APPENDIX I

Draft Vehicle Mobility Analysis

Little Cottonwood Canyon ENVIRONMENTAL IMPACT STATEMENT
S.R. 210 | Wasatch Blvd. to Alta

Draft Vehicle Mobility Analysis

Little Cottonwood Canyon Environmental Impact Statement S.R. 210 - Wasatch Boulevard to Alta

Lead agency:
Utah Department of Transportation

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Acronyms and Abbreviations

HOV	high-occupancy vehicle
PPSL	peak-period shoulder lane
S.R.	state route
SPT	Sketch Planning Tool
UDOT	Utah Department of Transportation

Glossary

30th-busiest hour: the 30th-busiest hour on a road as determined by traffic counts taken on the road over an entire year. For this analysis, the traffic volume on S.R. 210 during the 30th-busiest hour in 2017 was used as the basis for the traffic volume during the design hour in 2050.

design hour: the future hour whose projected traffic volume is used as the basis for designing or improving a road. A roadway is designed to accommodate the number of vehicles (traffic volume) during the design hour. For this analysis, the design hour is in 2050.

peak hour: the single busiest hour on a road as determined by traffic counts taken on the road over an entire year.

peak period: a period of the day with a high volume of traffic. Peak periods occur on S.R. 210 during the morning and afternoon.

1.0 Introduction

The purpose of this report is to explain the methods used, evaluation, and results of the per-person travel and queuing length analysis for the alternatives considered in the Little Cottonwood Canyon Environmental Impact Statement (EIS). The analysis is for roadway-based alternatives only. Travel times for gondola and train alternatives are provided in a separate report.

2.0 Design-hour Travel Time Analysis

2.1 Design Hour and Traffic Volume Used in the Analysis

Roads are designed to accommodate a specific number of vehicles per hour. This traffic volume, called the design-hour traffic volume, is typically less traffic than what is expected during the single busiest or peak) hour on that road during the entire year. Designing for the yearly peak hour is usually not economical or feasible because it would mean building the road to accommodate more vehicles than what will be on the road most days (FHWA 2018).

What is the design-hour traffic volume?

The design-hour traffic volume is the maximum number of vehicles per hour that a roadway is designed to accommodate.

For the Little Cottonwood Canyon Project, the Utah Department of Transportation (UDOT) is proposing improvements to S.R. 210 in the canyon. These improvements consider future travel in the canyon in 2050 (the project's design year). To determine the design-hour traffic volume, UDOT performed the following two steps.

1. Using traffic count data, select a specific hour during which S.R. 210 had a high volume of traffic during a recent year. Typically, in rural settings similar to S.R. 210 in Little Cottonwood Canyon, the hour that is selected is the 30th-busiest hour over the entire year (FHWA 2018). By using the 30th-busiest hour, UDOT avoids designing roads for extremely busy days that are outliers from the more common traffic volumes.
2. Determine the rate at which traffic volumes are projected to increase in the future, and use this rate to increase the traffic volume during the recent 30th-busiest hour to the projected traffic volume during the future design hour. This is the design-hour traffic volume.

Roadway projects are usually designed using a single design hour and associated design-hour traffic volume. However, in Little Cottonwood Canyon, there are different traffic impacts for people entering the canyon in the morning (traveling eastbound) and people leaving the canyon in the afternoon (traveling westbound). For this reason, UDOT initially looked at two 30th-busiest hours for S.R. 210 in the canyon: one for traffic going eastbound and one for traffic going westbound.

To determine the 30th-busiest hours, UDOT used traffic data from 2017 from its automated traffic counters in the canyon (Fehr & Peers 2018a).

- **Eastbound.** The 30th-busiest hour on S.R. 210 for eastbound traffic was the hour from 10 AM to 11 AM on Saturday, January 14. According to the traffic data, 1,061 vehicles entered the canyon going eastbound during this hour in 2017.
- **Westbound.** The 30th-busiest hour on S.R. 210 for westbound traffic was the hour from 4 PM to 5 PM on Friday, March 3. According to the traffic data, 1,051 vehicles left the canyon going westbound during this hour in 2017.

Since these traffic counts were similar, and since the 30th-busiest hour in either direction occurred in the eastbound direction, UDOT decided to use the 30th-busiest hour in the eastbound direction as the basis for the future design hour. Therefore, the traffic volume during the 30th-busiest hour in 2017 was 1,061 vehicles.

The Little Cottonwood Canyon EIS is using 2050 as its design year. To determine the expected traffic volume during the design hour in 2050, UDOT increased the traffic volume from the 30th-busiest hour in 2017. According to an analysis conducted for UDOT (Fehr & Peers 2018b), traffic on S.R. 210 has been increasing at a rate of 1.2% per year. Using this rate, UDOT increased the traffic volume during the 30th-busiest hour in 2017 (1,061 vehicles) over a 32-year period (2018 to 2050) to calculate the projected traffic volume during the design hour in 2050 (1,555 vehicles).

What are the design hour and design-hour traffic volume for this analysis?

For this analysis, the design hour is the 30th-busiest hour in the eastbound direction on S.R. 210 in 2050, and the design-hour traffic volume is 1,555 vehicles.

Therefore, for this analysis, the design hour is the 30th-busiest hour in the eastbound direction on S.R. 210 in 2050, and the design-hour traffic volume is 1,555 vehicles. This number is assumed to include both personal vehicles and buses.

2.2 Design-hour Person Demand Used in the Analysis

UDOT next determined the number of people who would be traveling on S.R. 210 during the design hour in 2050 as this would be the basis for screening alternatives. According to vehicle occupancy data from 2018 (L2 Data Collection 2018), the average number of occupants during the peak morning hour (on a weekend day) was 1.89 occupants per personal vehicle and 42 occupants per bus. For buses, the current 15-minute headways on Routes 953 and 994 were assumed (that is, 4 buses per route for a total of 8 buses per hour).

In 2050 during the design hour (1,555 vehicles), 336 people are projected to travel by bus (8 buses × 42 occupants) and about 2,924 people are projected to travel by personal vehicle (1,547 personal vehicles × 1.89 occupants) for a total of about 3,260 people entering Little Cottonwood Canyon during the design hour.

2.3 Per-person Travel Time Used in the Analysis

One purpose of the Little Cottonwood Canyon Project is to improve mobility on S.R. 210. UDOT used a reduction in travel time per person to measure this mobility criterion. Such a reduction in travel time per person allows an equal comparison of the alternatives analyzed in this report, alternatives that have different of configurations of travel mode (bus or personal vehicle), number and type of lanes, and bus headways. This would show the benefit for all users independent of traveling in a personal car or bus. For example, if a dedicated bus lane was implemented with a faster travel time for a bus than a personal vehicle the 42 persons in the bus would have a faster travel time than the 2 people in the personal vehicle giving a greater benefit to bus service.

What is headway?

As used in this report, *headway* is the time between two buses arriving at the same location on the same route.

To further allow an equal comparison of travel times between alternatives, UDOT used common starting and ending points of travel for all travel modes. For personal vehicles, travel time was calculated starting at Fort Union Boulevard and ending at the Alta ski resort. For buses, travel time was calculated starting at Fort Union Boulevard and ending at the Alta ski resort but also included time to transfer from one mode to another. Each transfer between modes was assumed to take 12 minutes. For example, UDOT assumed that it would take 12 minutes of additional time to park a personal vehicle in a parking garage and board a bus versus driving a personal vehicle directly to the ski resort.

The per-person travel time was modeled using the Little Cottonwood Canyon Sketch Planning Tool (see the following section).

2.4 Per-person Travel Time Modeling

The Little Cottonwood Canyon Sketch Planning Tool (SPT or model) is a data-driven planning tool designed for Little Cottonwood Canyon to estimate travel times in the canyon based on changes in travel demand and potential transportation improvements. The SPT is a system dynamics model that uses a Microsoft Excel format. System dynamics models are applicable to systems that have many individually dynamic components that are interrelated. The SPT focuses on relationships between travel demand in Little Cottonwood Canyon, travel mode choice, and travel times. Each approach to the canyon from Fort Union Boulevard to the Alta ski resort is programmed into the model, along with the existing number of travel lanes and the posted speed limits (HDR 2019a).

The SPT analyzes traffic from outside the canyon (at the intersection of S.R. 210 and Fort Union Boulevard) to the Alta ski resort. The SPT is able to adjust the overall daily travel demand for the canyon (the number of people who enter the canyon on a given day), hourly arrival times, mode(s) of transportation used by each person, bus headways and ridership capacities, and parking lot capacities throughout the canyon.

The SPT can evaluate various alternatives and estimate their expected travel times. A variety of scenarios can be evaluated, including combinations of the following elements:

- Number of travel lanes
- Speed limits
- Transit-only (bus-only) lane
- A high-occupancy vehicle (HOV) lane for buses and carpooling vehicles
- Bus schedule(s) and route(s)
- Mode of transportation used by each person (for example, carpooling versus taking a bus)
- Time of day when people arrive at or leave the canyon (for example, arriving or leaving later on closure days)

For the travel time analysis in this report, UDOT used the SPT to calculate travel times for personal vehicles and buses and the number of people in single-occupant vehicles, high-occupancy vehicles, and buses.

2.4.1 Travel Time Estimations

The SPT is sub-divided into several analysis modules, organized to mimic a person's travel decisions when choosing to visit Little Cottonwood Canyon, including:

- Built environment (physical infrastructure and policy decisions)
- Persons traveling to Little Cottonwood Canyon
- Mode choice distribution
- Hourly vehicle travel profiles (i.e. entering or exiting the canyon)
- Transit system operating characteristics

The model is heavily data-driven, and uses historic traffic patterns and local observations to estimate the impacts of future scenarios on travel times. As changes are made within the model to simulate a future scenario, the SPT automatically incorporates the effects from early modules into the results of subsequent analysis modules, creating a cohesive evaluation of travel times based upon the compounding effects of all of the transportation improvements implemented in the future scenario.

The travel time models within the SPT are based upon Greenshields model of traffic flow, which defines the interrelationships between traffic density, travel speed, and traffic flow. The key parameters necessary for applying this traffic flow model (e.g. maximum vehicle flow rate, jam density, free flow travel speed) were set as variables within the SPT, which automatically adjust to incorporate changes to the built environment as new scenarios are evaluated.

The adjustments redefine the relationships between vehicle flow, vehicle density, and travel speed for each future scenario, thereby creating a dynamic model which provides travel time estimations for the corridor. As vehicle density increases (i.e. cars are closer together – similar to a traffic jam), vehicles travel at slower speeds and therefore fewer vehicles can traverse the road segment (i.e. reduced vehicle flow). As vehicle density decreases (i.e. fewer cars on the roadway), vehicles may travel faster and there will be more vehicles that can traverse the road segment (i.e. increased vehicle flow). Similar changes occur as

adjustments are made to vehicle speed (density and flow rate change) and vehicle flow rates (speed and density change).

These three parameters are directly influenced by the transportation improvements selected for modeling. For example, adding an additional travel lane to the roadway increases its overall capacity, maximum vehicle flow rate, and the maximum vehicle density (i.e. jam density), and would result in decreased travel times (assuming travel demand and the free flow speed remained constant).

In another example, changes to add a transit lane along the corridor (assuming one general purpose lane and one transit lane) would move buses with slower climbing speeds to their own lane. This would allow vehicles to travel up to the posted speed limit, rather than be limited by the bus climbing speed. This scenario would calculate travel times separately for the vehicles traveling in the general purpose lane and the buses traveling within the transit lane.

The model also makes adjustments to account for scenarios where travel demand exceeds the capacity of the roadway, increasing the travel time estimation to incorporate the effects of vehicle queuing on the roadway.

2.5 Alternatives Evaluated

For the travel time analysis, UDOT evaluated multiple alternatives to determine the per-person travel time for each alternative during the design hour in 2050. Table 1 lists the alternatives that were evaluated which came from public, agency, and previous reports. The analysis for bus service includes headways of either 15 minutes (current conditions), 7.5 minutes, or 5 minutes to meet the ridership demand for the alternatives. Headways less than 5 minutes were considered infeasible because there would not be enough time for all riders to exit or board the bus and retrieve or stow their ski gear before the next bus arrived (UTA 2019).

The headways for the alternatives listed in Table 1 assume that two buses leave at the same time from two transit hubs: one at a gravel pit off of Wasatch Boulevard near Fort Union Boulevard and a second at 9400 South and Highland Drive. Therefore, a 5-minute headway assume a bus leaving every 5 minutes from both transit hubs to the ski resorts (2 buses every 5 minutes, or 24 buses per hour).

Table 1. Alternatives Evaluated in the Travel Time Analysis for the Peak-direction (Eastbound) Conditions in the Design Hour

Alternative	Number of Vehicles		Person Demand		
	Personal Vehicles[a]	Buses[b]	People in Personal Vehicles	People in Buses	Total Person Demand[c]
Baseline Conditions					
1. 2017 Baseline • Wasatch Blvd. – One lane each direction • Little Cottonwood Canyon – One lane each direction • Transit – 15-minute bus headways on two separate routes	1,053	8	1,990	336	2,326
2. 2050 Baseline (No-Action Alternative)[d] • Wasatch Blvd. – One lane each direction • Little Cottonwood Canyon – One lane each direction • Transit – 15-minute bus headways on two separate routes	1,547	8	2,924	336	3,260
No Additional Capacity to Wasatch Blvd. or Little Cottonwood Canyon Road and Increase Transit (Bus)					
3. Bus service with 5-minute headways on two separate routes • Wasatch Blvd. – One lane each direction • Little Cottonwood Canyon – One lane each direction • Transit – 5-minute bus headways on two separate routes	1,190	24	2,249	1,008	3,257
Additional Roadway Capacity to Wasatch Blvd. with No Additional Capacity to Little Cottonwood Canyon Road and Increase Transit (Bus)					
4. Bus service with 7.5-minute headways on two separate routes • Wasatch Blvd. – 4 or 5 lanes with transit priority • Little Cottonwood Canyon – One lane each direction • Transit – 7.5-minute bus headways on two separate routes	1,368	16	2,585	672	3,257
5. Bus service with 5-minute headways on two separate routes • Wasatch Blvd. – 4 or 5 lanes with transit priority • Little Cottonwood Canyon – One lane each direction • Transit – 5-minute bus headways on two separate routes	1,190	24	2,249	1,008	3,257

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Table 1. Alternatives Evaluated in the Travel Time Analysis for the Peak-direction (Eastbound) Conditions in the Design Hour

Alternative	Number of Vehicles		Person Demand		
	Personal Vehicles[a]	Buses[b]	People in Personal Vehicles	People in Buses	Total Person Demand[c]
Additional Roadway Capacity to Wasatch Blvd. and Peak-period Shoulder Lanes on Little Cottonwood Canyon Road and Increase Transit (Bus)					
6. One general-purpose lane and one bus-only lane in shoulder with bus 7.5-minute headways on two separate routes • Wasatch Blvd. – 4 or 5 lanes with transit priority • Little Cottonwood Canyon – one lane each direction plus peak-period shoulders • Transit – 7.5-minute bus headways on two separate routes	1,368	16	2,585	672	3,257
7. One general-purpose lane and one-bus only lane in shoulder with bus 5-minute headways on two separate routes • Wasatch Blvd. – 4 or 5 lanes with transit priority • Little Cottonwood Canyon – one lane each direction plus peak-period shoulder lanes • Transit – 5-minute bus headways on two separate routes	1,190	24	2,249	1,008	3,257

[a] Assumes 1.89 people per vehicle during the design hour based on vehicle occupancy counts conducted in 2018.

[b] Assumes buses from transit hubs at both the Gravel Pit and at 9400 South and Highland Drive. Buses have a standing capacity of 42 riders.

[d] Person demand in the design hour would need to be greater than 3,250 to meet 2050 demand.

[d] The No-Action Alternative serves as baseline against which to compare the action alternatives and is not evaluated against the screening criteria.

Since traffic volumes, bus service, and person throughput are nearly identical for both the eastbound (AM) 30th-busiest hour and the westbound (PM) 30th-busiest hour, the values in this table apply to both travel directions during the design hour.

Figure 1 shows the lane configuration for Alternatives 1 through 5. This lane configuration is the same as the existing roadway in Little Cottonwood Canyon.

Figure 1. S.R. 210 in Little Cottonwood Canyon – Existing Conditions

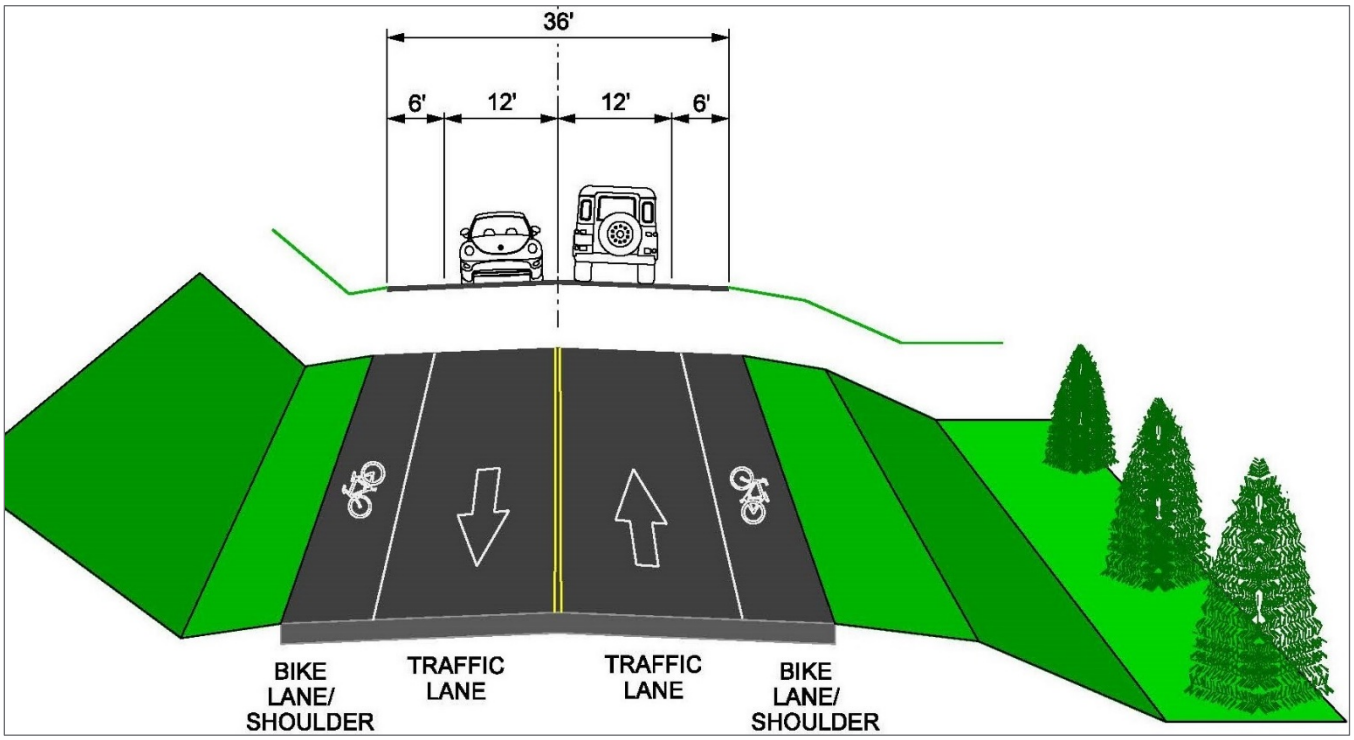


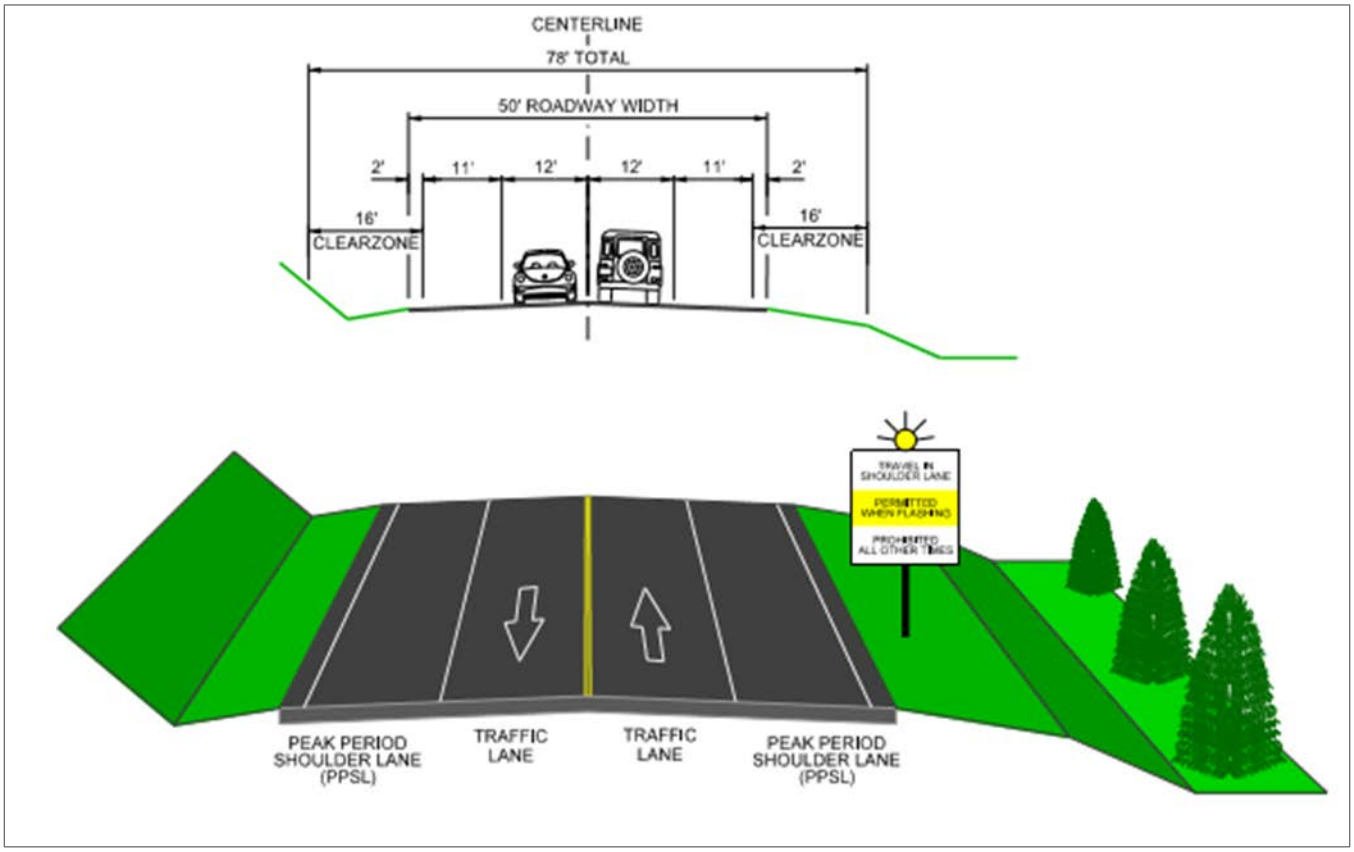
Figure 2 shows the configuration of peak-period shoulder lanes (PPSLs) for Alternatives 6 through 10. These lanes would be open to eastbound traffic in the morning and westbound traffic in the afternoon on heavy traffic days. The lanes would be closed for traffic during the summer and during the winter outside of peak periods unless UDOT observes congested conditions on S.R. 210. The PPSLs could be open to general-purpose traffic without restrictions, or they could be limited to buses only.

What are peak periods?

Peak periods are the periods of the day with the heaviest traffic. For this analysis, the peak periods on S.R. 210 occur in the morning and afternoon on busy ski days.

The transition areas at the beginning and end of the PPSLs would be fairly straightforward. Dynamic message signs would alert drivers whether the PPSL is open or closed. When a PPSL is closed, drivers would merge from the PPSL in the shoulder back into the general-purpose travel lane.

Figure 2. S.R. 210 in Little Cottonwood Canyon – Peak-period Shoulder Lanes



2.6 Travel Time Results

2.6.1 Design Hour Travel Time in the Morning (Eastbound Entering Canyon)

For UDOT's analysis of the travel time during the design hour in the eastbound direction (morning traffic), the number of vehicles entering Little Cottonwood Canyon and the number of travel lanes were the main factors that determined the travel time. Table 2 shows the per-person travel time analysis in 2050 by number of vehicles and lanes. The transit travel times in Table 2 do not include a 12 minute travel time addition for parking personal vehicle, unloading gear, bus wait time, and bus loading

With regard to the travel time per person using personal vehicles, travel times would be very similar for personal vehicles when all vehicles are placed in a single lane. For example, if both buses and personal vehicles share the same general-purpose lanes, and with bus service at 7.5-minute or 5-minute headways, the travel time per person for people using personal vehicles would be 52 minutes and 42 minutes, respectively. With the bus-only lane added and all personal vehicles in a single travel lane, and with bus service at 7.5-minute or 5-minute headways, the travel time per person for people using personal vehicles would be 50 minutes and 38 minutes, respectively. With the bus-only lane, travel times would improve because the buses would be removed from the lane with the personal vehicles. With bus/high-occupancy vehicle (HOV) lanes and all general-purpose lanes, and with bus service at 15-minute headways, the travel time per person for people using personal vehicles would improve to 28 minutes because personal vehicles would be allowed to use all travel lanes.

Travel times on narrow and steep canyon roads are very sensitive to the number of vehicles on the road. On S.R. 210 from the intersection with S.R. 209(the entrance to Little Cottonwood Canyon) to the Alta ski resort, if there are 900 vehicles on the road per hour, the road is operating under free-flow conditions (freely flowing traffic with little congestion or delay). Under these conditions, the travel time is about 23 minutes per person. However, once the number of vehicles exceeds 900 vehicles per hour, the road exceeds capacity, and the additional vehicles dramatically increase the travel time per person. Following are the modeled travel times per person in 2050 if no improvements are made S.R. 210 from the intersection with S.R. 209 to the Alta ski resort:

- 900 vehicles per hour = 23 minutes per person
- 1,200 vehicles per hour = 36 minutes per person
- 1,350 vehicles per hour = 46 minutes per person
- 1,550 vehicles per hour = 58 minutes per person

Table 2. Travel Time Analysis for the Design Hour in the Eastbound Direction (AM)

Alternative	Number of AM Eastbound Lanes in Little Cottonwood Canyon	Number of People	Average Travel Time per Person (minutes)		
			People in Personal Vehicles	People in Buses[a]	Combined
Baseline Conditions					
1. 2017 Baseline • 15-minute bus headways • 1,061 vehicles (8 buses + 1,053 personal vehicles)	One general-purpose lane	2,326	42	42	40–45
2. 2050 Baseline (No-Action Alternative) • 15-minute bus headways • 1,555 vehicles (8 buses + 1,547 personal vehicles)	One general-purpose lane	3.,260	84	84	80–85
No Additional Capacity to Wasatch Blvd. or Little Cottonwood Canyon Road and Increase Transit (Bus)					
3. 5-Minute Bus Headways • 1,214 vehicles (24 buses + 1,190 personal vehicles)	One general-purpose lane	3,257	47	47	45–50
Additional Roadway Capacity to Wasatch Blvd. with No Additional Capacity to Little Cottonwood Canyon Road and Increase Transit (Bus)[b]					
4. 7.5-Minute Bus Headways • 1,384 vehicles (16 buses + 1,368 personal vehicles)	One general-purpose lane	3,257	52	52	50–55
5. 5-Minute Bus Headways • 1,214 vehicles (24 buses + 1,190 personal vehicles)	One general-purpose lane	3,257	42	42	40–45
Additional Roadway Capacity to Wasatch Blvd. and Peak-period Shoulder Lanes on Little Cottonwood Canyon Road and Increase Transit (Bus)[b]					
6. 7.5-Minute Bus Headways • 1,384 vehicles (16 buses + 1,368 personal vehicles)	One bus-only lane and one general-purpose lane	3,257	50	24	45–50
7. 5-Minute Bus Headways • 1,214 vehicles (24 buses + 1,190 personal vehicles)	One bus-only lane and one general-purpose lane	3,257	38	24	35–40

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Table 2. Travel Time Analysis for the Design Hour in the Eastbound Direction (AM)

Alternative	Number of AM Eastbound Lanes in Little Cottonwood Canyon	Number of People	Average Travel Time per Person (minutes)		
			People in Personal Vehicles	People in Buses[a]	Combined

[a] Assumes transit priority on Wasatch Blvd. for all action alternatives. Travel time does not include bus transfer time from personal vehicle of 12 minutes.

[b] Assumes that Wasatch Blvd. is either 4 or 5 lanes to meet UDOT's PM design-hour objective of level of service (LOS) D or better.

[c] Assumes about 50% of personal vehicles are HOV sharing bus lane.

2.6.2 Design Hour Travel Time in the Afternoon (Westbound Leaving Canyon)

For UDOT's analysis of the travel time during the design hour in the westbound direction (afternoon traffic), the number of vehicles leaving Little Cottonwood Canyon and the number of travel lanes were the main factors that determined the travel time. Table 3 shows the per-person travel time analysis in 2050 by number of vehicles and lanes.

With regard to the travel time per person using personal vehicles, travel times would be very similar for personal vehicles when all vehicles are placed in a single lane. For example, if both buses and personal vehicles share the same lanes, and with bus service at 7.5-minute or 5-minute headways, the travel time per person for people using personal vehicles would be are 53 minutes and 43 minutes, respectively. With the bus-only lane added and all personal vehicles in a single travel lane, and with bus service at 7.5-minute or 5-minute headways, the travel time per person for people using personal vehicles would be 48 minutes and 36 minutes, respectively. With the bus-only lane, the travel time per person for people using personal vehicles would slightly improve because the buses would be removed from the lane with the personal vehicles. The transit travel times in Table 3 do not include a 12 minute travel time addition for parking personal vehicle, unloading gear, bus wait time, and bus loading

Table 3. Travel Time Analysis for the Design Hour in the Westbound Direction (PM)

Alternative	Number of PM Westbound Lanes in Little Cottonwood Canyon	Number of People	Average Travel Time per Person (minutes)		
			People in Personal Vehicles	People in Buses[a]	Combined
Baseline Conditions					
1. 2017 Baseline • 15-minute bus headways • 1,061 vehicles (8 buses + 1,053 personal vehicles)	One general-purpose lane	2,326	42	42	40–45
2. 2050 Baseline (No-Action Alternative) • 15-minute bus headways • 1,555 vehicles (8 buses + 1,047 personal vehicles)	One general-purpose lane	3,260	82	82	80–85
No Additional Capacity to Wasatch Blvd. or Little Cottonwood Canyon Road and Increase Transit (Bus)					
3. 5-Minute Bus Headways • 1,214 vehicles (24 buses + 1,190 personal vehicles)	One general-purpose lane	3,257	48	48	45–50
Additional Roadway Capacity to Wasatch Blvd. with No Additional Capacity to Little Cottonwood Canyon Road and Increase Transit (Bus)[b]					
4. 7.5-Minute Bus Headways • 1,384 vehicles (16 buses + 1,368 personal vehicles)	One general-purpose lane	3,257	53	53	50–55
5. 5-Minute Bus Headways • 1,214 vehicles (24 buses + 1,190 personal vehicles)	One general-purpose lane	3,257	43	43	40–45
Additional Roadway Capacity to Wasatch Blvd. and Peak-period Shoulder Lanes on Little Cottonwood Canyon Road and Increase Transit (Bus)[b]					
6. 7.5-Minute Bus Headways • 1,384 vehicles (16 buses + 1,368 personal vehicles)	One bus-only lane and one general-purpose lane	3,257	48	32	45–50
7. 5-Minute Bus Headways • 1,214 vehicles (24 buses + 1,190 personal vehicles)	One bus-only lane and one general-purpose lane	3,257	36	30	35–40

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Table 3. Travel Time Analysis for the Design Hour in the Westbound Direction (PM)

Alternative	Number of PM Westbound Lanes in Little Cottonwood Canyon	Number of People	Average Travel Time per Person (minutes)		
			People in Personal Vehicles	People in Buses[a]	Combined

[a] Assumes transit priority on Wasatch Blvd. for all action alternatives. Travel time does not include bus transfer time to personal vehicle of 12 minutes.

[b] Assumes that Wasatch Blvd. is either 4 or 5 lanes to meet UDOT's PM design-hour objective of LOS D or better.

[c] Assumes about 50% of personal vehicles are HOV sharing bus lane

2.7 Tolling Considerations

If UDOT were to implement a toll on S.R. 210 along with improved bus travel times, drivers would be forced to decide whether the toll makes the ski bus a better option. A toll along with improved bus travel times would be a tool to incentivize transit use. The amount of the toll has yet to be determined.

Congestion (variable) pricing is in use in areas around the United States and the world. For example, drivers could be offered a discount if they traveled during off-peak periods. This type of toll structure would encourage drivers to shift to the bus during peak periods or to drive during off-peak or discount periods.

Although the exact type of tolling system has yet to be decided, it would likely be an electronic pass system and/or a license plate recognition system. The advantage of tolling is that the toll could be used to pay for some or all of ski bus operations and thus result in free or substantially reduced fares.

Tolling would be most effective with a separate or shared bus/HOV lane where the bus travel time is faster than vehicle travel times. The toll to the vehicle along with the faster travel time would make the bus service more attractive given the inconvenience of transferring from a vehicle to the bus and carrying ski gear onto the bus.

3.0 Vehicle Queuing Analysis

One of the screening criteria for the alternatives analysis is to substantially reduce vehicle backups on S.R. 210 and S.R. 209 through residential areas on busy ski days. For this analysis, UDOT used a VISSIM model to determine the length of vehicles backing up from the S.R. 209/S.R. 210 intersection. The analysis is based on UDOT's Traffic Analysis Guidelines (UDOT 2018). The backup length criterion used in the analysis is the 95th-percentile vehicle queue, which is defined to be the vehicle queue length that has only a 5% probability of being exceeded during the analysis period. The length is measured from the stop bar of an intersection or from the beginning of a roadway bottleneck to the end of the last vehicle in the line.

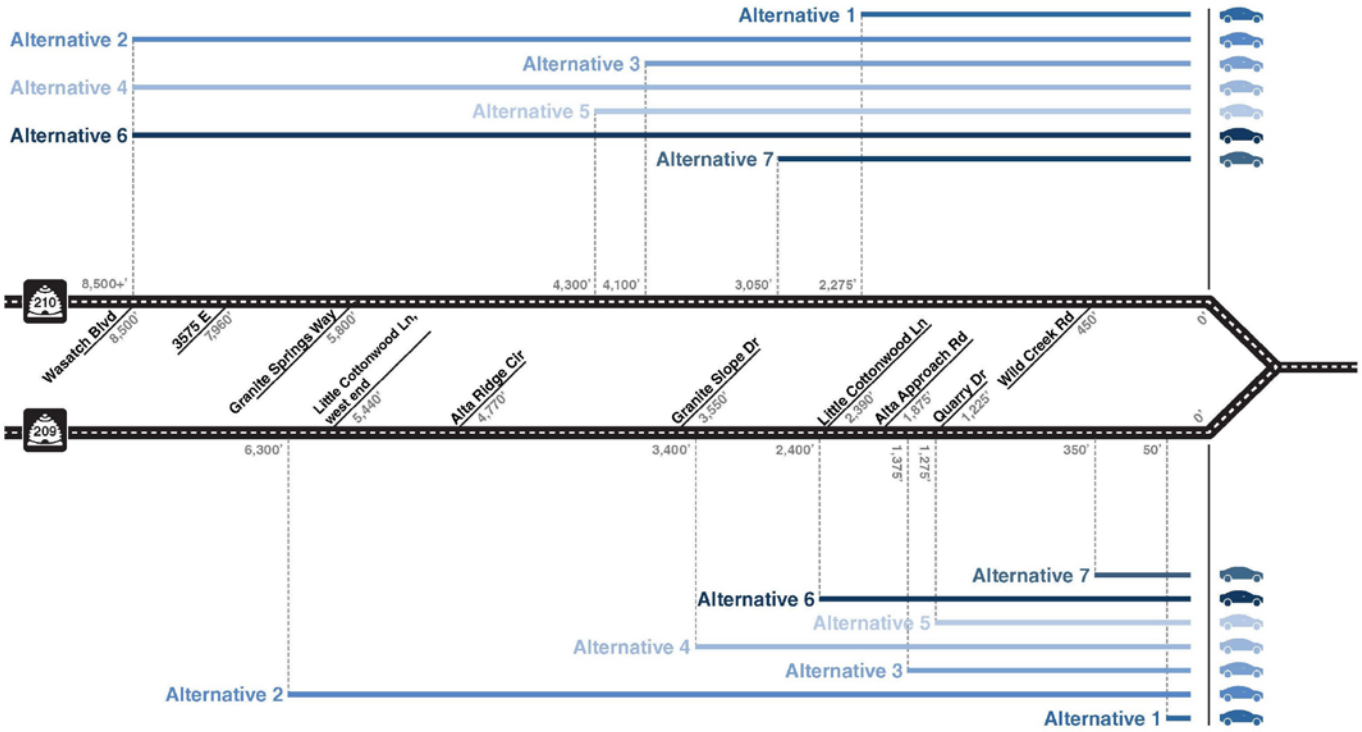
The purpose of using this screening criterion is to substantially reduce vehicle backups compared to the baseline (no-action) conditions in 2050 (that is, the conditions if no improvements are made to S.R. 210). As shown in Table 5 and Figure 3, under the baseline conditions (without improvements) in 2050, the vehicle backups on S.R. 209 are projected to extend past the traffic signal at the intersection of 9400 South and Wasatch Boulevard, and the vehicle backups on S.R. 210 are projected to extend past the traffic signal at the intersection of Wasatch Boulevard and North Little Cottonwood Road. Based on origin-destination data collected by UDOT, about 60% of the traffic entering Little Cottonwood Canyon comes from S.R. 210 and 40% comes from S.R. 209.

Table 4.Queuing Analysis during the Design Hour in the Eastbound Direction (AM)

Alternative	Number of AM Eastbound Lanes in Little Cottonwood Canyon	Queuing on S.R. 209 (feet)	Queuing on S.R. 210 (feet)
Baseline Conditions			
1. 2017 Baseline • 15-minute bus headways • 1,061 vehicles (8 buses + 1,053 personal vehicles)	One general-purpose lane	50	2,275
2. 2050 Baseline (No-Action Alternative) • 15-minute bus headways • 1,555 vehicles (8 buses + 1,047 personal vehicles)	One general-purpose lane	6,300+ (beyond traffic signals at 9400 South/Wasatch Blvd. intersection)	8,500+ (beyond traffic signals at Wasatch Blvd./North Little Cottonwood Road intersection)
No Additional Capacity to Wasatch Blvd. or Little Cottonwood Canyon Road and Increase Transit (Bus)			
3. 5-Minute Bus Headways • 1,214 vehicles (24 buses + 1,190 personal vehicles)	One general-purpose lane	1,375 (backup to Quarry Drive)	4,100 (backup halfway to Wasatch Blvd./ North Little Cottonwood Road intersection)
Additional Roadway Capacity to Wasatch Blvd. with No Additional Capacity to Little Cottonwood Canyon Road and Increase Transit (Bus)[a]			
4. 7.5-Minute Bus Headways • 1,384 vehicles (16 buses + 1,368 personal vehicles)	One general-purpose lane	3,400 (backup near Granite Slope Drive)	8,500+ (beyond traffic signals at Wasatch Blvd/North Little Cottonwood Road intersection)
5. 5-Minute Bus Headways • 1,214 vehicles (24 buses + 1,190 personal vehicles)	One general-purpose lane	1,275	4,300
Additional Roadway Capacity to Wasatch Blvd. and Peak-period Shoulder Lanes on Little Cottonwood Canyon Road and Increase Transit (Bus)[a]			
6. 7.5-Minute Bus Headways • 1,384 vehicles (16 buses + 1,368 personal vehicles)	One bus-only lane and one general-purpose lane	2,450 (backup to Little Cottonwood Lane)	8,500+ (beyond traffic signals at Wasatch Blvd./North Little Cottonwood Road intersection)
7. 5-Minute Bus Headways • 1,214 vehicles (24 buses + 1,190 personal vehicles)	One bus-only lane and one general-purpose lane	350	3,050 (backup one-third to Wasatch Blvd./North Little Cottonwood Road intersection

[a] Assumes that Wasatch Blvd. is either 4 or 5 lanes to meet UDOT's PM design-hour objective of LOS D or better.

Figure 3. Queuing Results



4.0 Results of the Travel Time and Vehicle Queuing Analysis

Table 6 shows the consolidated results of UDOT's analysis of travel time per person and vehicle queuing for the alternatives analyzed in this report. The transit travel times in Table 6 include a 12 minute travel time addition for parking their personal vehicle, unloading gear, bus wait time, and bus loading.

Table 5. Travel Time and Queuing Analysis Results during the Design Hour in the Eastbound (AM) and Westbound (PM) Directions

Alternative	Number of Vehicles		Person Demand			Travel Time per Person Eastbound/Westbound (minutes)[d]	Vehicle Backup (feet)	
	Personal Vehicles[a]	Buses[b]	People in Personal Vehicles	People in Buses	Total Person Demand[c]		On S.R. 209	On S.R. 210
Baseline Conditions								
1. 2017 Baseline • Wasatch Blvd. – One lane each direction • Little Cottonwood Canyon – One lane each direction • Transit – 15-minute bus headways on two separate routes	1,053	8	1,990	336	2,326	40–45 / 40–45 (40-45/40-45 – vehicle) (50-55/50-55 - bus)	50	2,775
2. 2050 Baseline (No-Action Alternative)[e] • Wasatch Blvd. – One lane each direction • Little Cottonwood Canyon – One lane each direction • Transit – 15-minute bus headways on two separate routes	1,547	8	2,924	336	3,260	80–85 / 80–85 (80-85/80-85 – vehicle) (95-100/90-95 - bus)	6,300+ (beyond traffic signals at 9400 South/Wasatch Blvd. intersection)	8,500+ (beyond traffic signals at Wasatch Blvd./North Little Cottonwood Road intersection)
No Additional Capacity to Wasatch Blvd. or Little Cottonwood Canyon Road and Increase Transit (Bus)								
3. Bus service with 5-minute headways on two separate routes • Wasatch Blvd. – One lane each direction • Little Cottonwood Canyon – One lane each direction • Transit – 5-minute bus headways on two separate routes	1,190	24	2,249	1,008	3,257	50-55 / 50-55 (45-50/45-50 – vehicle) (60-65/60-65 - bus)	1,375 (backup to Quarry Drive)	4,100 (backup halfway to Wasatch Blvd./North Little Cottonwood Road intersection)
Additional Roadway Capacity to Wasatch Blvd. with No Additional Capacity to Little Cottonwood Canyon Road and Increase Transit (Bus)								
4. Bus service with 7.5-minute headways on two separate routes • Wasatch Blvd. – 4 or 5 lanes with transit priority • Little Cottonwood Canyon – One lane each direction • Transit – 7.5-minute bus headways on two separate routes	1,368	16	2,585	672	3.257	50–55 / 50–55 (50–55/50-55– vehicle) (60-65/60-65 - bus)	3,400 (backup near Granite Slope Drive)	8,500+ (beyond traffic signals at Wasatch Blvd./North Little Cottonwood Road intersection)
5. Bus service with 5-minute headways on two separate routes • Wasatch Blvd. – 4 or 5 lanes with transit priority • Little Cottonwood Canyon – One lane each direction • Transit – 5-minute bus headways on two separate routes	1,190	24	2,249	1,008	3,257	45–50 / 45–50 (40–45/40-45 – vehicle) (50-55/50-55 – bus)	1,275	4,300
Additional Roadway Capacity to Wasatch Blvd. and Peak-period Shoulder Lanes on Little Cottonwood Canyon Road and Increase Transit (Bus)								
6. One general-purpose lane and one bus-only lane in shoulder with bus 7.5-minute headways on two separate routes • Wasatch Blvd. – 4 or 5 lanes with transit priority • Little Cottonwood Canyon – one lane each direction plus peak-period shoulders • Transit – 7.5-minute bus headways on two separate routes	1,368	16	2,585	672	3,257	45–50 / 45–50 (45–50/45-50 – vehicle) (35-40/40-45 – bus)	2,450 (backup to Little Cottonwood Lane)	8,500+ (beyond traffic signals at Wasatch Blvd./North Little Cottonwood Road intersection)
7. One general-purpose lane and one bus-only lane in shoulder with bus 5-minute headways on two separate routes • Wasatch Blvd. – 4 or 5 lanes with transit priority • Little Cottonwood Canyon – one lane each direction plus peak-period shoulders • Transit – 5-minute bus headways on two separate routes	1,190	24	2,173	1,008	3,257	35–40 / 35–40 (35–40/35-40 – vehicle) (35-40/40-45 – bus)	350	3,050 (backup one-third to Wasatch Blvd./North Little Cottonwood Road intersection)

[a] Assumes 1.89 people per vehicle during the design hour based on vehicle occupancy counts conducted in 2018.
[b] Assumes buses from transit hubs at both the Gravel Pit and at 9400 South and Highland Drive. Buses have a standing capacity of 42 riders.
[c] Person demand in the design hour would need to be greater than 3,250 to meet 2050 demand.
[d] Travel times include 12 minutes to transfer from personal vehicle to bus eastbound or from bus to vehicle westbound.
[e] The No-Action Alternative serves as baseline against which to compare the action alternatives and is not evaluated against the screening criteria.

5.0 References

[FHWA] Federal Highway Administration

2018 Traffic Data Computation Method Pocket Guide Publication No. FHWA-PL-18-027. August.

Fehr & Peers

2018a Traffic Data for S.R. 210 Little Cottonwood Canyon Environmental Impact Statement. April 5.

2018b Visitation Estimates for Little Cottonwood Canyon. May.

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2019a Sketch Planning Tool Methodology. September 12.

2019b Cottonwood Canyon Mode Shift Tool v2.1. September.

L2 Data Collection

2018 Traffic counts for intersection of S.R. 210 and S.R. 209. March 15.

[UDOT] Utah Department of Transportation

2018 Traffic Analysis Guideline. December.

[UTA] Utah Transit Authority

2019 Meeting notes between UDOT and UTA regarding winter bus service. August 6.