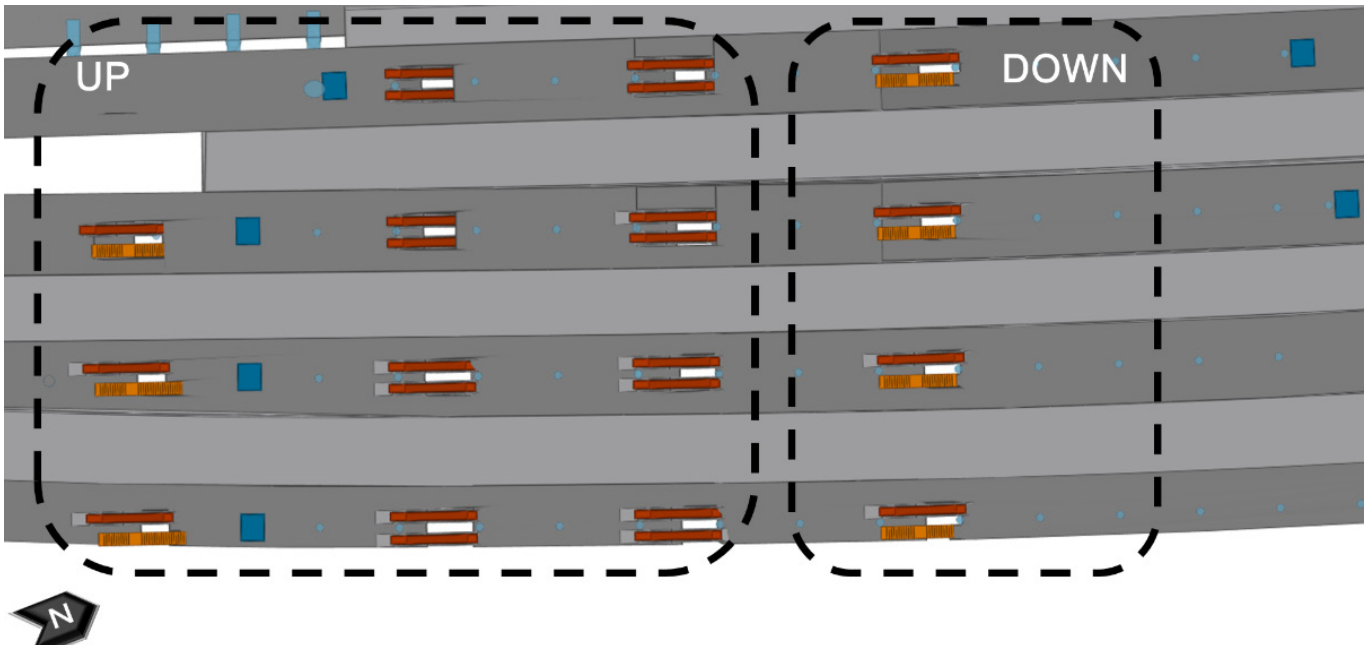

Figure 10: VCE layout connecting Tracks 22-28 to Concourse A. Escalator directionality indicated for the AM peak period.

2.1.2 CONCOURSE A CONNECTION VIA RUN-THROUGH TRACKS

Run-through track platforms (serving tracks 22-28) lie below grade from Concourse A. This allows the tracks to pass under Washington Union Station and connect to points south. Passengers traverse the grade change from platform to Concourse A via VCEs: stairs, escalators, and elevators. The stair and escalator VCE banks connecting tracks 22-28 to Concourse A are shown in Figure 10; escalators are shown in red and stairs are shown in orange. Escalator directionality during the AM peak hour is indicated within the dashed boxes.

Since VCEs can act as a pinch point by limiting flows, some queueing may occur. To assess these possible conditions, pedestrian LOS was evaluated. LOS is a measure of density (people/square foot) defined on a scale from A through F where A represents comfortable conditions in which flows are unrestricted and crossflows can occur and F represents extreme crowding where shuffling takes place, speeds are greatly restricted, and no such freedom of movement in any direction is possible. The following diagram represents the full LOS range for walkway conditions (Fruin 1971).

LOS is assessed using different thresholds based on the condition a person is experiencing. Table 5 indicates the differences in Fruin LOS thresholds used for walkway and queueing conditions.

Walkway LOS is typically applied when/where passengers are ambulating, i.e., in the middle of platforms. Queueing LOS is typically applied when passengers are queueing, i.e., at the landings of stairs, escalators or elevators.

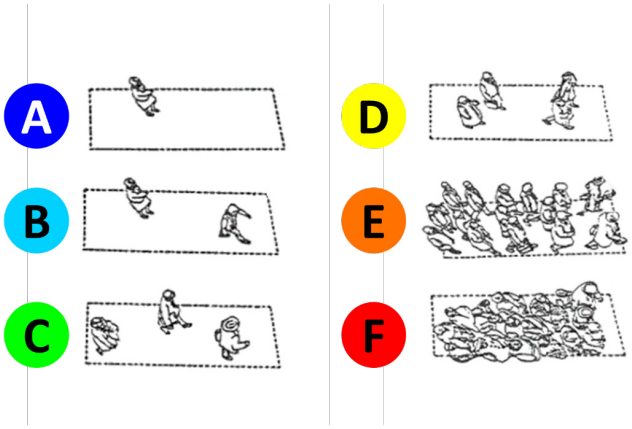

Figure 11: "Walkway" level of service diagrams showing LOS A through F (Fruin 1971).

Table 5: Level of service thresholds for walkway and queuing (Fruin, 1971).

LOS Level	Walkway LOS	Queueing LOS
A	35 feet2/person or more	13 feet2/person or more
B	25-35 feet2/person	10-13 feet2/person
C	15-25 feet2/person	7-10 feet2/person
D	10-15 feet2/person	3-7 feet2/person
E	5-10 feet2/person	2-3 feet2/person
F	5 feet2/person or less	2 feet2/person or less

Amtrak guidelines state that platforms should meet LOS C for a 15-minute peak period (Source: Amtrak Station Program and Planning Guidelines, 2013). The interpretation of this guideline is that level of service C must be met for passengers when traversing the platforms and also when queueing to use vertical circulation elements.

For the peak 15-minute period per platform (different periods per platform given train arrivals/departures), **Walkway** LOS analysis shows generally A-C on most areas of the platforms (see Figure 12) where passengers are walking. Pockets of LOS D-E can be seen near VCE landings.

In the areas showing Walkway LOS D-E, passengers are not experiencing walking conditions. Rather, they are queueing to use VCEs. Therefore, Queueing LOS is used to assess conditions in these locations. Applying Queueing LOS thresholds results in LOS C being met on the platforms, meeting Amtrak guidelines (see Figure 13).

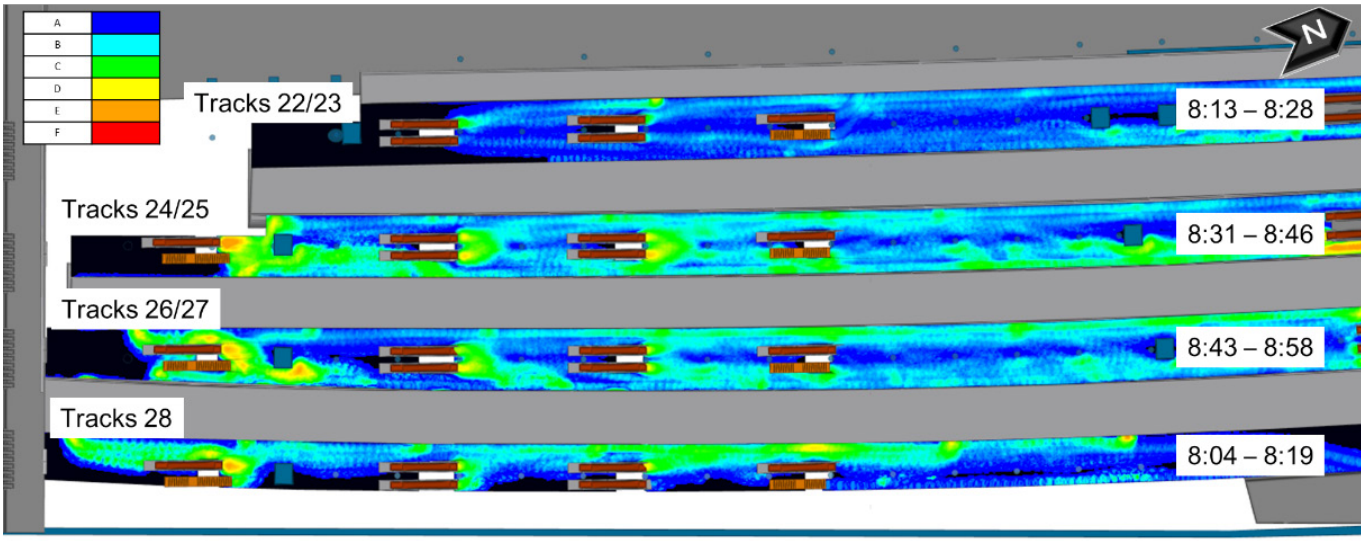

Figure 12: Walkway level of service for peak 15-min platform periods (Tracks 22-28). Peak periods per platform are shown to the right.

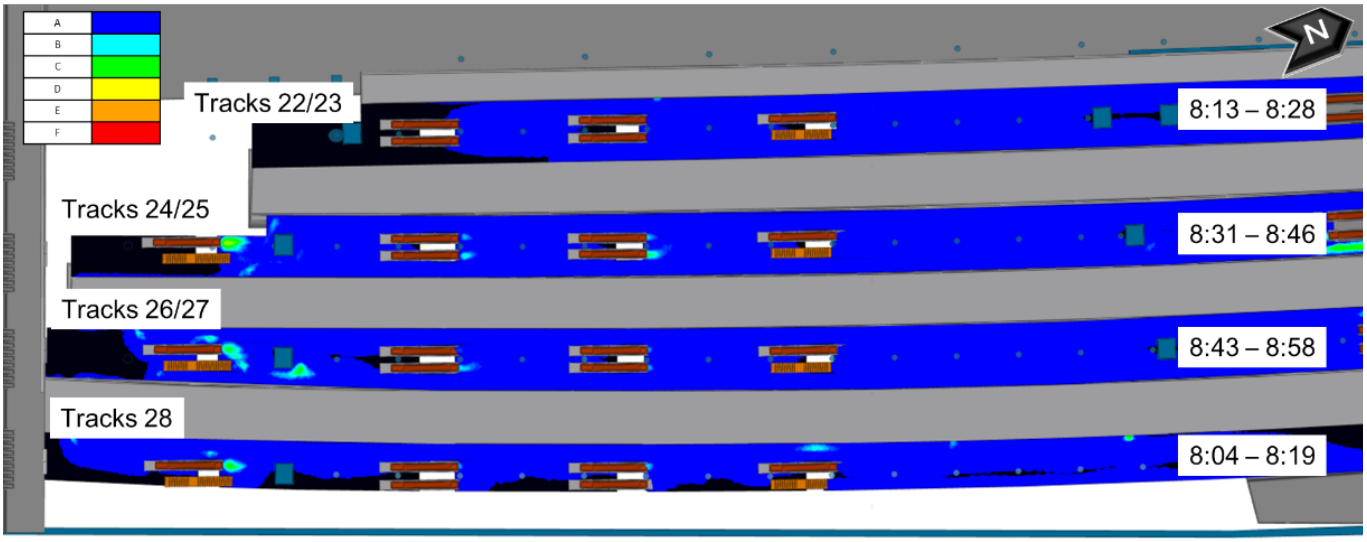

Figure 13: Queuing level of service for peak 15-min platform periods (Tracks 22-28). Peak periods per platform are shown to the right.

2.1.3 H STREET CONCOURSE CONNECTIONS

Similar LOS analysis was applied at the northern ends of the platforms where vertical connections to the H Street Concourse are found.

The VCE banks connecting Tracks 1-12 with the H Street Concourse are shown in Figure 14. Escalator directionality is indicated for the AM peak period. The orange objects north of the escalators are stairs at which no directionality is associated.

Tracks 1-12

For the peak platform populations, Walkway LOS analysis shows some pockets of LOS D-F at Tracks 1-8 (see Figure 15). These areas of higher passenger density are associated with the alighting positions of the trains and queueing for stairs and escalators.

Tracks 9-12 have lower passenger volumes in the AM peak hour, yielding LOS results that fully comply with Amtrak guidelines.

Queueing LOS analysis during the same time periods show improved levels of service (see Figure 16). Small pockets of LOS D remain on Tracks 1-2, 5-6, and 7-8, but this may not be indicative of serious issues for the following reasons:

- Amtrak guidelines are being applied to platforms that feature mainly commuter services. Commuters are generally more tolerant of higher densities due to higher overall passenger volumes and the (general) lack of baggage that Amtrak passengers often travel with.
- The positioning of train doors may vary slightly from day-to-day which would change the location at which passengers alight and, in turn, the platform LOS.
- Commuters often alter their behavior to avoid congestion and reduce travel time. In other words, if congestion is experienced at a particular location on a platform or at a particular train door or car, commuters will likely adjust their alighting position by using a different door to better position themselves on the platform to avoid congestion. This “rebalancing” could help to naturally mitigate some points of congestion.

Tracks 22-28

The same analysis was conducted for Tracks 22-28 with similar results. Walkway LOS shows mainly LOS A-C in walkway areas on the platforms, with small pockets of D and E as shown in Figure 17.

Queueing LOS is C or better, meeting the Amtrak guidelines (Figure 18).

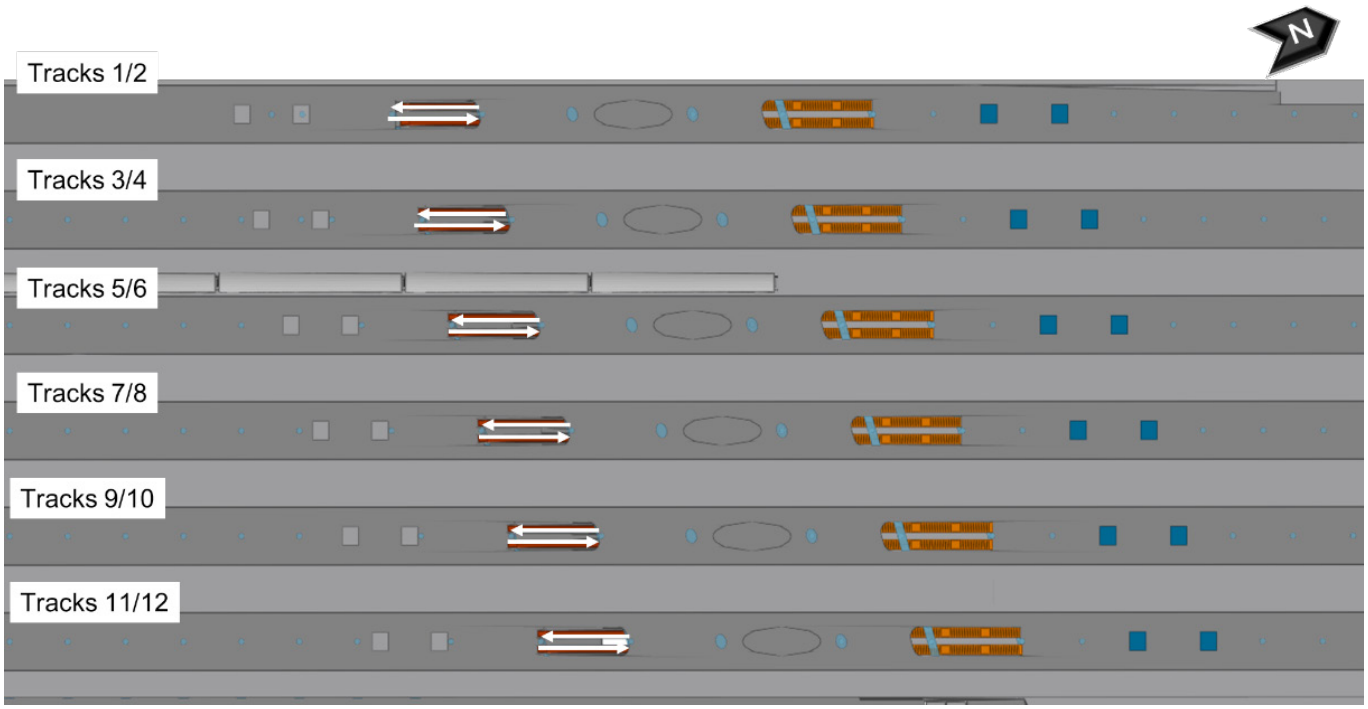

Figure 14: VCE layout connecting Tracks 1-12 to the H Street Concourse. Escalator directionality shown for the AM peak period.

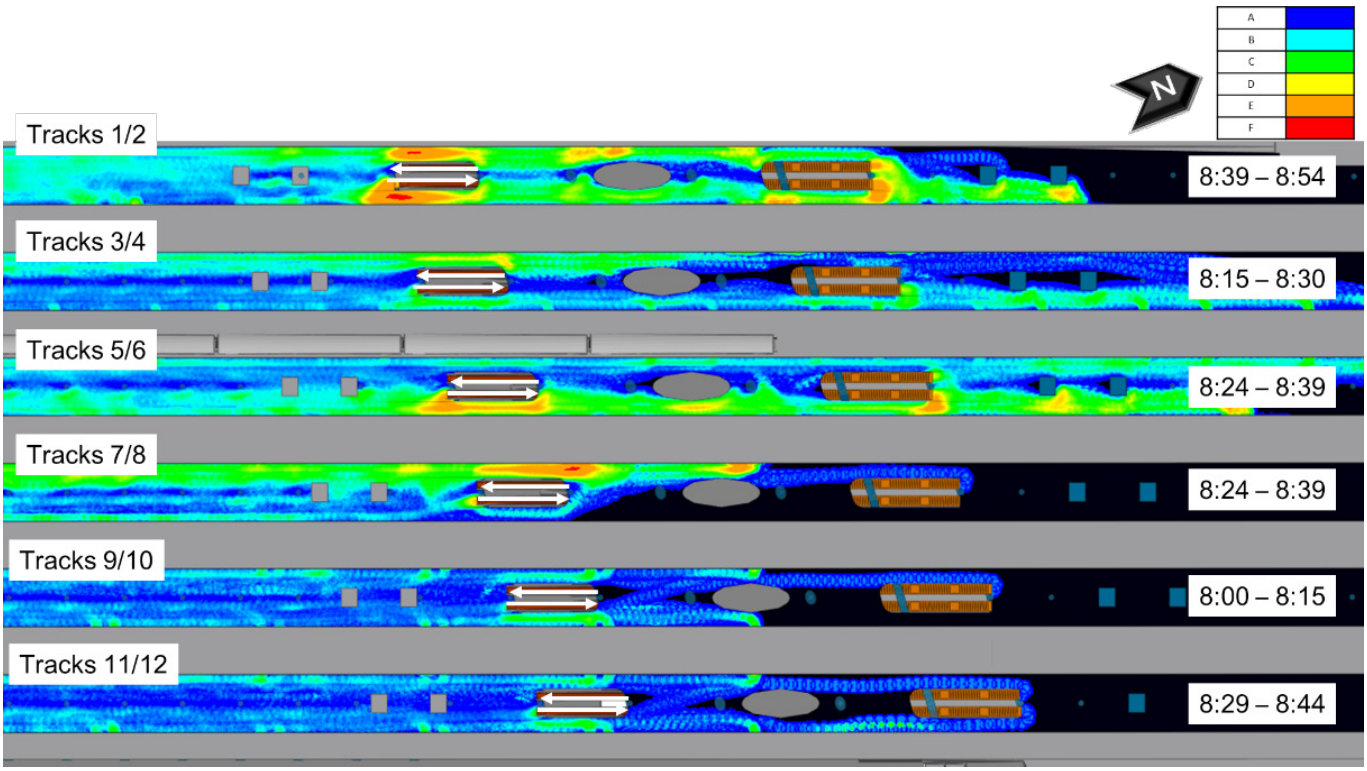

Figure 15: Walkway level of service for peak 15-min platform periods (Tracks 1-12). Peak periods per platform are shown to the right.

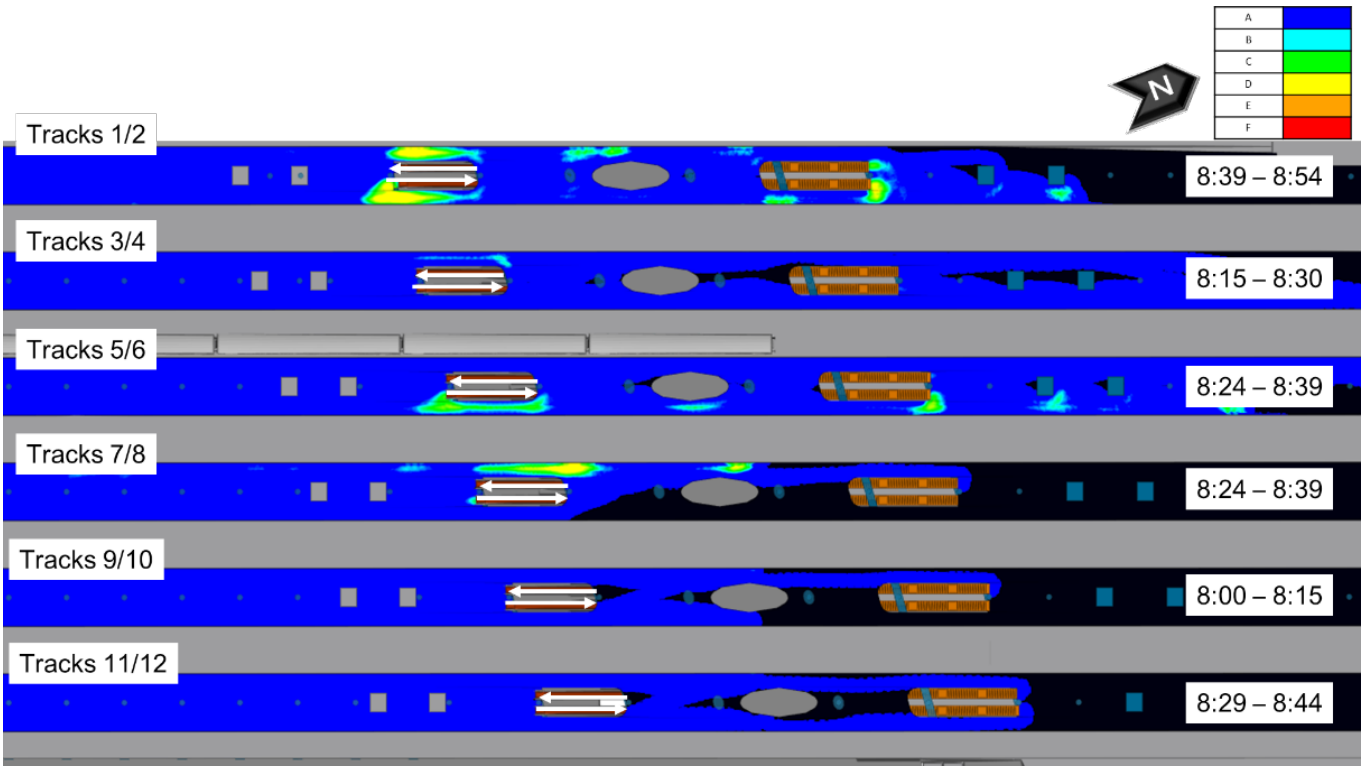

Figure 16: Queuing level of service for peak 15-min platform periods (Tracks 1-12). Peak periods per platform are shown to the right.

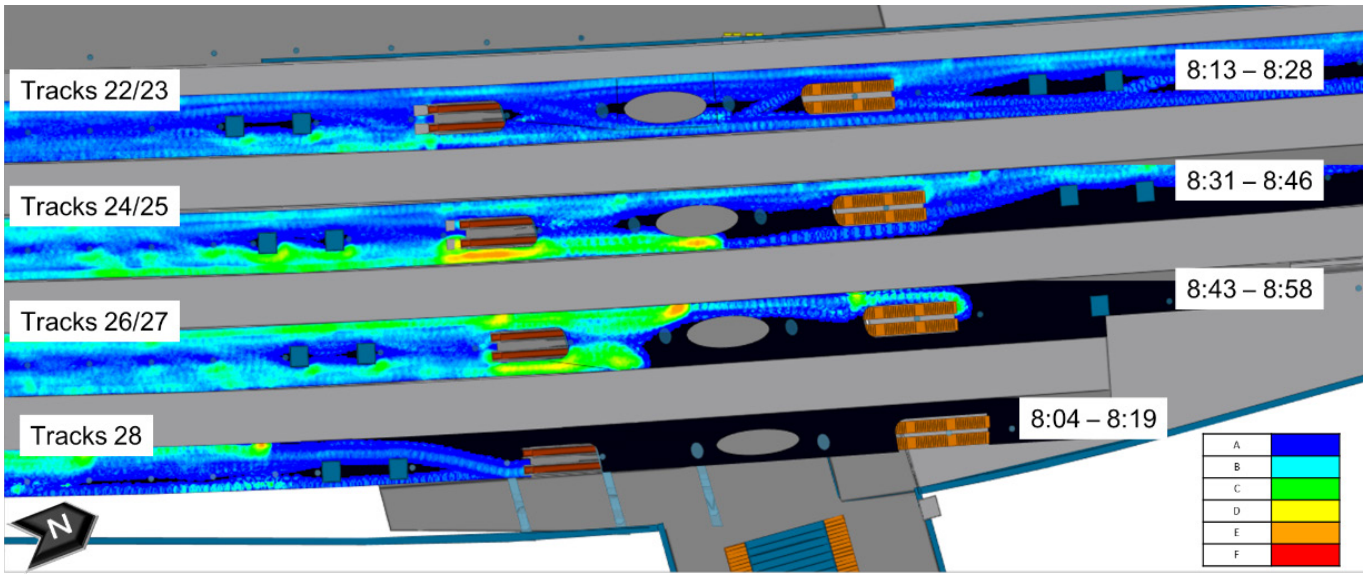

Figure 17: Walkway level of service for peak 15-min platform periods (Tracks 22-28). Peak periods per platform are shown to the right.

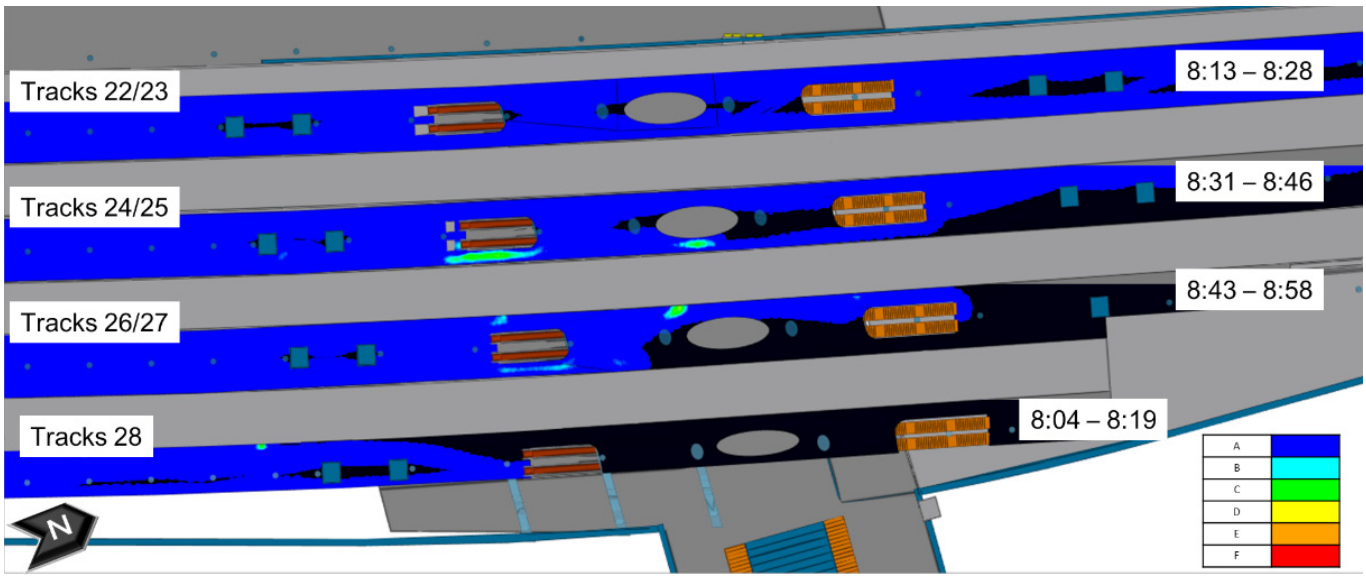

Figure 18: Queuing level of service for peak 15-min platform periods (Tracks 22-28). Peak periods per platform are shown to the right.

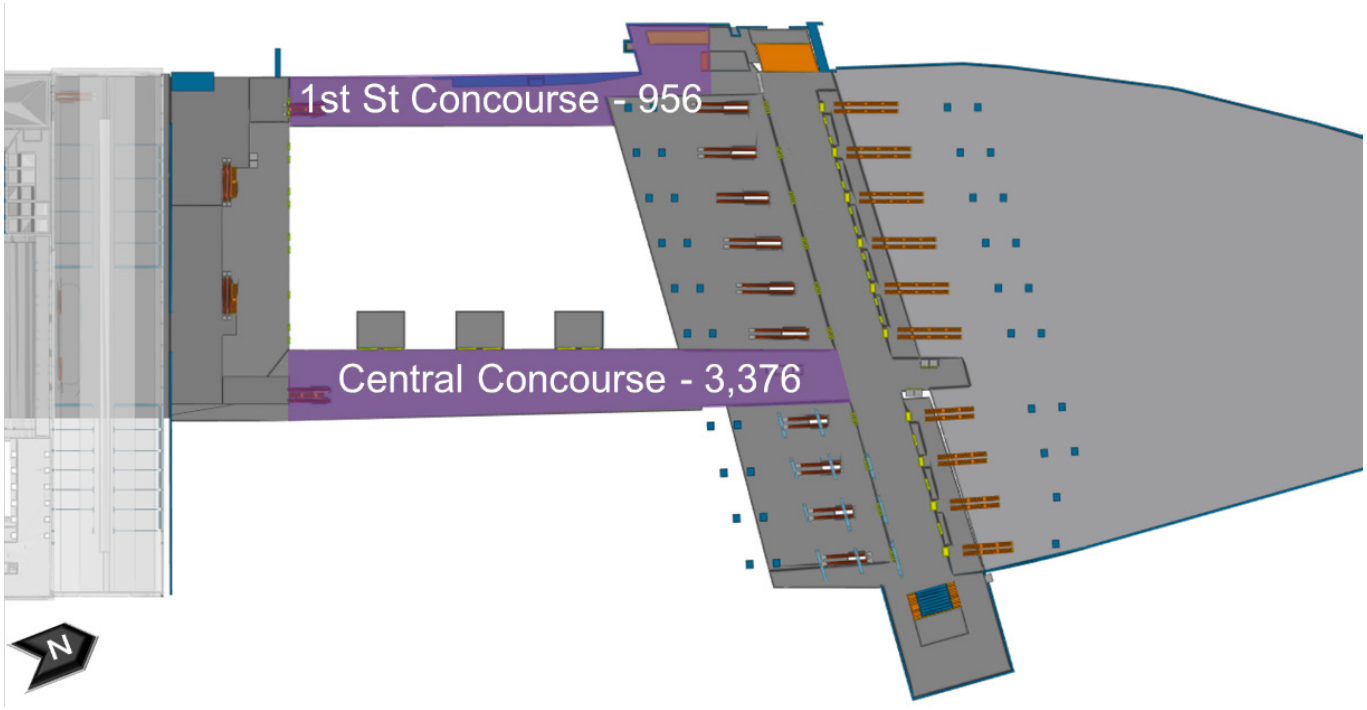

Figure 19: Lower Concourse utilization during AM peak hour (8:00 – 9:00 am).

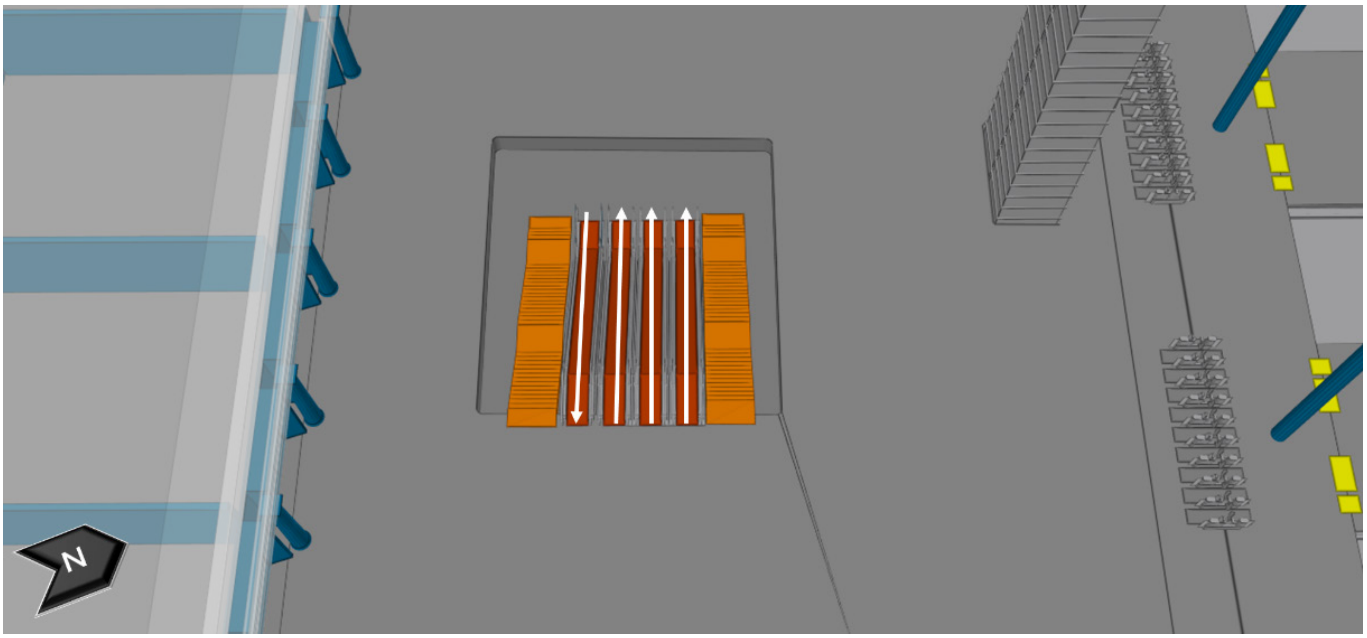

Figure 20: VCEs connecting Concourse A to mezzanine level: four escalators, two stair sets with escalator direction indicated for AM peak period.

2.2 Lower Level Concourse Flows

During the modeled peak hour, the lower concourses are lightly used when compared to the overall modeled population of approximately 39,000 people (see Figure 19). This could be due in part to the study period (8:00-9:00 AM) when many retail stores may not yet be open and passengers are moving between platforms and their final destinations as quickly and directly as possible.

Conditions in the lower concourses will likely be very different during the midday and PM time periods. The final retail program with anchor stores will also impact how the lower concourses are used throughout the day.

2.3 Metro Access

The Metro station represents the primary origin within Washington Union Station during the AM peak hour, when approximately 7,500 passengers (32% of the modeled population) move between the train platforms and Metro. As a result, it is critical that the vertical connections between the platform level and the mezzanine level are adequately sized to handle demand. An analysis of demand versus vertical circulation handling capacity was conducted to optimize the quantity of stairs and escalators.

The optimized arrangement with four escalators flanked by two sets of stairs is shown in Figure 20.

During the AM peak period, it is recommended that three escalators operate in the down direction to accommodate peak flows from Concourse A to the mezzanine level where the Metro entrance is located. It is anticipated that escalator operations would be flipped during the PM peak period, with three escalators operating in the up direction.

The following chart summarizes the analysis that was undertaken to arrive at the optimized vertical circulation condition. The chart compares AM peak hour passenger demand in the "down" direction (towards the Metro station) to VCE handling capacities.

- The solid blue line represents demand during the AM peak hour. The peaks and valleys represent fluctuations or "surges" associated with train arrivals.
- The blue dashed horizontal line at the top represents a maximum system processing rate of three down escalators and two full-width stairs allowing down flows only.
- The orange dashed horizontal line represents a system processing rate under "normal" operating conditions with three down escalators and two stairs each with one flow lane in the up direction (approximately 3 feet wide).
- The green dashed horizontal line represents a system processing rate under "disrupted" operating conditions, with two down escalators and two stairs each with one flow lane in the up direction.

Under the three potential operating scenarios, the peak demand between Concourse A and the mezzanine level can be accommodated by the processing rate of the VCEs as a system.

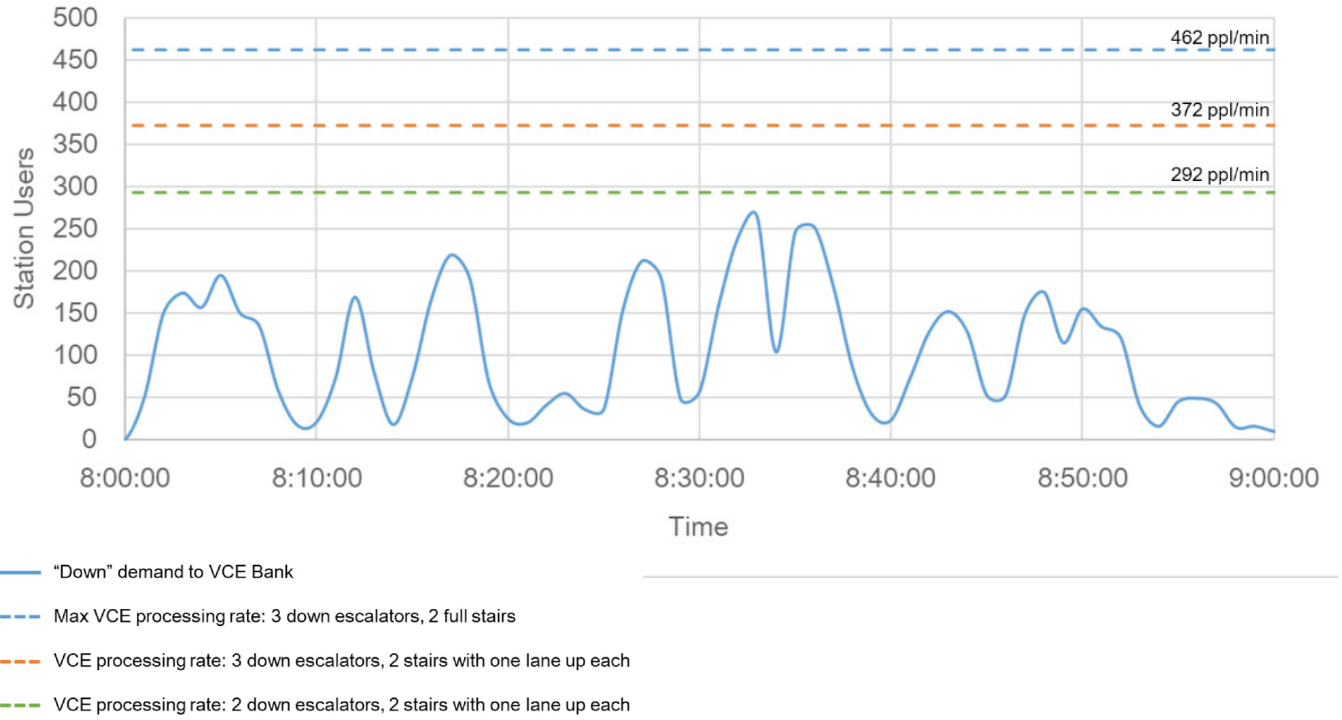

Figure 21: Demand versus the maximum processing rates of three possible VCE operating scenarios.

2.4 Bus Facility/Club Acela Access

In Alternative E, the Bus Facility and Club Acela lounge sit above Concourse A on a specially designed truss. Vertical flows to and from these locations were studied to assess adequate sizing of the VCE connections.

The trip generation model that provided trip volumes for this circulation study assumes a relatively low number of passengers moving to and from the Bus Facility and Club Acela during the peak AM period. The volumes to and from the Bus Facility are low because of the study time period. From 8-9am, tour bus volumes in particular are lower than at other times of day. The volumes to and from Club Acela are low because it is assumed only 20% of Acela passengers use this facility.

The VCEs connecting Concourse A to the facilities above are more than adequately sized to accommodate AM peak hour demand. In fact, the VCEs are adequately sized to handle much higher demand should it materialize in the future.

Figure 22 graphically depicts the directional demand (up and down) to and from Club Acela and the Bus Facility during the AM peak hour as well as the maximum processing rate of the VCEs (325 ppl/min, indicated by the dashed horizontal line). As the chart shows, demand does not approach capacity, indicating VCEs that are not only adequately sized but have redundancy in the event of breakdown, maintenance, or higher passenger volumes than estimated by the trip generation model.

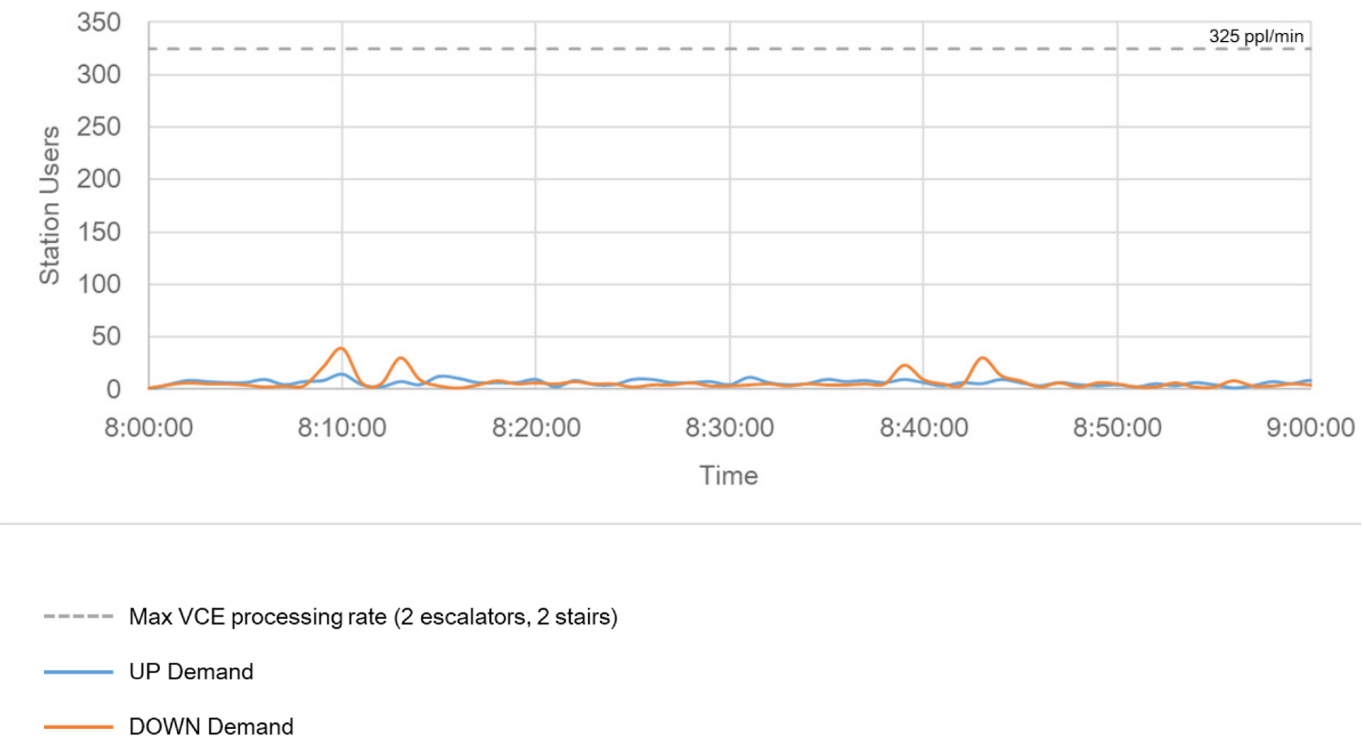

Figure 22: Demand in the up and down direction to/from the Bus Facility and Club Acela during the AM peak hour compared to the maximum processing rate of both vertical circulation sets (east and west).

3. Areas for Further Study

There are a few items related to passenger circulation, station design, and operations that should be investigated as the design advances beyond the 10% stage. These include:

Midday/PM Periods

This involves evaluating station conditions during the midday and/or PM time periods when the station will operate differently than the AM peak period.

- **Who this may apply to:** all station passengers and other station users who may be visiting the station and/or utilizing retail
- **Reasons for studying:** to study circulation conditions at the station during time periods when operating characters, demand, and passenger behaviors are very different than the AM period. The midday period may feature more tourists and retail use while the PM period will include different demand patterns, passenger waiting conditions, and platform activity.
- **Recommended study timeframe:** SD stage

Altered Operational Conditions

This analysis may involve several different operating scenarios that will likely occur at the station, including train cancellations, escalator breakdowns, or abnormal passenger demand.

- **Who this may apply to:** all station users
- **Reasons for studying:** scenario testing like this helps to plan for inevitable problems before they occur and incorporate resiliency and redundancy where necessary.
- **Recommended study timeframe:** SD stage

Passenger Waiting/Queueing

This involves studying how and where passengers may wait and/or queue in and around the concourses for departing trains.

- **Who this may apply to:** all departing station passengers
- **Reasons for studying:** to understand spatial needs associated with unorganized waiting behavior and organized queues. For the latter, it will be important to consider sizing and specific policies or procedures, e.g., staffing, security, ticket inspection, queueing by class or zone, etc.
- **Recommended study timeframe:** DD stage

Security

This involves studying how and where passengers may get screened in the future.

- **Who this may apply to:** all departing station passengers
- **Reasons for studying:** to understand protocols, processes, and optimal locations for screening as well as potential implications on queueing, passenger delay, and the overall passenger experience
- **Recommended study timeframe:** DD stage

Access Control

This involves assessing systems such as turnstiles that may restrict platform access based on passenger or ticket type.

- **Who this may apply to:** all departing station passengers
- **Reasons for studying:** to test different systems/approaches, optimize quantity and location based on particular operating characteristics, and evaluate potential congestion caused by limiting passenger throughputs
- **Recommended study timeframe:** DD stage

REFERENCES

Amtrak. 2013. *Station Program and Planning Guidelines*. Washington, DC: Amtrak .

Fruin, John J. 1971. *Pedestrian Planning and Design*. Mobile, Alabama: Elevator World, Inc.

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