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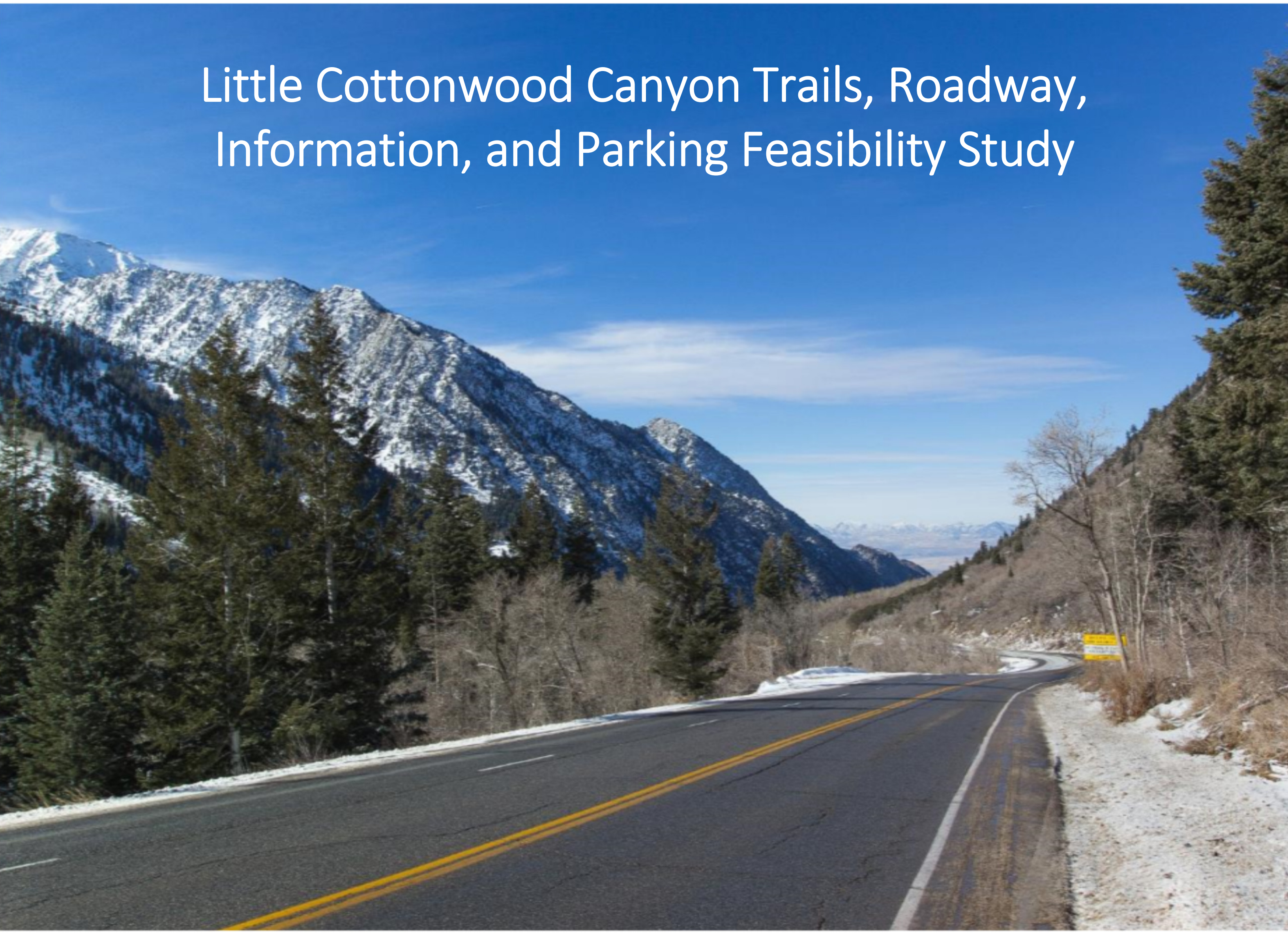

Little Cottonwood Canyon Trails, Roadway, Information, and Parking Feasibility Study

Bringing transportation diversity, information, and safety to LCC

Prepared for Granite Community Council
by Student Engineering Associates

CVEEN 4910 Professional Practice and Design [Spring 2018]
Department of Civil and Environmental Engineering
The University of Utah

PROJECT TEAM LETTER

Dear Granite Community Council,

The Student Engineering Associates (SEA) from the University of Utah Civil and Environmental Engineering Department are happy to present the Little Cottonwood Canyon Trails, Roadway, Information, and Parking Feasibility Study (TRIP FS) to the Granite Community Council (GCC).

Vision Statement

We envision Little Cottonwood Canyon (LCC) to remain a natural and captivating destination for people with diverse interests and hobbies to safely experience Utah's Wasatch Mountains. We believe this will be accomplished by protecting the Canyon's sensitive ecosystem and by minimizing the footprint of future transportation systems operating within its boundaries. We hold that these goals can be accomplished while maintaining the vitality of nearby communities. We propose to accomplish this vision through the introduction of intelligent transportation systems (ITS); automated vehicle networks (AVN); improved avalanche control and mitigation features; and additional roadway, pedestrian, and cyclist safety improvements to the Canyon.

Limitations of Study

There seems to be an endless amount of ideas for improving transportation throughout LCC. Due to schedule limitations within our semester, SEA is unable to look at every possible alternative. We attempted to include alternatives and features that we believed could make the most difference in LCC and that the GCC deemed essential. Many of us in the SEA have limited experience in creating a feasibility study, such as this one, and it is our understanding that a feasibility study of this caliber takes years to complete, but this feasibility study represents 10 weeks of work from the SEA. Considering all limitations, we believe that the FS will provide new alternatives or previously presented alternatives shown in a different light that the GCC can help suggest for implementation in the near future.

Appreciation

The SEA is very grateful to the GCC for all the help they have provided us, and for giving us this opportunity to gain experience on such a complex transportation system. We would also like to thank Utah Department of Transportation (UDOT), Utah Transit Authority (UTA), HDR Consultants, United States Forest Service, the Town of Alta, and the Central Wasatch Commission (CWC), for providing us with prior studies, presenting to our class, or providing information necessary to complete this study.

Moving Forward

The intent of the SEA is to take the selected alternatives and features recommended within this study and begin the preliminary design for the remainder of the semester.

Sincerely,

Student Engineering Associates

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EXECUTIVE SUMMARY

The purpose of this Feasibility Study is to explore alternatives and features that would help reduce traffic congestion in LCC during peak times while improving safety throughout the Canyon. After a review of the data, compiled from several prior studies, we noticed an average of 1.8 people in each vehicle are entering the Canyon. This alarming low occupancy rate per vehicle lead us to review an intelligent transportation system that would have the ability to: (1) incentivize visitors to increase occupancy, (2) incorporate autonomous vehicles that could communicate with signals and improve traffic flow, and (3) develop multimodal hub in the Salt Lake Valley to allow space for Canyon visitors to meet and carpool.

In this study, we also discuss the importance of reducing the number of vehicles traveling within the Canyon, while allowing an increased number of people to enjoy recreational experiences in LCC. Additionally, we discuss the need for snow sheds due to LCC's high avalanche activity. The snow sheds allow Canyon visitors to safety traverse the roadway during avalanche control while traffic continues to move, therefore reducing roadway closures. Other roadway improvements include: (1) resort ingress/egress redesign to allow for free flow traffic, (2) minor alignment changes along the roadway to improve sight distance, merging, and passing, and (3) shoulder adjustments to improve cyclist safety.

During our discussion with stakeholders and the public, we understood the importance for cyclist and pedestrian safety within the Canyon. After reviewing two path alignments for this user group, our team decided a path within the lower limits of LCC would benefit this recreational activity. Allowing a portion of this trail to be paved and constructed for ADA accessibility would support more user groups within the Canyon.

The results of the proposed features are to: (1) increase occupancy per vehicle, (2) increase in public transit utilization, and (3) increase in safety throughout the Canyon. The successful implementation of these features will allow Little Cottonwood Canyon to continue to provide a natural and inviting destination for people with diverse interests and hobbies. We believe this could be accomplished by protecting the Canyon's sensitive ecosystem and by minimizing the footprint of future transportation systems operation with the Canyon boundaries.

ACRONYMS/ABBREVIATIONS

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act of 1990
AV	Autonomous Vehicle (see Glossary)
AVN	Automated Vehicle Network
BCC	Big Cottonwood Canyon
Blvd.	Boulevard
Bypass Rd.	Alta Bypass Road
Canyon	Little Cottonwood Canyon
Creek	Little Cottonwood Creek
CWC	Central Wasatch Commission
EIS	Environmental Impact Statement
Forest Service	United States Forest Service
GCC	Granite Community Council
GPS	Global Positioning System
HOV	High Occupancy Vehicle
I-215	Interstate 215
ITS	Intelligent Transportation System (see Glossary)
KMZ	Keyhole Markup language Zipped
LIDAR	Light Detection and Ranging
LCC	Little Cottonwood Canyon
lf	Linear feet
MA	Mountain Accord
mm	Millimeter
mph	Miles per hour

National Forest	Twin Peaks Wilderness and Uinta-Wasatch-Cache National Forest
P&R	Park and ride
ROW	Right-of-way
SEA	Student Engineering Associates
sq. ft.	Square foot
SR-209	State Route 209 (S. Little Cottonwood Rd.)
SR-210	State Route 210 (N. Little Cottonwood Rd.)
TRIP FS	Little Cottonwood Canyon Trails, Roadway, Information, and Parking Feasibility Study
UDOT	Utah Department of Transportation
UDOT PM	UDOT Project Manager
UFA	Unified Fire Authority
UPD	Unified Police Department
USU	Utah State University
UTA	Utah Transit Authority
Valley	Salt Lake Metropolitan Valley

GLOSSARY

Autonomous Vehicle	Autonomous vehicles (AV) have been built by companies that can navigate existing roads with almost no human input. The connected vehicle systems use wireless signals, digital imagery, global positioning system (GPS), and light detection and ranging (LIDAR) to relay informational data between other vehicles, roadside infrastructure, and other modes of transportation (pedestrians, bikes, etc).
Gazex®	Gazex® devices are used for avalanche control in LCC. These devices are a remote-controlled system based on exploding a propane/oxygen gas mixture inside an open metal tube. The metal tube angles out of the mountain side and bends downward at the end of the tube, toward the ground. During avalanche control, the device is primed for the blast and the explosion leave the end of the metal tube and generates energy that causes an avalanche.
Intelligent Transportation System	The intelligent transportation system (ITS) is an advanced application that provides innovative services to differing modes of transportation and the overall traffic management system. This technology allows traffic to be more coordinated, safer, and transportation networks become more efficient.
Multimodal Transportation Hub	A location where passengers and cargo are exchanged between vehicles or between transportation modes. This report uses a hub to bring common users – LCC visitors – to a location that allows them to leave their personal vehicle to get into a different mode of transportation – bus, shuttle, or other high occupancy.
Network	Little Cottonwood Canyon Network, consisting of SR-209, SR-210, infrastructure features (e.g. UTA Park and Ride lots, intersections, signage, pullouts, etc.)
Roadway	S. Little Cottonwood Rd. (SR-209) and N. Little Cottonwood Rd. (SR-210) join near the mouth of LCC and SR-210 becomes Little Cottonwood Rd.
StreamStats	StreamStats is a web application that provides access to an assortment of geographic information systems analytical tools that are useful for water-resources planning and management, and for engineering and design purposes. In this report, StreamStats was used to obtain ground surface slope data for the cyclist and pedestrian path.
System	Little Cottonwood Canyon System, consisting of Network and roadway users (e.g., vehicles, bicyclists, pedestrians, etc.)

1.0 INTRODUCTION

This document summarizes potential improvements to increase safety and awareness in Little Cottonwood Canyon (LCC), Utah, and to decrease congestion within the associated transportation network. The University of Utah Student Engineering Associates (SEA) has been commissioned by the Granite Community Council (GCC) to evaluate alternatives for transportation improvements to the LCC transportation system.

LCC is located near the southeast corner of Salt Lake County in Utah. This Canyon is located within the Wasatch Mountains bordered by Twin Peaks Wilderness and Uinta-Wasatch-Cache National Forest (National Forest) to the north, the Town of Alta and National Forest to the east, Lone Peak Wilderness, National Forest, and Little Cottonwood Creek to the south, and the Salt Lake Metropolitan Valley (Valley) to the west. The transportation route serving this Canyon is a convergence of 9400 South (which become S. Little Cottonwood Rd.) and Wasatch Boulevard (Blvd.) to State Route 210 (SR-210), also referred to as Little Cottonwood Canyon Road (Figure 1). SR-210 provides an access route for Canyon visitors to reach destinations, which allow them to enjoy hiking, climbing, skiing, snowboarding, biking, running, and shopping within LCC. In addition to recreational Canyon visitors, SR-210 provides access for residents to reach their year-round homes, employees to reach resorts, and tourists and residents to reach restaurants and other businesses.

For purposes of this study, the transportation network (Network), municipalities and other recreational features considered are:

- Salt Lake Metropolitan Valley
  - Park and Ride Parking Lots; and
  - Roadways: 9400 South (SR-209) and Wasatch Blvd. (SR-210).
- SR-210
  - Parking Areas;
  - Trailheads;
  - Campgrounds;
  - Ski and Snowboarding Resorts;
  - The Bypass Road; and
  - The Town of Alta.

The roadway users consist of vehicles, busses, vans, bicyclists, and pedestrians that must be accommodated in the Network; thus, this becomes the transportation system (System) and its potential users.

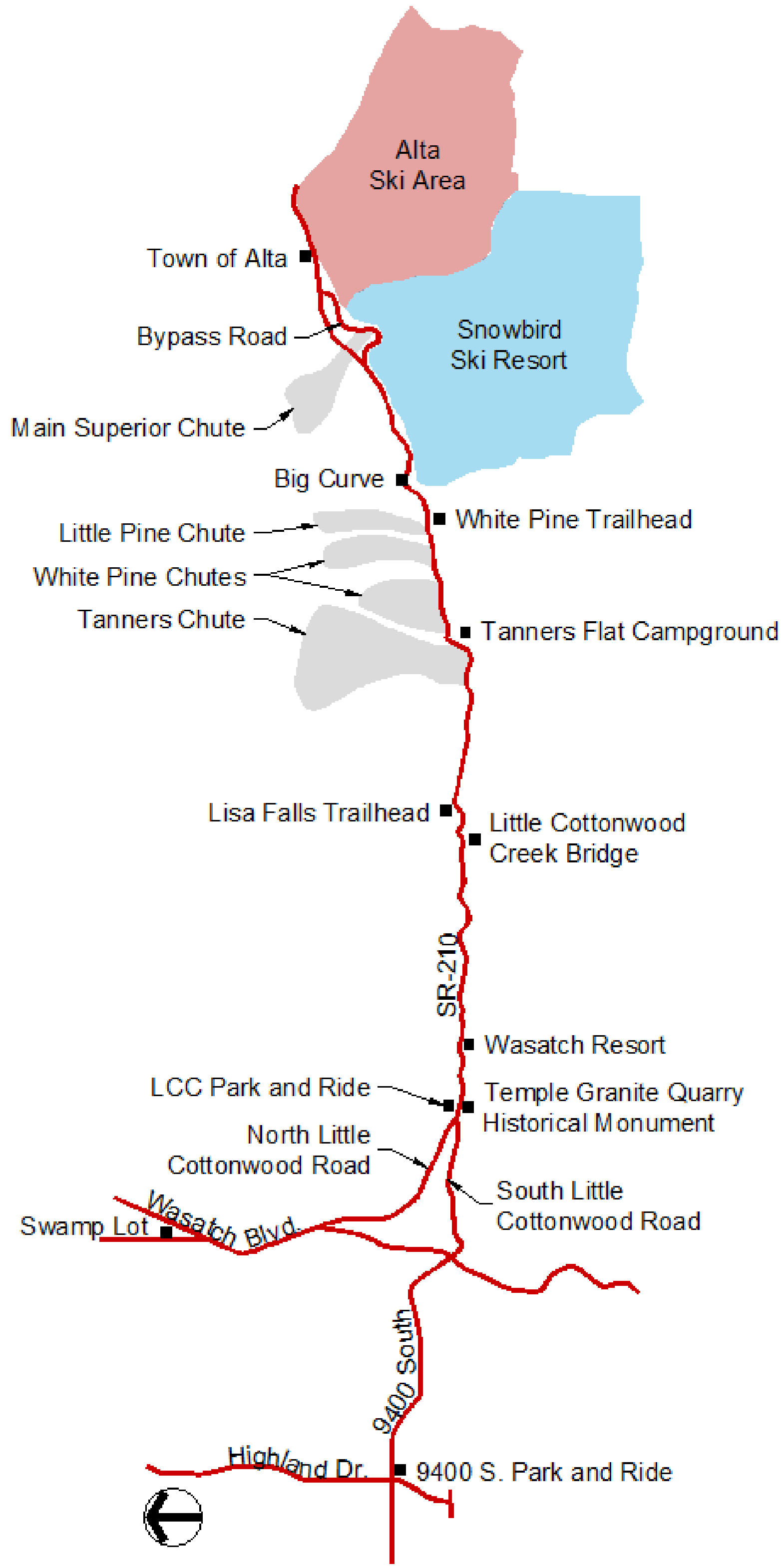

Figure 1 – Little Cottonwood Canyon System

2.0 BACKGROUND

This section describes how the Transportation System and its components have been historically used, and how historical operations have affected that use.

The Canyon and its resources have had multiple uses (e.g., mining, quarrying, trapping, exploring, logging, and milling operations) (Anthony Bowman's 1967 thesis titled From Silver to Skis: A History of Alta, Utah and Little Cottonwood Canyon, 1847 – 1966 [1]). Bowman describes the mining boom during the 1870's followed by a decline of activity within LCC until organized skiing was developed in Alta in 1937. Although several settlements were generated throughout the Canyon, Granite became the first settlement to truly qualify as a settlement; with approximately fifty buildings, Granite flourished until quarrying was terminated [1]. Granite, located very near the mouth of LCC, grew into the Canyon as the quarries grew. Once quarrying ended, the settlement, also named Wasatch Station by the railroad, divided into Granite and Wasatch Resort. Today, these two historical settlements make up the Granite Community.

LCC's first transportation system consisted of wagons for mining operations, which was soon replaced after the railroad hub in Ogden, Utah was completed [1]. The Utah Southern Railroad operated the rail from the mines in Alta to Sandy Station in the Valley [1]. During logging and mining activities, LCC was left bare and without stability of the mountain slopes, therefore causing avalanches predominately along the north side of the rail line and present-day SR-210. By 1884, the removal of timber from LCC was so extensive that there was very little to hold accumulated snow back; avalanche and fire during 1884 almost completely wiped out the Town of Alta [1]. Due to the catastrophic avalanches from deforestation, the railroad utilized snow sheds to protect the rail line. An artist's depiction of LCC, the railroad, and the snow sheds is shown in Figure 2.

In addition to the mining and logging operations, other resources in LCC have long sustained life in the Valley. Soon after the founding of Salt Lake City, it was declared that no private ownership of water would be allowed [1]. From that point on, Little Cottonwood Creek (Creek) has "provided a source of water for culinary purposes, irrigation and mill power" [1]; presently the Creek supplies culinary water to the Valley and is within a protected watershed.

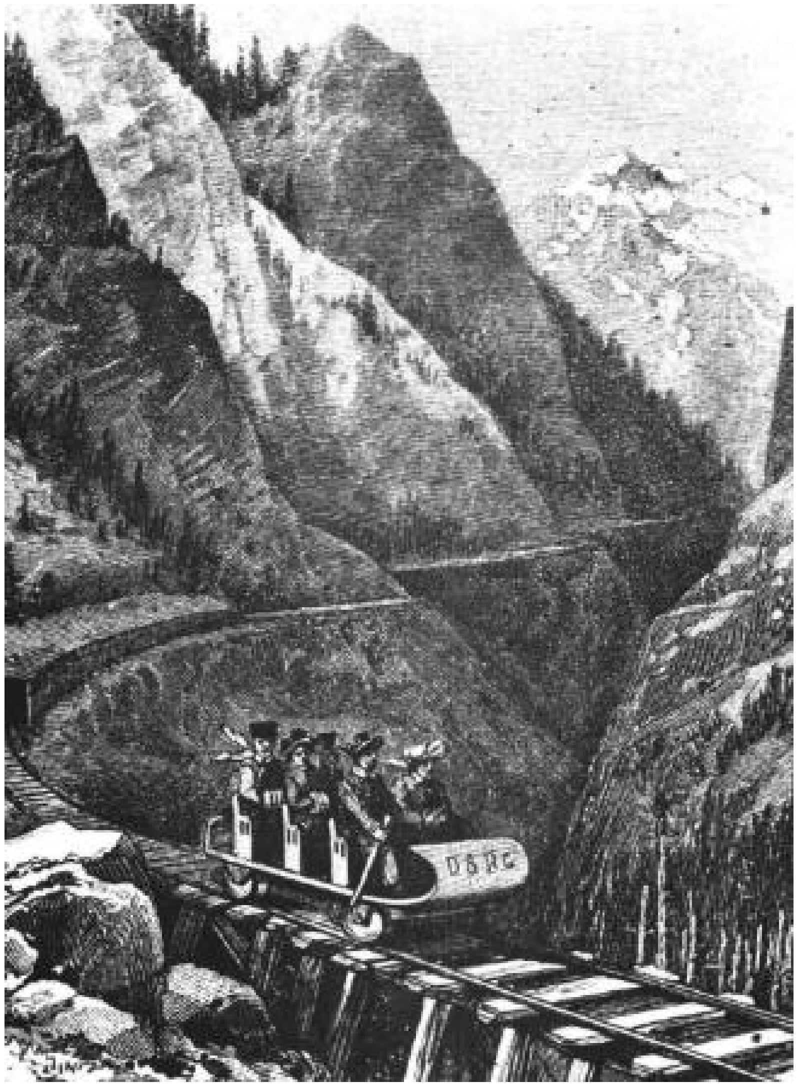

Figure 2 – Artist's conception of passengers descending narrow-gauge tramway in Little Cottonwood Canyon. Note snow sheds [1]

During the late 1800's, Scandinavian residents in Alta utilized skis that were described as "Norwegian snow-shoes – skees [sic] – fourteen feet long and six inches wide" [1]. At first, skis were utilized for transportation during the winter months, and then later developed into races held on the slopes in Alta. From production of natural resources to more recreational uses, the Canyon began to evolve as organized skiing became popular. With inspiration from Idaho's emerging Sun Valley ski areas, the United States Forest Service (Forest Service) decided to develop a similar experience in Utah as they were already in the process of developing all-weather roads in Utah's canyons [1]. Following land acquisitions, the road within the Canyon was relocated from the former wagon road near the Creek to the abandoned railroad right-of-way [1], presently known as SR-210.

As the first ski lift was installed, from a refurbished aerial mining tram in 1938, LCC’s user-base developed into more recreational use [1]. The Forest Service soon became aware of their responsibility to study avalanche hazards and provide active responses to unstable conditions rather than allowing natural slides to occur. Prior to the use of leftover artillery from World War II, dynamite was utilized to trigger avalanches and to evaluate the stability of the snow [1]. During the late 1940’s, the Forest Service adopted the European concept of shooting artillery into the snow pack and therefore the use of howitzers began [1]. This became the first use of artillery in the United States and presently the only use of live artillery in a non-war zone over civilians. A decline in the use of artillery has occurred due to newer technologies, namely Gazex® devices, which are being phased into the Canyon. An image showing the present-day avalanche mitigation tools is shown in Figure 3.

Figure 3 – Alta’s Howitzer (left) and Gazex® Device (right)

Prior to 1941, Salt Lake County and the Forest Service maintained the Canyon roadway to the resorts. However, Little Cottonwood Canyon Road became a State Highway in 1941 and the State assumed responsibility to maintain the roadway [1]. With the responsibility to maintain SR-210 came a myriad of entities to help support the System. Entities that help operate and maintain the System include: Utah Department of Transportation (UDOT), Town of Alta, Unified Police Department (UPD), Forest Service, Unified Fire Authority (UFA), Utah Transit Authority (UTA), Alta Ski Area, and Snowbird Ski Resort.

3.0 EXISTING SYSTEM CONDITIONS

The purpose of this section is to describe the following:

- Network infrastructure;
- Network users;
- System data; and
- User perspectives of the System.

The existing roadway features, communications systems, observed behaviors from drivers, traffic and parking counts, and drivers' roadway experiences will be discussed in this section to help further understand the need for System improvements. Due to the complexity of this System and limited schedule for SEA, a higher overview will be provided at this time; SEA's limitations for the TRIP FS will be described in Section 7.

3.1 NETWORK INFRASTRUCTURE

Prior to the convergence at the mouth of LCC, Interstate 215 (I-215) and Wasatch Blvd. transport Canyon visitors from the north and 9400 South provides a route for Canyon visitors from the west and south. Static signage along Wasatch Blvd., as drivers travel south, conveys information regarding park and ride (P&R) facilities and the location of the ski bus. Along Wasatch Blvd. there is a dedicated bike lane for most of the roadway as it enters the Canyon. 9400 South offers static signage to communicate to drivers the location of P&R lots, the location of the ski bus, mileage to reach the ski areas in LCC or Big Cottonwood Canyon (BCC), and the AM radio station for ski and canyon information. 9400 South does not have a dedicated bike lane, but rather bicyclists are required to use the vehicular lane. Both roadways have posted speed limits of 40 miles per hour (mph) and static signs requiring snow tires or chains in vehicles from October 1 to April 30.

From the mouth of LCC, where 9400 South and Wasatch Blvd. converge to become SR-210, to the Town of Alta, SR-210 is approximately 8 miles long. Currently, SR-210 is predominately two lanes wide with passing lanes placed incrementally up the Canyon for uphill and downhill traffic, occasional left turn lanes, and pullouts for hiking locations. Uphill and downhill bike users share the vehicular lane on SR-210. The roadway has a host of entry and exit points that lead users to pullouts, trailheads, ski and snowboard resorts, and parking lots. Within the LCC limits, SR-210 has posted speed limits of 40 mph, with slower sections observed near sharp curves or areas where sight distance is limited. In addition to the posted speed limit signs, other signage includes:

- Snow tires or chains required in vehicles October 1 to April 30;
- Protected watershed area;
- Vehicles exceeding 65 feet long and 9 feet wide permit required;

- Snow Avalanche Area: No parking or stopping November 1 to May 15; and
- No parking November 1 to May 15.

At the mouth of the Canyon, one dynamic sign is available for UDOT to display necessary roadway information to drivers. This dynamic sign is updated by UDOT's Traffic Operations Center.

During peak times, SR-210 becomes congested due to a high volume of traffic and low capacity of the two-lane roadway. The roadway occasionally becomes congested to a point that vehicles are backed up for miles along Wasatch Blvd. and 9400 South, into neighborhood roads leading to those highways. During avalanche mitigation this congestion can worsen. The blocked neighborhoods lead to resident's inability to enter or exit their homes. When avalanche chutes provide optimal conditions for an avalanche, the UDOT Avalanche Forecasters determines that an active measure shall be implemented. This activity requires the closure of SR-210 while chutes from Lisa Falls to Monte Cristo are controlled (Figure 4).

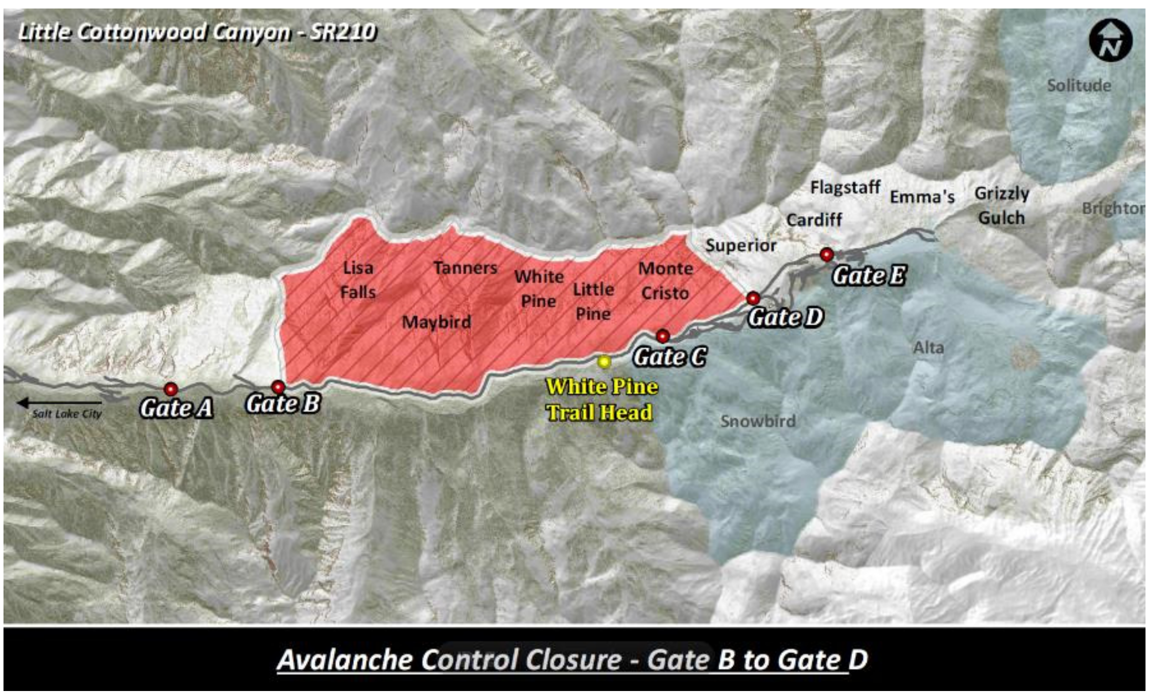

Figure 4 – SR-210 Road closure area and chutes being controlled (source: UDOT)

During avalanche mitigation, SR-210 road closures have been known to last for an average of 4 hours. Generally, the expectation for this type of closure occurs approximately 15 times per winter season.

Near the Town of Alta and Snowbird Ski Resort, the Alta Bypass Road (Bypass Rd.) is used to re-route SR-210 traffic during avalanche control of the Main Superior chute. When Gates D and E are closed (shown on Figure 4), SR-210 is re-routed onto the Bypass Rd (shown on

Figure 6). The restricted use of the Bypass Rd. requires roadway users to navigate steep grades, sharp curves, and approach unprotected roadway parking at the Snowbird resort; a photo of unprotected and unsafe parking is shown in Figure 5.

Figure 5 – Photographs of unprotected and unsafe parking near Snowbird Resort

In addition, when SR-210 is rerouted for Main Superior chute control, area residents can no longer access or leave their homes and portions of Snowbird's parking areas are closed (Figure 6).

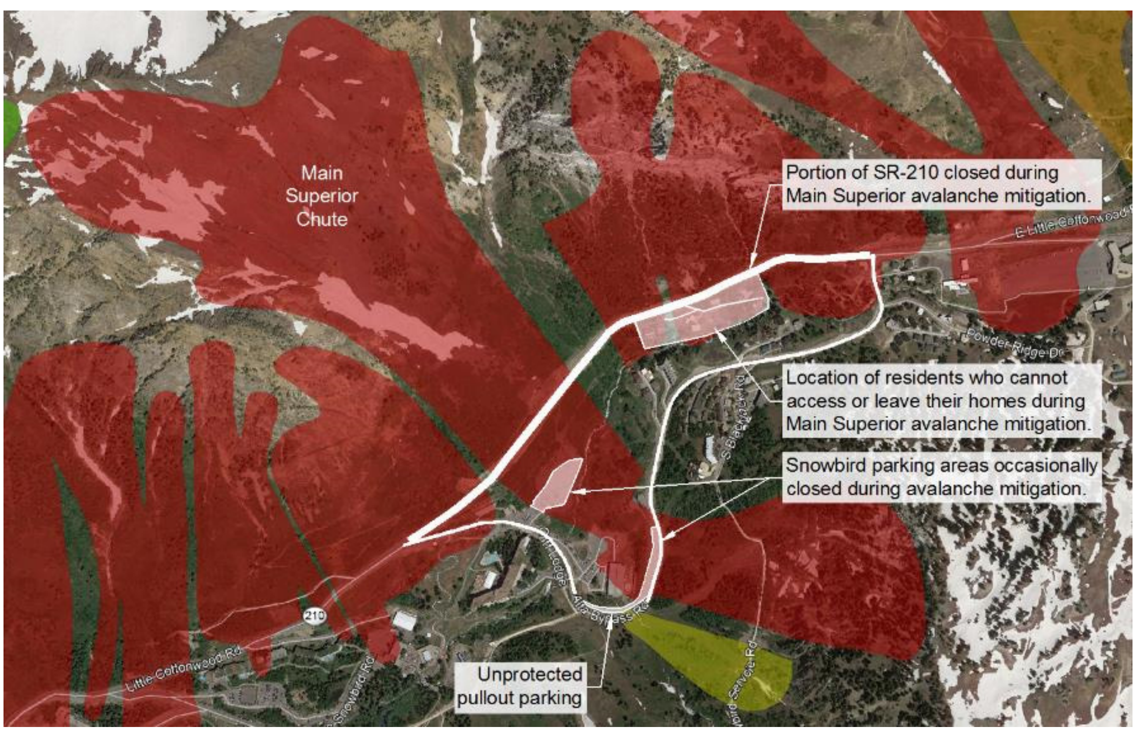

Figure 6 – Alta Bypass Road and areas affected by Main Superior Chute

As mentioned previously, entry and exits along SR-210 take users to many destinations, including the Snowboard and Alta resorts. Several of the entry and exits near the Snowbird Ski Resort were designed and constructed at odd angles, making it difficult for drivers exiting the resorts to safely enter SR-210. These exits place drivers at an incline looking upward so they are unable to see oncoming traffic while making a left turn. During peak times, the System requires four police officers to direct traffic at these intersections to maintain System flow down SR-210 (Figure 7). In addition to the manpower being utilized at these intersections, the unified operations team, comprised of the Town of Alta and UPD, generally cones off one downhill lane to mitigate slow merging between vehicles west of Snowbird Entry 1 near the Big Curve.

Figure 7 – Police officers directing downhill traffic at Snowbird Entry 1
(Photos taken February 24, 2018 by Alta Marshall)

Little Cottonwood Canyon experiences bicyclists and pedestrians using SR-210 despite the lack of a dedicated bike or pedestrian lane. Along the north side of the roadway, a narrow shoulder is available for users. Due to downhill user's speed, the existing roadway lane is generally utilized. On the south side of the roadway, there is a wider shoulder; therefore, bikers and runners can be removed from traffic.

3.2 NETWORK USERS

Little Cottonwood Canyon is an increasing popular area for natural recreation due to its proximity to the Salt Lake City metropolitan area. To support recreational users, there is a host of employees at the resorts, emergency personnel, avalanche control teams, the Town of Alta, and operations and maintenance crews. Within the Network, but outside the mouth of LCC, several residential areas exist, including the western section of the Granite Community. Additionally, within the Canyon there are residents at the Wasatch Resort and in the Town of Alta. Recreational users of the Canyon include: skiers, snowboarders, hikers, climbers, runners, bikers, sports enthusiasts, shoppers, and Sunday drivers.

As roadway users interact with the Network, they are required to manage the following types of conditions:

- Navigate icy and narrow roadways, blind curves, and steep slopes toward Little Cottonwood Creek;
- Decide to drive their personal vehicle or take mass transportation;
- Watch for bicyclists and pedestrians on roadway;
- Address conflicts at driveways and resort intersections; and
- Follow slow-moving commercial vehicles with little opportunity for passing.

Frequent winter visitors at Alta and Snowbird resorts have indicated that attempts to locate a parking spot at the resorts can take upwards of 30 to 45 minutes. When parking lots are full, Canyon visitors will find non-permitted or informal places to park; this is also true for trailheads in the summertime. Hikers will park on the side of SR-210 due to lack of parking at the trailheads, therefore increasing the pedestrian and vehicular hazard.

During winter storms, drivers are known to be optimally cautious to prevent leaving the roadway or causing a collision with another vehicle. If unfamiliar drivers are not aware of the upcoming roadway conditions (e.g., a blind curve or snow-covered roads), they have been observed traveling at speeds well below the posted limits, in sometimes unnecessary situations, therefore causing additional delays and higher congestion along SR-210. Particularly, two areas in which this behavior has been observed in downhill motorists are: the Big Curve and the curves near Tanners Flat.

However, when Canyon visitors park their vehicles along SR-210, bikers and runners are forced to navigate around the informal parking and increased interactions with vehicular traffic is encountered.

3.3 SYSTEM STATISTICS

3.3.1 CANYON USER TRIP ORIGINS

In the May 2017 Mountain Accord (MA) Cottonwood Canyons Short to Mid-Term Transportation Solutions Technical Memorandum, information was collected on Canyon users and where they originate from. Information gathered considered users who travel from home to LCC for recreation, users traveling from a hotel to LCC for recreation, and users traveling from home to work in LCC. Accordingly, of the 19,986 users from this study, the following percentages were determined:

- Home to LCC for work: 7%
- Home to LCC for recreation: 50%
- Hotel to LCC for recreation: 43%

This data was broken into five districts to understand the geographic location in which users were traveling from. Figure 8 demonstrates geographically where recreational users travel from to get to LCC.

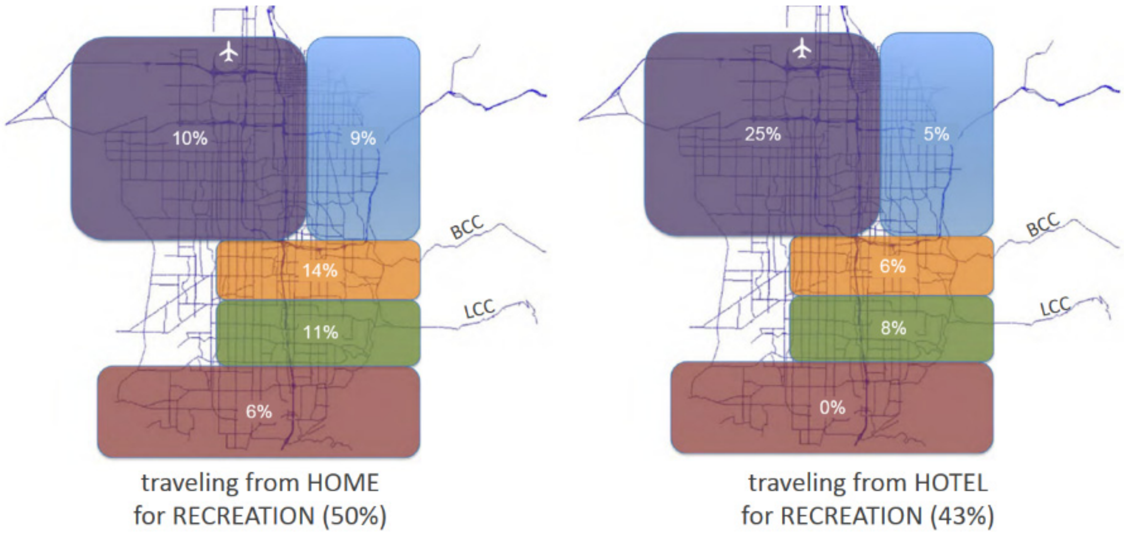

Figure 8 – Percentage of users traveling to Little Cottonwood Canyon [2]

3.3.1.1 TRAFFIC COUNT

Within Little Cottonwood Canyon, UDOT maintains a traffic counter east of the LCC P&R lot. As traffic travels up and down the Canyon, the counter records the data regardless of the direction the vehicle is traveling. Therefore, the data does not have the ability to segregate duplicate vehicle counts. For purposes of the data presented below, it is assumed that the volumes obtained mostly contain duplicated data and have been divided by two for single count purposes. This annual average daily traffic (AADT) data from 2012, 2014, and 2016 was obtained from UDOT and developed into Table 1 and Figure 9.

Based on a seasonal review, it was determined that February (winter), March (spring), July (summer), and September (autumn) experienced the maximum amount of vehicle users in the Canyon. Except for the autumn of 2014 and 2016, vehicle volumes have increased over time.

Table 1 – Annual average daily traffic

		2012	2014	2016
Winter	**December** (previous year: 2011, 2013, 2015)	2,992	3,423	3,915
	January	3,073	3,577	3,966
	February	**3,484**	**3,850**	**4,161**
Spring	**March**	**3,288**	**3,763**	**4,192**
	April	2,328	2,728	2,797
	May	1,500	1,817	1,928
Summer	**June**	1,871	1,905	2,336
	July	2,298	**2,580**	**3,129**
	August	**2,319**	2,492	2,885
Autumn	**September**	**2,261**	**2,357**	**2,855**
	October	1,630	2,116	2,039
	November	1,982	2,068	1,892

Source: UDOT

Note: **BOLD** numbers indicate highest volume of vehicles per season

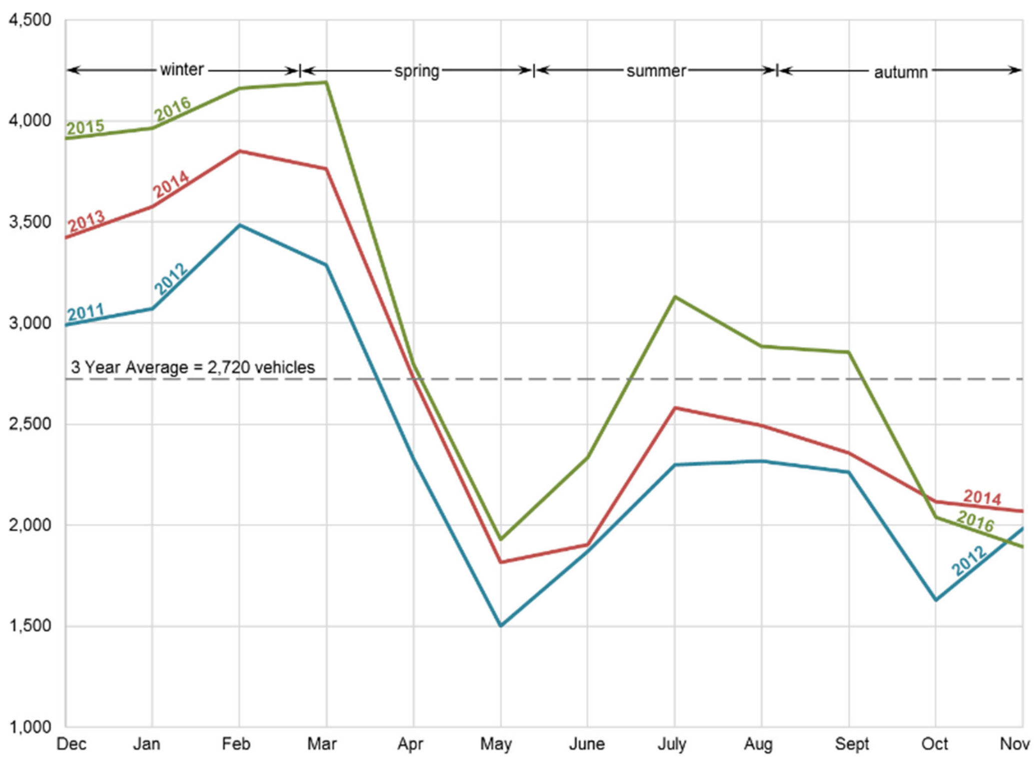

Figure 9 – Annual average daily traffic (Source: UDOT)

3.3.1.2 AVAILABLE PARKING AT RESORTS

During a President's Day parking study completed by Avenue Consultants in 2012, a total of 4,766 parking spaces were identified [3]. In Table 2, shown below, only the parking spots east of UDOT's traffic counter and those that do not pose a safety concern are shown; therefore, shoulder parking has been removed. The last column in the table shows the number of vehicles that traveled up the Canyon on February 20, 2012.

Table 2 – Parking capacity and average daily traffic

	Winter (2/20/2012) President's Day			UDOT's Daily Traffic Moving Up Canyon (February 2012)
	Capacity (vehicles)	Peak Day Occupancy	Number of Vehicles	
Lower Snowbird	1,518	88%	1,336	
Upper Snowbird	925	97%	897	
Lower Alta	1,163	89%	1,035	
Upper Alta	690	100%	690	
Pullouts	302	52%	157	
Grand Total	**4,598**		**4,115**	**5,332**

Source: Avenue Consultants [2]

In a 2015 review of data provided by MA, there were approximately 6,600 vehicles traveling on peak winter days to reach 4,600 parking stalls. As shown in Table 1 above, the annual average number of vehicles traveling in the Canyon is near 4,200; therefore almost 4,600 parking stalls represents 91% utilization. During the 2016/2017 winter season, 33 days experienced greater than 4,600 vehicles traveling up the Canyon to the resorts, as shown in Table 3. Although this count does not suggest the time each vehicle spent within their parking stall, it is assumed that drivers held those spaces long enough to cause congestion on SR-210.

Table 3 – Winter days where more than 4,600 vehicles traveled up SR-210

Date	Total Daily Volume Traveling Up LCC
Saturday, December 3, 2016	5,534
Monday, December 4, 2016	4,695
Tuesday, December 5, 2016	4,792
Saturday, December 10, 2017	5,226
Sunday, December 11, 2018	5,590
Saturday, December 17, 2017	-
Sunday, December 18, 2016	5,085
Friday, December 23, 2016[1]	5,414
Sunday, December 25, 2016[1]	-
Monday, December 26, 2016[1]	6,630
Tuesday, December 27, 2016[1]	-
Wednesday, December 28, 2016[1]	-
Thursday, December 29, 2016[1]	6,552
Friday, December 30, 2016[1]	6,434
Saturday, December 31, 2016[1]	6,296
Monday, January 2, 2017[1]	5,851
Saturday, January 7, 2017	5,709

Date	Total Daily Volume Traveling Up LCC
Friday, January 13, 2017	5,971
Saturday, January 14, 2017	7,260
Sunday, January 15, 2017	6,294
Monday, January 16, 2017[2]	-
Sunday, January 22, 2017	5,434
Friday, January 27, 2017	5,653
Saturday, January 28, 2017	6,941
Sunday, January 29, 2017	6,213
Saturday, February 11, 2017	6,434
Sunday, February 12, 2017	7,073
Saturday, February 18, 2017	5,698
Sunday, February 19, 2017	5,573
Monday, February 20, 2017[3]	5,652
Friday, February 24, 2017	4,609
Saturday, February 25, 2017	6,533
Sunday, February 26, 2017	6,749

Source: UDOT

Notes:

[1] Canyons School District observed winter recess

[2] Canyons School District observed Martin Luther King Jr. Day

[3] Canyons School District observed President's Day

- No data available, however date was assumed to have greater than 4,600 vehicles

3.3.1.3 CANYON VISITORS PER VEHICLES

During a 2016 study completed by Utah State University (USU) regarding visitor use in LCC, BCC, and Millcreek Canyons, it was determined that the average number of people per vehicle traveling in LCC was 1.81 [4]. This value was based on dispersed Canyon use and the study mentions the difficulty of removing non-recreational users from this number. Non-recreational visitors can include: operations and maintenance vehicles, ski resort personnel, and residents of Wasatch Resort and Alta. However, ridership traveling to Alta was 2.57 people per vehicle and 2.31 people per vehicle traveling to Snowbird [4].

During the 2011/2012 ski season, Alta reported 364,090 skier days and Snowbird reported 418,000 skier days [3]. Based on the USU survey, it was determined that 69% of users traveling to Alta used a personal vehicle whereas 74% of users to Snowbird used a personal vehicle [3]. Using this data, the study found the number of vehicles used to access Alta and Snowbird over the entire 2011/2012 winter season:

- Alta: 97,751 vehicles
- Snowbird: 133,936 vehicles
- Total: 231,687 vehicles

Information obtained from MA indicates approximately 12,400 average daily winter users recreate within LCC on a peak day. Of these 12,400 Canyon visitors, approximately 500 users take the ski bus and 11,900 users arrive to the resorts in vehicles.

3.3.2 USER PERSPECTIVE OF SYSTEM

The GCC provided a survey to the public they serve and allowed responses to the Mountain Accord Report that discussed potential improvements to LCC. During the April 2014 survey, when asked what issues related to transportation in Granite and LCC concern you the most, members of the public made the following comments (these comments have not been edited for grammar or punctuation):

- Environmental impacts, including air quality, of existing vehicular traffic and future increases. Need for incentives to increase carpooling & bus usage. Need to reduce/eliminate shoulder parking to improve bicycle safety. Need to improve bus transit time and bus service. Need to increase parking for hikers where feasible.
- The ability to get up-canyon easily & swiftly on stormy winter days, by public transportation. Wildlife deaths due to vehicles. The large amount of car traffic going through the neighborhood in both directions during winter.
- Heavy traffic on weekends and big powder days, especially in the morning after the parking lots are full forcing people to drive cars and after 4:00 with everyone leaving at once. I've experienced 2-hour drive times from Alta to the canyon mouth. Clearly there isn't enough park and ride parking. I feel it would be detrimental to the canyon environment to construct a TRAX rail or aerial tram.
- Not being able to get home or have the school bus pick up kids because traffic is backed up when the canyon is closed. It has been significantly better the past few years with the road being closed at Wasatch but was a big problem before.
- Buses will not be a viable alternative until they start running from the Little Cottonwood Park and Ride by 7:30am or shortly thereafter so that one can arrive early enough for first tram. Second, for buses to be a viable alternative, they must run continuously throughout the ski day with no longer than 20-minute intervals between buses.
- Too many cars and not enough carpooling and bus use. 2. Adequate and safe parking at trails and points of interest. 3. Noise Pollution (motorcycles) 4. Safety for Bikes
- Eliminate all private vehicles except service vehicles and property owner vehicles. 2. Charge canyon visiting fees for all but property owners and resort employees. 3. Develop bigger park and ride lots at points along the main routes of travel in the

flatter portions of the Salt Lake Valley that will be points of embarkation for busses that will be the only personal transportation into the canyon. 4. Make safety improvements to the road up LCC in its exact footprint. 5. Avalanches are a natural condition that must be lived with. Busses can be more easily controlled than the thousands of cars in the winter. 6. Provide bus stops at major sightseeing, hiking trailheads, picnic and camping sites and at the resorts. 7. Provide local shuttle services in, between and around the two ski resorts as well as to Albion Basin.

The accounts presented above have been selected from a list of approximately 30 responses to the above-mentioned question. Appendix A provides a full list of responses to this including additional questions as they pertain to the Canyon. In summary to the remaining questions, respondents expressed their most important priorities for LCC as:

- Limiting Canyon recreational use to current levels or modest increases; and
- Making efforts to decrease Canyon traffic.

Whereas their least important priorities for LCC were:

- Increase recreation Canyon use (skiing, other); and
- Allowing Canyon traffic to increase.

Other portions of the survey expressed a desire to protect the Canyon environment and to improve transportation in the Canyon. Overall respondents heavily agreed on more mass transportation systems and no rail or aerial tram up the Canyon. As the survey relates to the System, it shows 45% or more of respondents finding select transportation solutions desirable when asked about parking and personal vehicle use in Granite and within the Canyon.

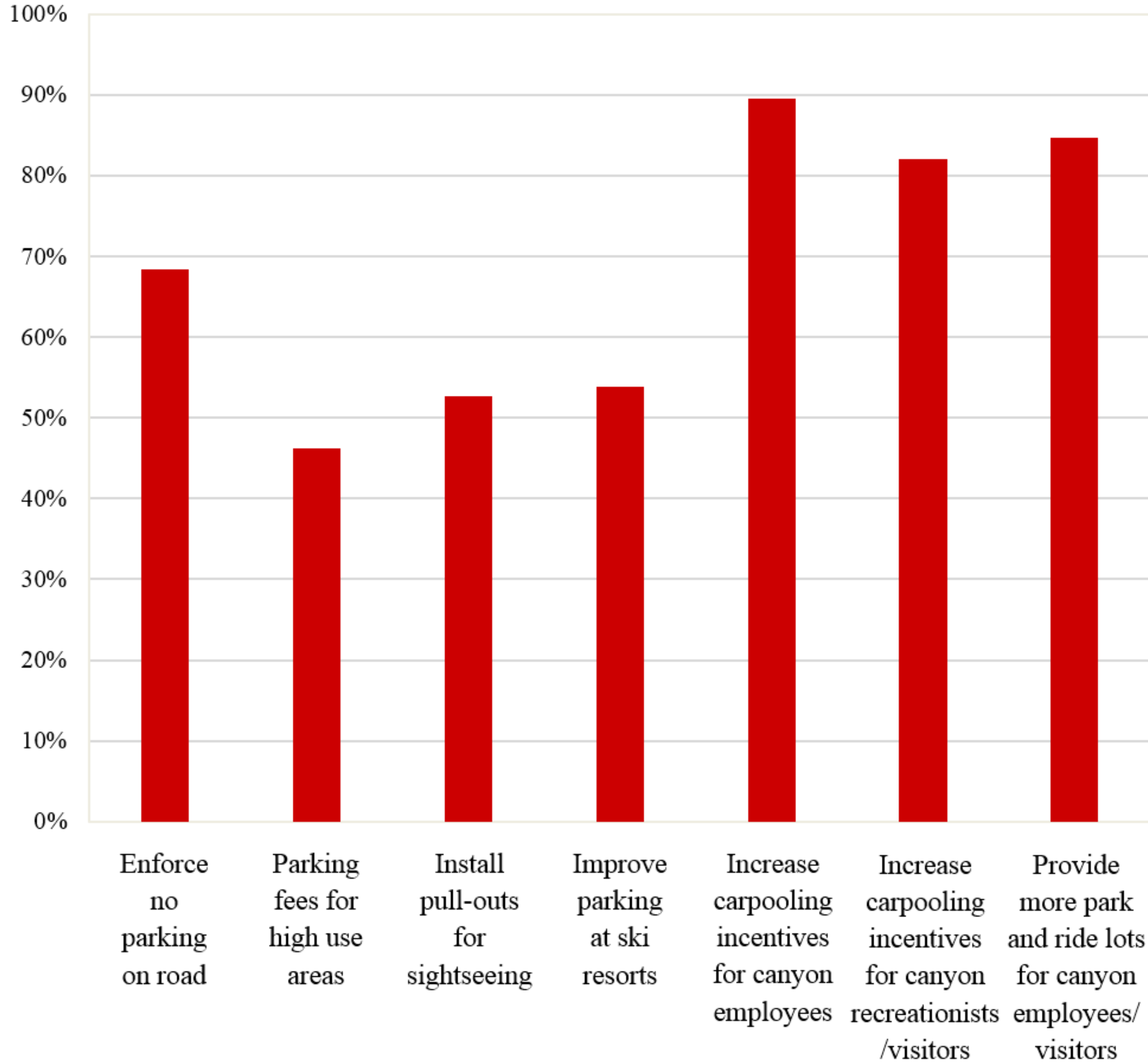

Figure 10 – Granite Community response to possible solutions to parking and transit problems in Granite and Little Cottonwood Canyon

In addition to the localized effects felt by the Granite Community, the Town of Alta experiences similar congestion at the end of a snow day. The congestion along SR-210 affects emergency personnel, residents, and recreational commuters.

4.0 STATEMENT OF NEEDS

The transportation system in and around LCC is suffering from severe congestion, especially during peak snow days and holiday weekends when many visitors are trying to access the Canyon (Table 3). Congestion and severe weather events have caused significant delays (at times up to several hours) in accessing and traveling within the Canyon. The subsequent traffic backup in roadways and residential streets near the Canyon has greatly frustrated residents to the point where they feel "trapped" in their own homes, unable to leave their driveways. More extreme cases have involved children missing school because school buses have not been able to reach their driveways. Therefore, it is easy to understand why residents of the Granite Community have been long frustrated, and without future planning and significant improvements, these conditions will only worsen.

Figure 11 – Two lanes of LCC traffic backed up to Fort Union Blvd [5]

For example, Figure 11 shows traffic along Wasatch Blvd. with backing to Fort Union Blvd., which is approximately 4 miles from the convergence of 9400 South and Wasatch Blvd. near the mouth of LCC [5]. The two lanes of traffic shown in this photo are forced to merge in approximately 0.75 miles, followed by another merge at the mouth of the Canyon with 9400 South Street.

In addition, roadway closures in the Canyon and at its mouth have caused significant delays in accessing the Canyon as shown in Table 4. According to information gathered from UDOT's Avalanche Control Team during the 2016/2017 winter season, LCC ski and snowboard visitors experienced 28 roadway closures, causing 80 hours of traffic delay. These roadway closures appear to be a major source of congestion that delays access to the Canyon and contributes to major traffic backups on 9400 South (SR-209) and Wasatch Blvd. (SR-210). Unfortunately, any congestion that causes vehicular traffic to become slow or stopped increases the risk of avalanche injury or death, impedes emergency response access, and diminishes the recreational experience in LCC.

Table 4 – SR-210 road closures impacting ski and snowboarding traffic (2016/2017 winter season)

	Snowbird Village		Mid Canyon		Highway 210		TOTALS	
	# of Closures	Time (hours)	# of Closures	Time (hours)	# of Closures	Time (hours)	# of Closures	Time (hours)
November 2016	-	-	-	-	1	1.5	**1**	**1.50**
December 2016	1	0.5	1	1.25	2	4.5	**4**	**6.25**
January 2017	4	1.5	2	3	6	31.25	**12**	**35.75**
February 2017	1	0.5	2	6.5	5	23.25	**8**	**30.25**
March 2017	-	-	2	4	1	2.25	**3**	**6.25**
April 2017	-	-	-	-	-	-	**-**	**-**
May 2017	-	-	-	-	-	-	**-**	**-**
							28	**80.00**

Source: UDOT

In addition, future growth will add to congestion of the Canyon if management and future improvements do not accommodate such growth. For example, the Forest Service estimates a 2% annual user increase for Little Cottonwood Canyon. Thus, in 50 years, it is projected that LCC will see a 100% user growth. Therefore, the present 12,400 visitors may increase to approximately 24,800 visitors by year 2068.

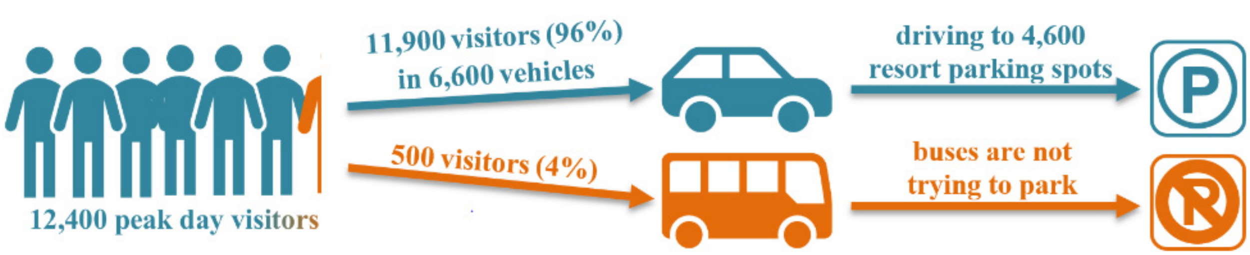

Figure 12 – Visual representation of present day Canyon visitors, their preferred transportation method, and the number of parking spaces at resorts

Further, the way people access the Canyon (e.g., car, van, bus, etc.) has a significant impact on congestion. Currently, the average vehicle occupancy is relatively low. For example, of the estimated 12,400 daily visitors, only 500 are using buses and 11,900 are traveling in personal vehicles. Therefore, on a daily average, there are about 1.8 occupants per vehicle, consisting of approximately 6,600 vehicles accessing the Canyon. If this behavior continues to year 2068, there will be 13,200 vehicles trying to enter LCC daily. This is unsustainable growth, both in terms of roadway and in-canyon parking capacity, unless timely and prudent countermeasures are taken. Obviously, this behavior must change to accommodate eco-friendly and sustainable growth within the Canyon.

Lastly, the mix of users recreating in the Canyon and seasonal demands are changing. Non-skier use (e.g., pedestrian, hikers, joggers, climbers, cyclists, bird watchers, picnickers, snowshoeing, etc.) is significantly increasing and will continue to place new demands on the roadway and parking systems of the Canyon. These demands introduce the potential for vehicular-pedestrian or vehicular-cyclist accidents on the roadway and its shoulders. For example, informal or unsafe vehicular parking on roadside shoulders exposes cyclists and pedestrians to significant traffic risks due to the narrow and dangerous shoulders of the Canyon.

5.0 VISION STATEMENT

We envision Little Cottonwood Canyon to remain a natural and captivating destination for people with diverse interests and hobbies to safely experience Utah's Wasatch Mountains. We believe this will be accomplished by protecting the Canyon's sensitive ecosystem and by minimizing the footprint of future transportation systems operating within its boundaries. We hold that these goals can be accomplished while maintaining the vitality of nearby communities. We propose to accomplish this vision through the introduction of intelligent transportation systems (ITS); automated vehicle networks (AVN); improved avalanche control and mitigation features; and additional roadway, pedestrian, and cyclist safety improvements to the Canyon.

6.0 OBJECTIVES

6.1 INTRODUCTION

The Granite Community has expressed to us the desire to develop and evaluate concepts that assist in reducing vehicular congestion in their community. This feasibility study evaluates prior studies, stakeholder feedback, and data obtained from UDOT and others to develop alternatives and other safety features recommended for the Canyon. It makes recommendations regarding improved transport / transit methods, other ways to decrease congestion, improve safety, and offers an enjoyable and sustainable future for LCC.

We have identified the following issues for further evaluation:

1. Visitor exposure to avalanches
2. Congested roadway, especially during peak demand days, due to:
   - Avalanche control closures
   - Lack of up-Canyon information reaching Canyon visitors prior to their recreational trip
   - Single occupancy vehicles and low ridership in vehicles competing for roadway space in the Canyon.
3. Safety issues associated with vehicular and cyclist/pedestrian conflicts due to shared roadway, narrow shoulders, and inadequate or illegal parking.
4. Additional safety concerns and congestion near resorts and in the Town of Alta due to:
   - Poorly designed resort intersection and parking lot egress that forces drivers to approach SR-210 at obscure angles and steep grades; and
   - Driver behavior on roadway curves and at merge points that cause a delay in traffic that reciprocates to the entire driver-base following behind them.

6.2 OBJECTIVES

The primary purpose of the TRIP FS is to evaluate alternatives that increase safety and awareness in the system and features that decrease congestion in and near the mouth of LCC. The specific objectives are:

1. Develop potential alternatives and solutions that minimize congestion and improve safety. Preference will be given to solutions that minimize impacts to the ecosystem of the Canyon as reflected by the views of many citizen groups commenting on potential improvements in the Canyon. The study will evaluate improvements to enhance the Canyon visitors' experience while minimizing the vehicular traffic needed to access recreational opportunities.

2. Develop an objective ranking system to compare rationally developed alternatives and solutions. The following ranking criteria are proposed:
    - Safety
    - Serviceability
    - Environmental Impact
    - Affordability/Value
    - Aesthetics

3. Apply the ranking system to the potential solutions and alternatives to develop recommendations for further evaluations and preliminary engineering design studies.

6.3 SYSTEM DESIGN LIFE AND PROJECT PHASING

We propose a 50-year design life for this project with multiple phases of funding and construction anticipated due to the scope and complexity of the issues. For the first phase of the project, it is expected that the State of Utah will fund about $65 million for improvements to LCC, through Senate Bill 277. This funding has been allocated to UDOT and concurrent to our FS, UDOT is completing an environmental impact statement to review improvements in LC. This study will attempt to develop alternatives and safety features that might be implemented with this initial funding. However, as our study progresses, and the preliminary engineering design report is prepared, we will offer a more comprehensive view of the recommended construction, cost, potential project phasing, and funding / revenue models for improving and operating the transportation system within the Canyon.

7.0 LIMITATIONS

Because this is a student-work product and not developed by professional engineers, no claims are made to the accuracy of this report. All data, information and findings are preliminary and must be verified and evaluated by others qualified to do so.

Several studies have already been completed for several canyons near Salt Lake City; namely, Mill Creek Canyon, Big Cottonwood Canyon, and Little Cottonwood Canyon. We have reviewed many of these studies to extract necessary data, and have met with stakeholders, and obtained current data from UDOT's traffic tracing system. However, due to the schedule constraints we have within one semester (approximately 16 weeks), SEA will not have the opportunity to truly evaluate the entire complexity of the system. Our goal is to highlight the areas which we believe will have the most impact within the Canyon using the initial capital funds appropriated from the Utah legislature. This vision will help create diversity within the system and allow for a multitude of Canyon visitors using various types of transportation methods (e.g., private vehicles, commercial vans, State-ran transit, automated vehicles, bicycles, etc.) which we believe will create a stronger system for the next 50 years.

8.0 ALTERNATIVE DEVELOPMENT

8.1 CONCEPTS EVALUATED BY SEA

Between January 8 and January 25, our team (i.e., SEA) brainstormed many possible solutions to issues currently being experienced in and around LCC. Due to the complexity of the System, UDOT's project manager (UDOT PM) – for the in-progress LCC EIS – provided several areas for our team to consider during our study. From those suggestions, our team spent several class periods discussing the alternatives and features that would benefit the System with the initial capital cost. Many different factors play into the long-term success of LCC and consequently solutions varied widely.

One proposed solution to the congestion problem was to prevent a large portion of vehicles from ever needing to enter the Canyon. The two main approaches were to increase vehicle occupancy and to increase parking in the Valley where visitors could transfer to higher occupancy vehicles. Several ideas are presented below:

- At the mouth of Big Cottonwood Canyon land north of the existing parking lot could be developed to provide "500" more spots.
- Increasing the number of buses up the Canyon, having some buses stop at specific resorts to reduce travel time.
- As an alternative to vehicles or traditional buses, UDOT's PM suggested using smaller shuttle buses or an Uber-type service, with additional consideration for a shuttle van with a trailer to hold gear and equipment.
- Other additional parking was considered at the Swamp Lot or along 9400 South at an existing park and ride lot.
- Expansion of parking at the mouth of Little Cottonwood Canyon, with improved bus pickup and drop-off locations.
- Construction of a queue for vehicles to wait at the mouth of Little Cottonwood Canyon to hold vehicles during temporary Canyon closures, while maintaining vehicles' place in line.
- Incentivize carpooling through tolling based on current number of vehicles already in the Canyon and the number of occupants in the vehicle.
- Building a light rail or personal rapid transit to the top of the Canyon.
- Construction of an overhead gondola to carry visitors from the mouth of the Canyon to the ski resorts.
- Autonomous vehicles and shuttles.

Another aspect of LCC under consideration was the traffic jams that resulted from accidents or avalanche closures of the Canyon. Many ideas were generated to help mitigate these situations.

- Snow sheds/barriers at prevalent avalanche locations to prevent Canyon closures during avalanche operations.
- Heated pavement under the snow sheds and possibly the whole length of the Canyon to decrease ice buildup and improve safety.
- Designated location prior to the mouth of the Canyon for chains to be put on tires and for officers to turn vehicles away that were not adequately prepared for snowy conditions.
- Gazex® or other onsite avalanche control devices.

In the Canyon, especially during the warmer months when climbing and hiking is more popular, illegal or informal roadside parking and the safety of bicyclists and pedestrians often becomes an issue. To mitigate this, the following ideas were generated:

- Safe parking at trail heads in the Canyon;
- Enforcement of illegal parking laws; and
- Designated bike and pedestrian lanes running the length of the Canyon to improve safety and comfort while recreating.

Problems with traffic also generate issues because of certain curves within the Canyon, single lane in both directions for much of the Canyon, and exits from the ski resorts. Therefore, the following concepts were developed:

- Straighten out the Big Curve with cut and fill or a bridge to reduce vehicles dramatically reducing speeds;
- Reconfiguration of Snowbird intersections to provide better visibility to drivers;
- Tunnels leaving the Snowbird resort that would travel under the road and merge with the downhill traffic to reduce left turns;
- Add a third flex lane to the length of the Canyon that could alternate direction of traffic flow when needed;
- Removal of merge lane just below Snowbird Entry 1, as it causes a pinch point during high traffic times;
- Reduction of grade at points in the Canyon that significantly reduce speeds of some vehicles; and
- Tunneling or having a double-decker road.

Another approach that the UDOT PM presented us with, was to incorporate intelligent technology into the Canyon. Therefore, our team began reviewing some concepts:

- Cellphone application with information related to parking availability, weather conditions, carpooling opportunities, road closures, etc.;
- Electronic signs along the road sharing information about parking and other conditions;
- Equipping bicyclists and runners with electronic trackers that give drivers a heads-up of who was around the next bend;
- Updating trailheads with intelligent kiosks that would provide information about wildlife, recreational opportunities, and Canyon preservation tips; and
- Tolling system at mouth of Canyon that would rely on infrared scanners to detect number of passengers rather than person-to-person tollbooth.

Other ideas were generated to simply improve the quality of the visitor's experience while in the Canyon:

- Better restrooms with running water at trail heads; and
- Visitor center hosting exhibits and concessions to visitors waiting for the next bus.

Several of these concepts were presented to GCC during a January 25, 2018 presentation, which is provided as Appendix B.

8.2 CONCEPTS RECOMMENDED FOR ADDITIONAL STUDY

Several people have provided suggestions for our TRIP FS; however, our time constraints do not allow us to review all ideas presented. The purpose of this section is to highlight concepts that we have studied to a limited extent. The level of research we have completed is presented as Appendix C.

- Avalanche mitigation
    - Braking Mounds – this is an energy dissipation structure that would help reduce the kinetic energy of an avalanche. Since Snowbird owns a portion of Mount Superior, just north of SR-210, it is possible for braking mounds to be constructed to protect SR-210 and Snowbird's property.
    - Snow Barrier – this is a structure that can be earthen with a retaining wall that can be utilized in diverting avalanches to snow sheds or to use near SR-210 to block avalanches from reaching the roadway. An historical China Wall is still standing from early railroad operations in LCC.
- Parking
    - Swamp Lot – a potential location for a dispersed parking lot that could be connected to the intelligent transportation system (ITS, see Glossary for definition).

8.2.1 CONCEPTS SELECTED FOR STUDY

After reviewing the many ideas developed, we narrowed down our scope to a few different categories that we determined to be manageable based on availability of data, modeling tools, person-power, and time constraints. The categories consisted of a couple of overall approaches to the Canyon and several smaller, yet much needed, improvements to safety and operations within the Canyon. The first approach was construction of a multimodal transportation hub in the Valley, which would incorporate a new autonomous vehicle network of higher occupancy vans or privately-owned vehicles. The second approach was an aerial gondola system that would serve to transport Canyon visitors from the mouth up to the resorts while reducing the number of vehicles on the roads. Finally, several smaller features were selected for further development in the TRIP FS. These were considered essential features and categorized as either safety or operational in nature. The safety projects consisted of snow sheds and a designated bike path, while the operational projects consisted of reconfiguring resort entries and straightening the Big Curve.

8.2.2 SELECTION CRITERIA

8.2.2.1 SELECTION CRITERIA AND WEIGHTING

As the purpose of this study is to determine which upgrades to the Canyon are most feasible and will do the most overall good, a way of measuring the effectiveness of each idea had to be created. To do this we developed a list of criteria, or metrics, that we believe encompassed the values expressed to us by the GCC. These criteria were then presented to the GCC and they gave input as to how each criterion should be weighted in the selection process. A description of the criteria and their assigned weights are shown in Table 5.

Table 5 – Selection criteria

Criteria	Description	Weight
Safety	Ability of the system or feature to increase safety for users, workers, and bystanders	30%
Serviceability/ Mobility	Ability to meet the demands of the system both present and long term (50 years); Anticipated level of comfort and reliability	25%
Environmental Impact	Likelihood for environmental impact to be minimized during construction and operation of feature or system	20%
Cost	Likelihood that life cycle costs (purchase, own, operate, maintain and dispose) are within budget and self-sustaining	15%
Aesthetics	Potential for incorporation into the natural surroundings and nearby community	10%
	Total	**100%**

8.2.2.2 CRITICAL SCORE SCALE AND PERFORMANCE SCORE

To allow a direct comparison of features, each criterion was given a ranking of 3 (High), 2 (Medium), or 1 (Low). A ranking of *high* means that within that criterion the feature or project is viewed as having a positive impact, while a ranking of *low* means the feature would have a negative impact. To calculate the over-all score of each feature, the assigned weight of each criterion was multiplied by the assigned ranking of each criterion and then added up.

$$Performance\ Score = \sum (Criteria\ Weight * Criteria\ Score)$$

9.0 INTELLIGENT TRANSPORTATION SYSTEM WITH MULTIMODAL TRANSPORTATION HUB

9.1 INTRODUCTION

Roadway congestion along Wasatch Blvd. and 9400 South heading towards the entrance of LCC is often related to snow conditions within the Canyon that result in road closures and/or road delays as well as parking capacities within the Canyon that are insufficient to meet peak demands. We believe that by increasing the number of people traveling per vehicle and reducing the number of vehicles accessing the canyons, the occasions of dense gridlock within the Valley will decrease.

The traffic congestion poses a threat to safety and accessibility for residents along these routes and members of the Granite Community. The primary method for reducing the congestion will be to increase occupancy in vehicles traveling in the Canyon through incentivizing and restructuring the current carpooling and public transit opportunities.

As discussed previously, the current vehicle occupancy is roughly 1.8 (2.4 during peak hours) people per vehicle. Therefore, one of the main challenges the mass transit system faces is the ability to entice riders to choose shared vehicles rather than private ones, which comes with a variety of unknown factors such as experience, trip duration, comfort, and conveniences to be expected. It is critical that an effective system address these needs of the user to make high occupancy options more attractive than low occupancy, personal vehicles.

We believe an intelligent transportation system (ITS) with automated vehicles AV would have the ability address low occupancy and help reduce congestion during peak recreation periods. The ITS is an advanced application that provides innovative services to differing modes of transportation and the overall traffic management system. This technology allows traffic to be more coordinated, safer, and transportation networks become more efficient. The ITS can be incorporated into signals and allow communication directly with vehicles, such as emergency vehicles that need a light to change to red in all directions, so they can travel through the intersection safely. An autonomous vehicle could be incorporated into the ITS and could communicate with the signal or other vehicles. AVs have been built by companies that can navigate existing roads with almost no human input. The connected vehicle systems use wireless signals, digital imagery, global positioning system (GPS), and light detection and ranging (LIDAR) to relay informational data between other vehicles, roadside infrastructure, and other modes of transportation (pedestrians, bikes, etc). Some automated features on AVs that exist today are lane assist, adaptive cruise control, and parking assist, where the driver initiates or allows the feature to operate. Currently, AVs are not requiring transportation planners to develop special pavement marking or stop signs. However, as transportation engineers design future roads, signs, pavement marking, we may see a collaboration between autonomous vehicle makers and transportation planning.

9.2 DESIGN

We believe an ITS with an AVN would have the ability to reduce congestion during peak recreation periods, increase occupancy rates, and maximize transit revenue with a specialized communication/information network, and the incorporation of dispersed and concentrated parking nodes with multi-modal transportation.

The main goals of the ITS and AVN are:

- Reduce congestion due to single occupancy vehicles;
- Encourage sustainable increases in ridership per vehicle; and
- Provide incentives and increase conveniences within mass transit services across the region.

In addition, a multimodal transportation hub would serve as a place for people to congregate, carpool, and extend their Canyon experience with conveniences and amenities. A multimodal hub is a location where passengers and cargo are exchanged between vehicles or between transportation modes. This report uses a hub to bring common users – LCC visitors – to a location that allows them to leave their personal vehicle to get into a different mode of transportation – bus, shuttle, or other high occupancy. The destination would provide discrete multi-level parking through the utilization of underground levels while maintaining an aesthetically inviting façade and waiting areas. We propose the hub provides amenities such as food services, shops, and a visitor/educational center, which offer additional activities for families, out-of-towners, and outdoor enthusiasts.

To attract visitors that seek quick transportation within the Canyon, we would rely on technology to communicate with visitors through physical street signs as well as smart phones or computers; anticipated goals for the communication system are discussed below.

Transportation methods incorporated within the multimodal hub include but are not limited to personal carpooling vehicles, commercialized shuttles, public bus lines and an AVN. Each mode of transportation would provide different circumstances in respect to cost, mobility, and convenience in hopes of accommodating the variety of needs posed by the diversity of the visitors. The transportation Network would rely on technology that connects available services with the visitor's demands to maximize efficiencies for the transportation provider and visitor.

The features under consideration have the following key components/available resources:

- 9400 South and Wasatch Blvd. are the main roadways to access the Canyon and they merge at the mouth of the Canyon to become SR-210;

- Existing P&R along the above-mentioned routes, serve as main points of connection for mass transit. Most of the P&R have parking capacity limited to about 100 parking stalls each;

- Any new feature in the system must be integrated with existing features, including communication and information systems; and

- Personal vehicles, shuttles and UTA Ski Buses use the same two routes to access the Canyon.

9.2.1 LOCATION

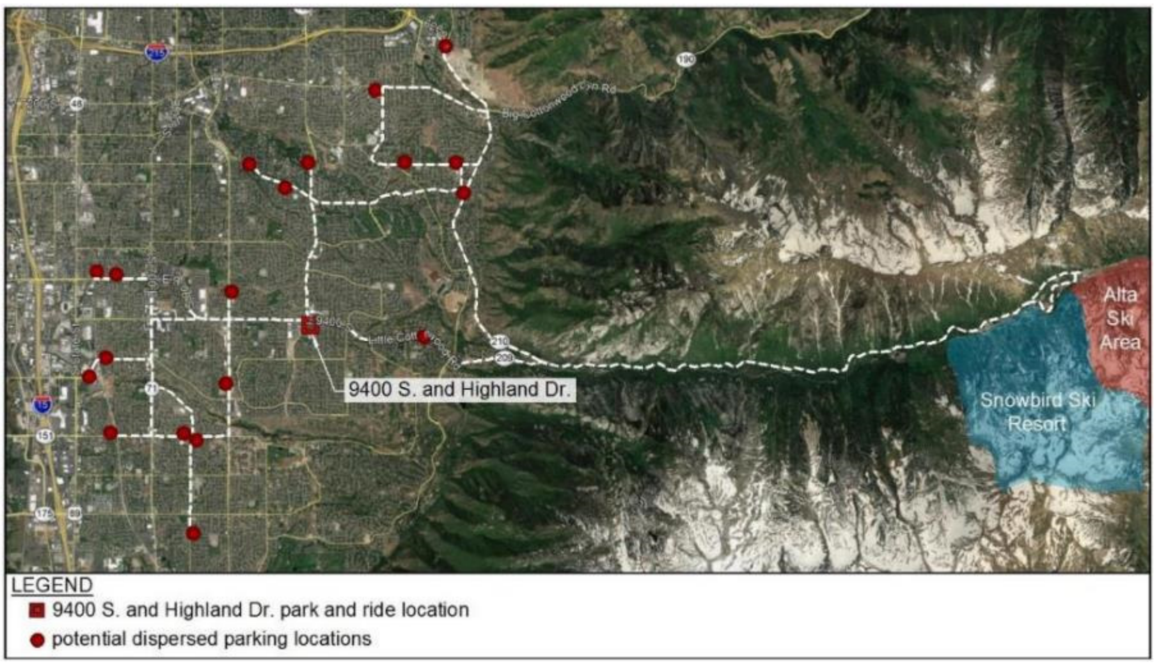

Figure 13 – Location of 9400 S and Highland Drive Hub and other possible parking nodes for the intelligent transportation system and autonomous vehicle network

9.2.2 DESIGN DETAILS

9.2.2.1 COMMUNICATION NETWORK

We believe that a communication and information portal can connect visitors to the current Network conditions before leaving their homes, which could provide an effective way for redirecting the behavioral patterns of the commuters. We anticipate the use of computers and cell phone applications that compile relevant information into one source, such as weather, road conditions, available parking, and multimodal transit information including wait and transit times. A communication network that connects transportation providers to visitors could increase ridership whether it is through private carpooling, commercialized high occupancy transit, or public transit.

Currently, there are mobile phone applications that provide information about Canyon conditions (including UDOT and CanyonAlerts), but a more coherent and streamlined system is desirable to accommodate both future and existing transportation within the Canyon.

9.2.2.2 AUTOMATED VEHICLE NETWORK

AVN aims to reduce congestion during peak hours by increasing occupancy. Integral components include concentrated parking hubs, dispersed parking with the potential to accommodate private residential locations and public lots, and information communication systems. AVN aims to become an attractive alternative to personal vehicle travel.

Incorporating AVN into the transportation system previously purposed, it would include the following components:

- Fleet
  - The AVN fleet encourages ridership with comfortable and convenient vehicular travel.
    - We envision vans carrying 8-15 passengers with extended storage space in order to transport Canyon visitors to their desired location in the Canyon.
    - Vehicles would need to be capable of operating through mountainous terrain and extreme weather conditions within the Canyon.
  - As autonomous vehicle technology improves, the need for paid drivers decreases, which reduces long-term operational costs.
  - Prior to complete autonomous vehicle operations, the operating work force can be commercialized, public, or a combination of the two.
    - Private enterprises, resembling Uber and Lyft, could eliminate taxpayer burdens because UTA does not own or operate the vehicles. This business model has been successful for private enterprises such as Chariot, Downtowner, and Via.
    - To ensure safe service due to weather and terrain hazards, the driving ability and record must be limiting factors in the qualifying workforce.
- Information Communication Systems
  - The AVN requires communication between the fleet, the parking hubs, and the visitors. Therefore, vehicle-to-infrastructure and vehicle-to-vehicle interactions are required, and federal and local standards would apply to the technologies used within the chosen model. Communication between the visitors and the fleet is also a necessity considering the

vehicle would require data pertaining to the value of the fare as well as initial and final destination.

9.2.3 POTENTIAL LAND ACQUISITIONS

UTA owns the existing parking lot at 9400 South and Highland Dr. Due to the expressed interest for transit improvements by the governing agencies, additional land acquisition would be minimal and the ability to make changes would be ideal within reason.

9.2.4 CONSTRAINTS – PARKING OPTIONS

9.2.4.1 MAINTENANCE

- Parking areas within the multimodal hub can be designed for minimal maintenance using material stabilizers and storm water drainage. Features of the design should include epoxy-coated rebar, additional clear cover for concrete, and more, to reduce corrosion and wear on the structure [6].
- The multi-use needs of the multimodal hub would require regular maintenance, but we anticipate the businesses providing services that generate revenue to support ongoing maintenance.
- The communication network would require computer programing maintenance and staffing. Revenue could be generated through moderate use of advertisement to offset operational costs.
- AVN maintenance is unclear at this time, but it is reasonable to assume that operating maintenance would be required similar to traditional vehicles and vary depending on the accessibility of parts and knowledgeable mechanical laborers.

9.2.4.2 EXISTING CONDITIONS

- The 9400 South and Highland Dr. P&R reaches capacity on relatively low-demand days.
- Canyon visitors use this P&R location to carpool and to ride the UTA Ski Bus.

9.2.4.3 STAKEHOLDER INPUT

Collectively, meetings on January 25 and February 26, 2018, confirmed that the interests of GCC was to disperse the parking from the mouth of the Canyon and reduce the use of single occupancy vehicles. All parking structures must be sensitive to surrounding neighborhoods, incorporate aesthetics, and mitigate increased congestion due to the redirection of vehicles to the structure.

9.2.4.4 ENVIRONMENTAL

A construction of a multimodal hub will require the use of concrete and steel, which produce harmful emissions during the mixing of concrete, transporting of materials, and operating of equipment. Emission and air quality relationships would require future investigations regarding the effects of vehicle origin, trip length, and engine-to-exhaust output. Lastly, since the proposed areas are already paved lots, the changes in storm water drainage are not expected to increase [7].

9.2.5 CONSTRAINTS – AUTOMATED VEHICLE NETWORK

9.2.5.1 CAPACITY

The LCC roadway infrastructure is extremely susceptible to user demand exceeding capacity, especially during the ski and snowboard season. The AVN aims to mitigate this effect on the roadway by reducing the number of vehicles entering the Canyon from 9400 South and Wasatch Blvd. Unfortunately, this increases demand for parking outside of the Canyon. The hub at 9400 South and Highland Dr. removes approximately 900 vehicles from the roadway, assuming complete utilization. However, population growth projections suggest that the best way to approach the capacity problem in the future is by having the automated vehicles pick up Canyon visitors from their homes instead. With carpooling applications and information being received by autonomous vehicles, the vehicle could generate an efficient route and pick up Canyon visitors. This vehicle could be a shuttle with Canyon conveniences depending on the season; ski racks for the winter and trailers for mountain bikers in the summer.

9.2.5.2 RIDERSHIP

Current occupancy is estimated at 1.8 people per vehicle, indicating that the transportation Network currently operating within the Canyon is severely underutilized. In fact, the occupancy suggests that the transportation Network is so inconvenient that recreators prefer waiting up to 3 hours in their own vehicle without moving, over riding the bus. The AVN encourages greater ridership by communicating with these users, accommodating their needs, and serving them at a lower cost and greater convenience than a bus or personal vehicle can.

9.2.5.3 TECHNOLOGY

Until autonomous vehicle technology is fully developed and implemented into regular traffic, users must depend on the current applications to communicate roadway and parking conditions in the Canyon prior to departure, such as: UDOT's traffic application or UPD's CanyonAlerts application. In addition, a driver is needed with the shuttle until the vehicle is fully equipped with autonomous component. Currently, some vehicle-to-infrastructure and vehicle-to-vehicle communication is present within our daily drive and this is continuing to evolve. For instance, some vehicles available today, can sense other vehicle and can provide park assist or cruise control adjustments. This System would also allow for snow plows, UTA buses, and UPD vehicles to have a line of communication with the infrastructure.

9.2.5.4 STAKEHOLDER INPUT

Due to the lack of available models, input is centered on optimism and curiosity for implementation and safety. Overall, the views were hopeful towards solutions and services that could eliminate the needs for people to use their private vehicle.

9.2.5.5 ENVIRONMENTAL

The AVN is extremely noninvasive. Aside from one parking structure, located outside of LCC, this alternative does not suggest building anything at all. Therefore, the environmental risks are relatively low. Vehicular emissions present the most probable detriment to the natural environment. These effects can be quantified in terms of either the carbon or energy footprints.

9.2.6 COST ESTIMATE

Multimodal Hub

- The unit price used for estimating cost of the parking region within the multimodal hub was $75 per square foot (sq. ft.) and 250 sq. ft. per stall. It is estimated that the hub will accommodate approximately 900 vehicles costing roughly $20,000 per stall, which equates to $18 million.
- Alternatively, a parking study facilitated by the Mountain Accord evaluated the cost of a 9- and 5-story parking structure at the 9400 South and Highland Drive location. The number of stories to obtain the cost per story of parking structure divided their result. Then, it was determined that a 2- and 3-story structure would cost either $15 million or $22.5 million, respectively. The results are relatively consistent with the unit price method.
- Cost estimates would increase due to additional levels that require temperature-controlled levels and increased water, gas, and electrical utilities. Our goal is to generate revenue from these areas to offset capital and operational costs [8].

Automated Vehicle Network

- The cost of an AVN is difficult to assess with the current technology available, and will need to be considered in the future, instead, as the technology develops. However, the AVN is expected to present few economic risks, as it is not proposed for UTA (taxpayers) to purchase or operate the vehicles. Instead, private enterprises and partnerships may develop a business model to share the fiscal burden.

9.3 ALTERNATIVE EVALUATION

Proposed Benefits

The benefits proposed by this concept would increase ridership through high occupancy vehicles and provide convenient and reliable information, parking, and transit for skiers and other Canyon visitors. We believe, the proposed locations provide a convenient alternative parking, not considering in-Canyon parking, which is one of the leading factors in determining if a visitor will engage in shared transit. AVN could generate frequent departures from this location as well as others around the Valley and provide an attractive alternative to the personal vehicle mode of travel.

Prior to full development of the AVN, the multimodal hub can be implemented for present day commuters. The location also provides easy access for transit going in the up-Canyon direction, as it is located on the right side of the 9400 South. Leaving the hub, transit vehicles would not be required to cross two lanes of oncoming traffic. Another benefit of the proposed hub is that it serves as a convenient location for people to congregate as they meet to carpool, utilize the AVN or Ski Bus services. It should be noted that this hub could be developed prior to full development of the ITS and AVN, since Canyon visitors can utilize this location for carpooling and help reduce traffic congestions in LCC.

Alternative Pursued to Mitigate

The multimodal transportation hub is proposed to reroute congested traffic from Wasatch Blvd. to 9400 S, which has a higher vehicle capacity. The AVN has the potential to eliminate or reduce the need for paid drivers, therefore creating a transit system that does not rely on a human work force. Through advances in AVN, users may be able to recreate in the Canyon without using their personal vehicles and the supporting technology could help optimize vehicular space so that half-empty vehicles are no longer a common occurrence.

10.0 GONDOLA SYSTEM

One long-term solution that is worth exploring in this FS is the development of an alternative mass transit system that can improve Canyon access and ease or solve current transportation issues in the Canyon. This study proposes that a gondola system be considered thoughtfully as a means of achieving increased safety, reduced congestion, increased tourism, and providing a means of ingress/egress to the Canyon that is separate from the current road system that can be used in case of emergency.

Worldwide, gondolas have become increasingly popular as a means of mass transit. Areas that are particularly mountainous, have large rivers or bodies of water, or other geographic barriers to transportation are particularly amenable to adoption of new methods of transportation. Considering the geographic restraints the Wasatch Mountains present due to grade and alignment in the adoption of a rail or funicular system or even the amount of blasting that would be required to expand the roadway to accommodate more lanes, it is reasonable to consider the increased feasibility of a gondola system.

SEA's proposed choice is the 3S Detachable Gondola system developed by Doppelmayr and Garaventa. This lift system combines the traditional gondola system where cars are pulled along a fully locked track rope up to 20 miles per hour. For passengers to easily enter and exit the carriages, the gondolas can detach and then move on eight wheels affixed to the top of the gondola connection arm. Each carriage moves slowly enough that young children or the elderly can easily walk into the cars and then it accelerates back up to speed and reattaches to the track rope.

Each car has redundant and independent safety systems providing that in case of an emergency each car can safely return to the nearest station, and the 3S system boasts comfort for passengers in high winds. As each carriage is pulled along the track rope the wheels on the top of each carriage are rotated against a stationary rope that allows the generation of energy to provide each cabin with environment control and lighting. Seating can vary from smaller cabins up to 35 passengers per carriage; in addition carriages designed to carry vehicles up the lift can be attached to the system.

This system would not only provide comfortable and safe travel but would also provide a new kind of Canyon experience that could bring tourism and more recreational traffic into the Canyon and up to ski resorts, increasing state revenue in taxes and providing enough ridership to make such a large system self-sustaining. Doppelmayr lists that the maximum capacity of the 3S system to be 5,500 persons per hour in each direction of travel. The Forest Service reports that at peak times there are 11,000 vehicles that travel the Canyon a day. They also project that there about 1.7 persons per vehicle, suggesting that about 18,700 persons take vehicles up the Canyon at peak times. Therefore, the 3S system would be able to provide adequate transportation for current needs in a matter of a few hours single-handedly. Future needs for the Canyon are projected to be at 2% growth for the next 50 years projecting nearly 54,000 Canyon users at peak times. Without another means up the Canyon, the road system will be severely inadequate without widening. If a significant number of Canyon users can be influenced to move to mass transit such as a gondola system, the road may not need to be widened considering the capacity of the gondola system.

10.1 DESIGN DETAILS

Location

In order to be feasible and to retain the support of the ski resorts, who would have a large stake in the development of such a project, it is expected that the gondola system would need to serve riders at the outside of the Canyon and then up to both Alta and Snowbird Resorts. SEA's contact at Doppelmayr suggested that the Chickadee area at Snowbird had been marked in previous discussions as a good landing point for the gondola system, but they did not specify other specific points at Alta or Snowbird to make a station for access.

Other routes that tie BCC and LCC have been discussed in previous talks between state agencies and Doppelmayr. Routes connecting Park City and its ski resorts to BCC and LCC are another alternative. Each presents opportunity for canyon enthusiasts to enjoy increased access to these canyons and increased mobility in case of a canyon shutdown.

It is suggested that a large multimodal hub farther from the mouth of the Canyon, namely 9400 South and Highland Dr. as mentioned within the ITS and multimodal hub alternative, would serve as a starting point for the gondola system. It is noted here that that would increase the cost estimate given by Doppelmayr for the system due to their preliminary concepts landing closer to the mouth of the Canyon.

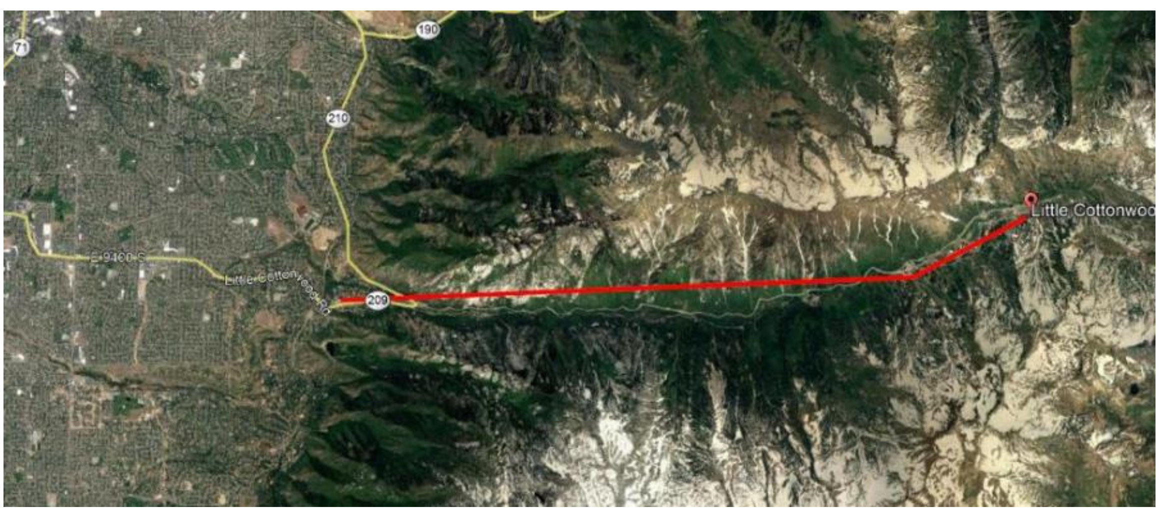

Figure 14 – Potential alignment of the gondola system

Design Requirements

To gain public support, it is anticipated that any new transportation system up the Canyon will have to satisfy the following criteria:

- Ensure the safety of occupants during high winds or an earthquake event;
- Design must be aesthetically pleasing and not detract from LCC visually;
- The amount of time required to obtain a ride must be short;
- Both ski resorts must be serviced;
- Optionally, White Pine or another large hiking location should be serviced;
- The cost of service and location of services should be such that riders will feel inclined to use such services;
- The cost of service should pay for maintenance and provide a return on investment;
- Parking will need to be included in the design of the out-of-Canyon access that is designated. This parking could be provided at an educational center for the Canyon or existing parking hub such as a UTA P&R given sufficient capacity;
- Connectivity to other mass transit is highly recommended;
- Wilderness Areas must be avoided; and
- "Intelligent transportation systems" should incorporate new developments with traditional methods.

Potential Land Acquisitions

- Easements and right-of-ways (ROW's) will need to be obtained for the construction, use, and maintenance of any new system in the Canyon. Doppelmayr requires a sufficient easement to maintain their system. This requires 35 feet of airspace on each side of the track system to be obtained as a right-of-way and easement in favor of Doppelmayr. Therefore, if the track system was 15.75 feet in width; a total easement of 85.75 feet would be required. This land is owned by the Forest Service, which presents a major challenge for acquiring land.
- In addition, the requirements for construction could require the use of other lands. Some land uses during construction include:
    - Access for construction vehicles along the mountainside; and
    - Locations for construction facilities such as: trailers, toilets, materials storage, and washouts.
- Towers for the gondola system would require land acquisition. The size and placement of the towers would depend on the desired capacity of the system as well as the number of desired access points. Typically, the towers for the system are spaced just over half of a mile and only have a footprint of a couple of hundred square feet each.

Constraints

Any project comes with opposition and it is relevant to list some of the projected constraints that may affect the implementation of the gondola system:

- Economic
  - Large capital cost est. at $100 million
  - Obtaining funding - state funded or otherwise
  - Maintenance costs of the Gondola System
- Social
  - Canyon user access may be limited or impaired during construction.
- Environmental
  - Environmental backlash
- Political
  - If taxes are used to fund this project, any raise in taxes may be opposed heavily
  - Forestry Service Land acquirements
  - Proximity to Wilderness Areas

Maintenance

System pieces to be maintained:

- Gondola carriages
- Towers
- Track ropes
- Facilities at each stop, including restrooms, conveniences, parking, and pedestrian areas

Stakeholder Input

Stakeholders from the GCC view the gondola as an approach with merit that could be used to reduce vehicular traffic in the Canyon and quite successful. Concern was demonstrated about capital costs, operating costs and how Canyon visitors would access the system. Adding additional towers in the Valley to allow visitors to reach the Canyon were not deemed favorable. Overall, they expect this solution could be an exciting and lasting one and should be looked at in further detail in a future study if not this one.

Environmental

Environmental impacts need to be addressed by any proposed system. Few rigorous studies on the impacts of gondola systems on the environment have been published, but some studies done by groups such as Cascade Environmental have noted that such a system would have little impact on environments in general. Since the towers for the system are spaced a little over half a mile apart and only have a footprint of a couple of hundred square feet each, there would not be nearly the impact that would be seen with a new roadway or rail line. Another benefit of the gondola system is that traffic is elevated and will not be in direct conflict with much of wildlife habitat or trails. Since stations for access to the system will be located at existing ski resorts or cities the stations will also be located outside of wildlife habitats. Noise from the gondola system is also reported by Doppelmayr's website to be very minimal.

10.2 COST ESTIMATE

Doppelmayr USA has estimated that the capital cost of constructing a 3S Detachable Gondola system that serviced Alta, Snowbird, and a base at the mouth of Little Cottonwood Canyon may be near $100 million. This cost was based on projections that came out of meetings comprised of UDOT, UTA, Doppelmayr, and other concerned parties regarding transportation in the canyons.

Other potential costs, economic and time related, associated with this concept would include obtaining licensing, right of ways and easements, negotiations with the Forest Service, engaging the public at large and local councils, engaging environmentalists, the addition of intelligent technologies to increase user information and safety, and maintenance costs over the full lifespan of the system. In order to maintain the gondola system there would need to be a constant source of revenue, which would most likely be provided by the sale of tickets, however, the potential season usage may deem this too costly.

10.3 ALTERNATIVE EVALUATION

10.3.1 COST

- $100 million exceeds the budget assigned by UDOT to LCC but is not so great that this idea is unreasonable.
- Since this system has the ability to generate revenue in a traditionally recognized manner for use of the system operational costs can be offset.

10.3.2 SERVICEABILITY/MOBILITY

- Current peak day demands could be handled within a few hours and eliminate all cars on the road.
- Future needs can be handled with the current road system and the Gondola system combined.
- Easy access carriages - elderly or young children can access.
- More simple than other modes of mass transit due to reliable schedule and set route.
- Access is the only concern, requires parking or connectivity to other mass transit systems.

- Hikers would have to hike down from Snowbird or Alta to other hiking sites unless a 4th stop was instituted at a popular hiking area.

10.3.3 ENVIRONMENTAL IMPACT

- Assuming wilderness areas can be avoided, limited impact to protected lands.
- Towers for system have significantly less square foot impact than adding lanes to LCC road.
- Elevated system eliminates many contact issues with fauna.

10.3.4 SAFETY

- Gondola system boasts independent redundant safety systems and critical systems.
- Carriages perform well in high winds.
- Improves the accessibility to the Canyon during events that would shut the road down.
- Stations have cameras and other public safety systems

10.3.5 AESTHETICS

- Gondola system will not strip land of natural features.
- Towers and track may not be viewed by all as aesthetically pleasing.
- Carriages can be colored to be non-obtrusive.
- Will increase aesthetic opportunities regarding Canyon viewing.

10.4 PROPOSED BENEFITS

Based on the prior discussion and ranking, the project has the following benefits:

- Limited impact to wildlife or natural features
- Ability to generate revenue
- Access to LCC independent of the road
- Attractive views and tourist attraction
- Easy access to Canyon
- High capacity
- High safety system

11.0 ROADWAY SAFETY IMPROVEMENTS

11.1 SNOW SHEDS

11.1.1 DESIGN DETAILS

Snow sheds, in combination with snow barriers, are designed to direct the flow of an avalanche above the roadway. This greatly reduces the amount of snow removal for snowplows. This in return will greatly reduce the time of closure, as there would be no avalanche debris on the roadway. See Figure 15 for a typical concrete box culvert (snow shed) in an avalanche-prone area. These snow sheds may also be able to double as wildlife crossings, so that wildlife can safely cross the roadway.

Figure 15 – Typical concrete box culvert (snow shed) in an avalanche-prone area

11.1.1.1 LOCATION

Little Cottonwood Canyon is a frequent area for avalanches, which primarily come from the south facing Wasatch Mountains. From Google Earth, a keyhole markup language zipped (KMZ) file was provided by UDOT, which outlined the frequent chutes in red, occasional-frequent chutes in orange, occasional chutes in yellow, and infrequent chutes in green. Figure 16 shows all chutes within Little Cottonwood Canyon.

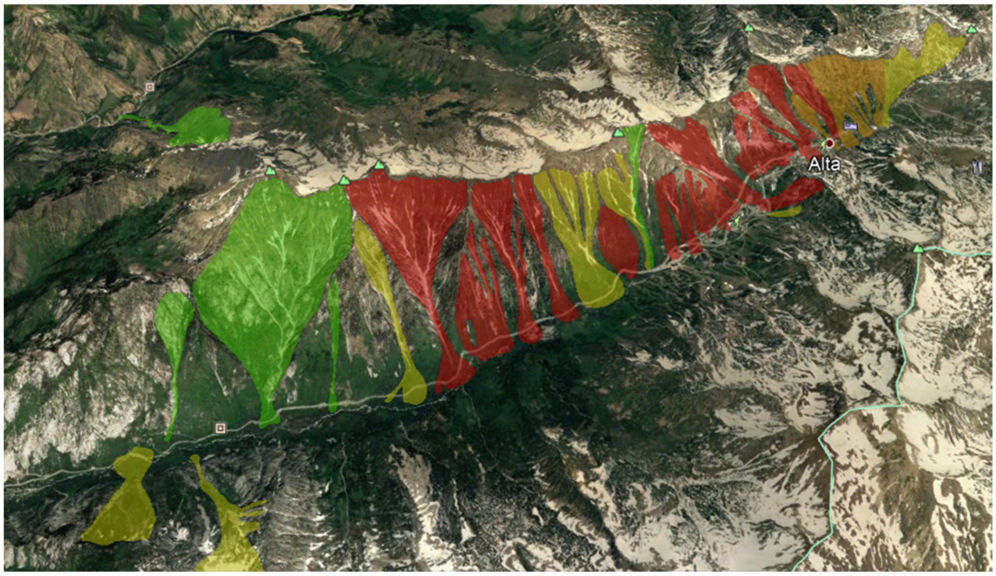

Figure 16 – Avalanche chutes within Little Cottonwood Canyon

UDOT has also outlined the frequencies of avalanches reaching SR-210 from 1973 to 2008. Figure 17 shows the amount of naturally occurring avalanches for each chute that have reached SR-210 from 1973 to 2008 and Figure 18 shows the amount that were controlled. These figures also show the artillery locations where 105-millimeter (mm) Howitzers are launched to trigger avalanches. Following the triggered avalanches, the unified team – comprised of the Alta Marshall, UDOT, and UPD – determine if the roadway is safe to reopen.

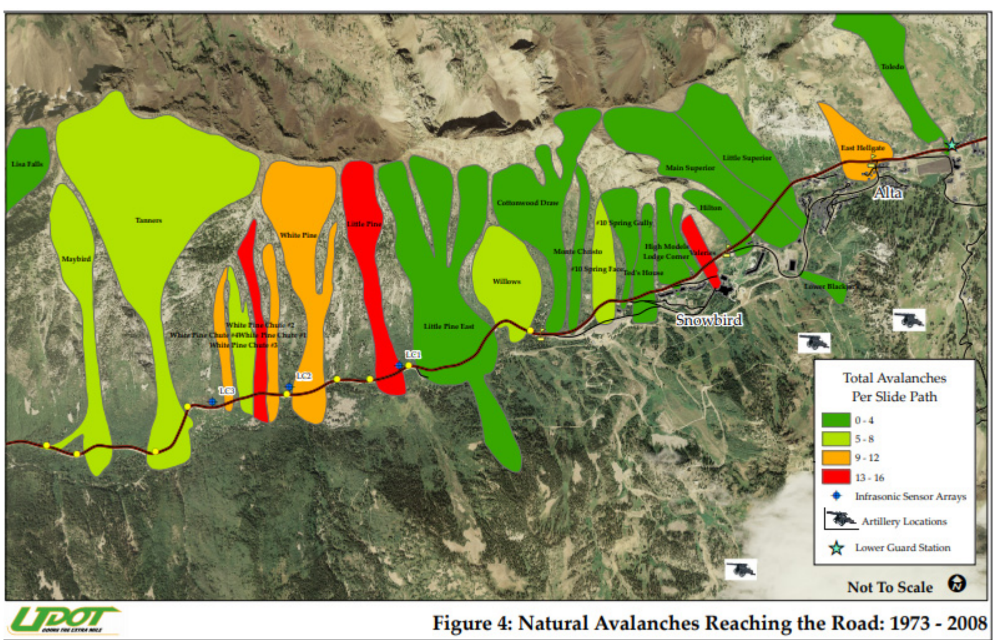

Figure 17 – Frequency of natural avalanches reaching SR-210 from 1973 – 2008

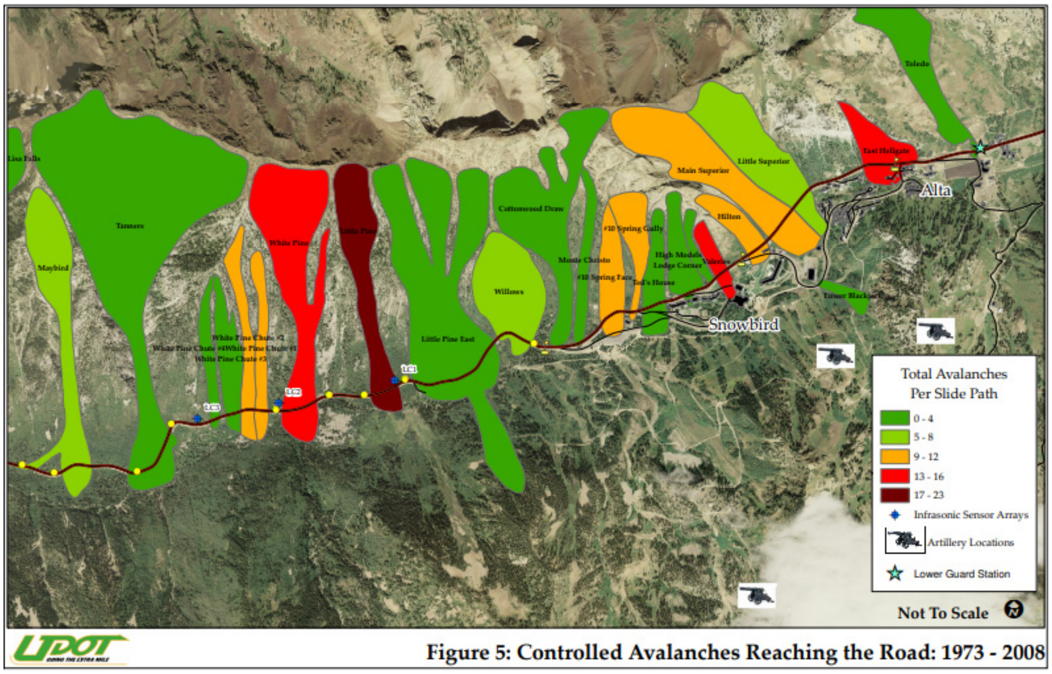

Figure 18 – Frequency of controlled avalanches reaching SR-210 from 1973 – 2008

The following listed below are the avalanche chute/no-stop avalanche roadway sections primarily including the pertinent frequent chutes and their spillways onto SR-210 roadway:

1. Main Superior and Little Superior, 950 feet of spillway;
2. East Hellgate, 1167 feet of spillway;
3. White Pine, 899 feet of spillway;
4. White Pine Chutes, 1897 feet of spillway;
5. Little Pine, 959 feet of spillway; and
6. Willows, 810 feet of spillway.

The priority of avalanche control for these chutes are the following in order: Little Pine, White Pine, White Pine Chutes, East Hellgate, Willows, and finally Main Superior and Little Superior. Figure 19 shows these frequent chutes of the most concern for avalanches outlined in red and labeled.

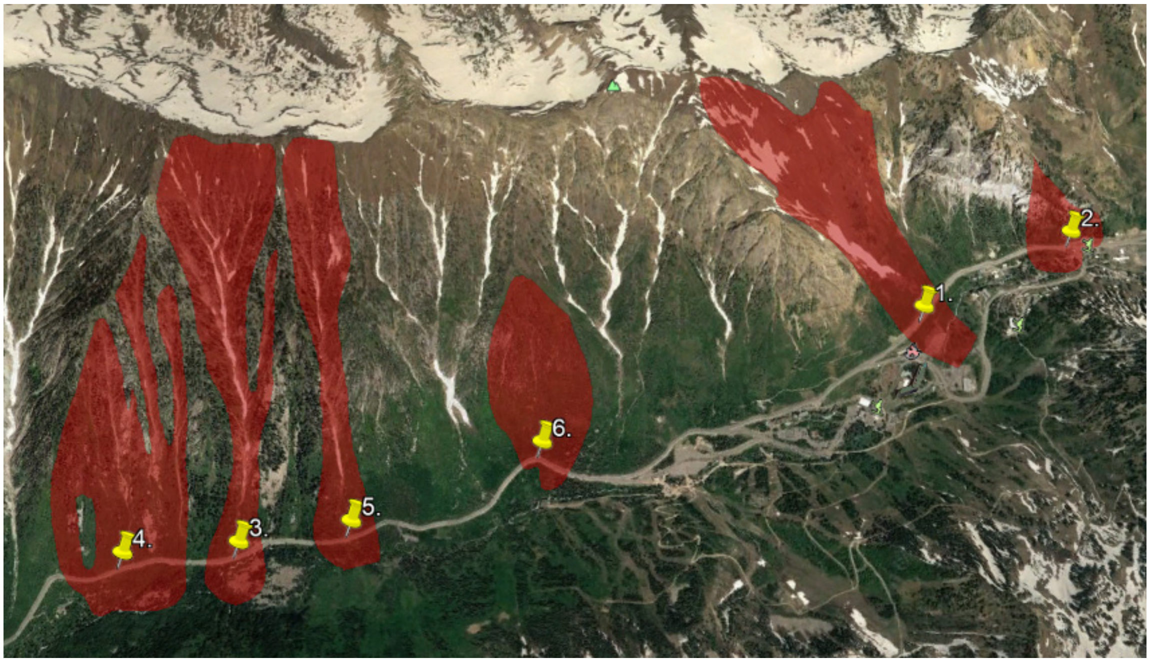

Figure 19 – Frequent avalanche chutes shown in red within Little Cottonwood Canyon

11.1.1.2 EXISTING CONDITIONS

Existing infrastructure are 105 mm Howitzers, avalauncher, snowplows, Gazex® firing exploders, and a China wall with avalanche berm at White Pine Chute. These avalanche control systems are mainly used to trigger avalanches and then plow the resulting avalanche debris off the road, while the Canyon is closed. When the 105 mm Howitzers are fired, the shells have a trajectory over houses and buildings. When the avalanches are triggered, the road must be closed to all traffic, causing delays throughout the system. When avalanche danger is considered, Hellgate is closed and all traffic to Alta is diverted to the Bypass Rd.

11.1.1.3 DESIGN REQUIREMENTS

Strong enough to withstand avalanches and reduce time of closure for avalanche control and plowing, snow sheds must be safe and must not disrupt current development, the current roadway, or future roadway features outlined in the report. If they are also made into wildlife crossings than there must be a barrier, and graded slope, so the wildlife can safely cross.

11.1.2 POTENTIAL LAND ACQUISITIONS

Land acquisitions are within the right-of-way of SR-210 because the snow shed structure covers the road with supports on either side of the road. Twin Peaks Wilderness is around 500 feet north of SR-210 and Lone Peak Wilderness is around 500 feet south of SR-210.

11.1.3 CONSTRAINTS

Maintenance

Snow sheds will require some kind of ice melt whether that is heated pavements or salt. Lighting will be required in most sections of the snow sheds because of their length. If the snow sheds were dual-purposed as wildlife crossing areas, then any fencing or vegetation on the top of the structure would have to be maintained.

Stakeholder Input

Stakeholders from GCC and UDOT have explained that these snow sheds are necessary if road closures are going to be reduced and traffic flow improved. However, MA studies have found that snow sheds commonly produced an entry hazard due to potential ice buildup or crashing into the structure itself.

Environmental

The first environmental concern is the use of salt for de-icing the Canyon and impacting the runoff water toxicity. More environmentally friends de-icing should be considered for tis alternative. Alternatively, the snow sheds can be used as a wildlife crossing.

11.1.4 COST ESTIMATE

A completed snow shed will cost approximately $5.8 million per 330 feet. If all sections of the roadway that fall under the frequent avalanche danger are to be protected by snow sheds, then snow sheds will most likely need to be constructed in phases. If the top three highest priority chutes had snow sheds, then the total cost would be $66.4 million dollars. If all chutes had snow sheds, then the total cost would be $118 million dollars.

11.1.5 ALTERNATIVE EVALUATION AND PROPOSED BENEFITS

The snow sheds would be constructed to mitigate the congestion at the mouth of the Canyon during avalanche control periods. During the closure of SR-210, traffic extends west on 9400 South and north on Wasatch Blvd. leaving neighborhoods and residents trapped in their homes. It is our hope that snow sheds would allow avalanches to be redirected over the roadway and reduce the need for live ammunition shooting. We also believe snow sheds would assist in snow removal by reducing the amount of plowing required. There is also a safety benefit, because if there were to be an avalanche event while traffic was moving up the Canyon, then vehicles would not be hit by the avalanche debris. Vehicles outside of the snow shed would not be within the avalanche pathway, as the snow sheds would be built well within the avalanche spillway.

The selection criteria for snow sheds were based on five criteria including: cost, serviceability, environmental impact, safety, and aesthetics. Cost was rated low, because the cost alone for the top three chutes is over UDOT's current budget. However, it is possible that UDOT could implement an initial snow shed at the highest risk chute, using currently available funding, and test the concept. Serviceability was rated high, because we anticipate the snow sheds would meet the performance and goals of the project by decreasing the amount of road closures due to avalanche control. Environmental Impacts were rated as medium due to the disturbance in the roadway and the fill and concrete that would be required to support the structures. Safety was rated high because our recommendation requires the snow sheds to be designed with adequate lighting and ice removal within the structure. We also anticipate an increase in safety due to the increased protection to vehicles and people within the shed. Aesthetics was rated as medium because from within the structure, people will lose their scenic view, but from the outside they can be made into animal crossings that adapt the natural environment.

11.2 PEDESTRIAN ROUTE USING THE OLD HIGHWAY (ROUTE 1)

11.2.1 DESIGN DETAILS

11.2.1.1 LOCATION

The location for the proposed pedestrian route for Little Cottonwood Canyon will begin at the Temple Quarry and travel to the end of the Little Cottonwood Trail near Tanner Flats, then continue along SR-210 up to Alta for the uphill users. In the future, this trail can be used as a connection to the proposed Bonneville Shoreline Trail that runs across the Wasatch Front. The red path in Figure 20 details the approximate alignment for this route option.

Figure 20 – Route 1 using the Old Quarry Road

11.2.1.2 EXISTING CONDITIONS

Physical Trail Conditions

The existing trail conditions of Little Cottonwood Trail consist of a rudimentary dirt path following the historic Old County Road alignment. The path contains a variety of grades and curves throughout the entire length of the trail, approximately 2.8 miles. An approximate elevation profile of the length of the Canyon, taken from StreamStats, is shown in Figure 21. The width of the trail is about a 5-foot average for the whole length of the trail, surrounded on both sides by relatively undisturbed native plants and rock outcroppings (Figure 22).

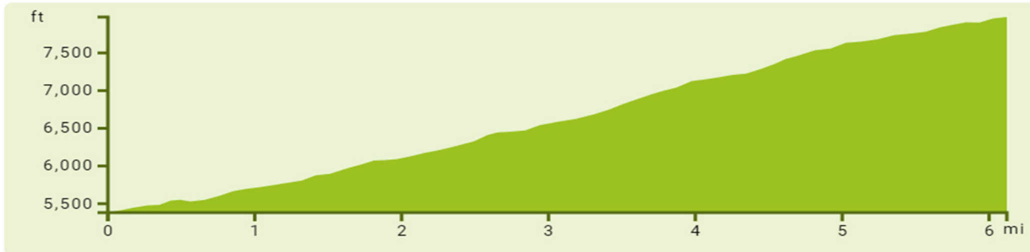

Figure 21 – Canyon elevation profile taken from StreamStats


Figure 22 – Beginning of path at Temple Granite Quarry

Figure 23 – Little Cottonwood trailhead sign at Temple Quarry Monument

Trail Signage and Infrastructure

Signage and trailhead conditions for the three major trail access points along the trail are aging and would require updates (Figure 23). The three major trail access points that have been identified are located at the Temple Quarry Historical Monument, Little Cottonwood Creek Bridge, and across from the Lisa Falls Trailhead. Other pertinent existing aspects of the Little Cottonwood Trail include the two bridge crossings over Little Cottonwood Creek; these locations are detailed in the trailhead map shown in Figure 20. It is expected that improvements to these bridge crossings will be necessary to accommodate the anticipated increase in use and different users associated with this proposed Route 1. There is also an existing, but outdated and abandoned, power plant approximately one quarter of a mile up from the Temple Quarry Historical Monument trail access point (Figure 24). With the existing structure near the trail, its potential involvement with this system will need to be considered if trail widening and/or paving is undertaken.

Figure 24 – Power plant along SR-210

Trail Ownership

The pedestrian route will be split up between the uphill users and downhill users. The uphill users' path will start at the Old Quarry Road, which is on the Forest Service Land and will continue up the Old Quarry Road until it reaches the campground at Tanner Flats. The campground site is on the Forest Service property and has a connection to SR-210. This location will be used to merge the uphill users onto the SR-210 road. The downhill users will use the SR-210 as well as the uphill users that go past Tanner Flats campground to the ski resorts. SR-210 is on an easement that has been granted from the Forest Service to UDOT. There is a power plant along the current quarry trail and discussion will need to take place between the owner and the Forest Service to determine if the plant can be removed or if the trail will need to be realigned to accommodate the widening of the path.

Trail Utilities

Trail utilities such as water, sewage, and electrical will need to be investigated further for construction of the path along the Old Quarry Road. Trail utilities could be updated as well as placing drinking stations along the route. There is the potential for ITS in some areas beyond Tanner Flats; this could help alert cyclists and motorists of each other.

11.2.1.3 DESIGN REQUIREMENTS

The proposed pedestrian path route south of SR-210 will need to accommodate uphill users until Tanner Flats, where the users will be merged back onto SR-210 with the vehicular traffic for the remainder of the Canyon. The downhill users will be aligned with the Canyon vehicular traffic on SR-210. Separating the uphill and downhill bikers will provide additional safety for all users due to the varying speed differences between uphill and downhill users. The path off SR-210 will be developed to meet the Americans with Disability Act of 1990 (ADA) requirements where feasible. It is anticipated that the lower half of the path will provide desirable slopes for ADA requirements; however, sections of this alignment may no longer accommodate specified grades without large impacts to the environment for extended ramps. This design will attempt to minimize the environmental impacts on the Canyon and accommodate multi-users of the Canyon.

11.2.2 POTENTIAL LAND ACQUISITIONS

Route 1 requires the land acquisition of the existing Old Quarry Road from the Forest Service. It will be necessary to obtain the easement, lease, or purchase property from the landowners that currently own the land for the proposed trail. Some segments may also need to expand into the undeveloped trail from the Lisa Falls parking lot to the Tanners Flats Campground pull-off.

11.2.3 CONSTRAINTS

Maintenance

Seasonal and yearly maintenance will be required for the pedestrian and bike path. Snow removal and ice management of the path will need to be investigated to better the experience for the users, so that the path can be used year-round. Year-round maintenance of vegetation control will need to be conducted to maintain and control over-growth of the vegetation surrounding the path. If a hardwearing surface is used as an overlay on the proposed pedestrian path, general maintenance will also be required.

Stakeholder Input

A pedestrian route is needed going up and down the Little Cottonwood Canyon. The Old Quarry Road will need to have locations that connect back to SR-210. The Forest Service suggested a boardwalk option for the trail and this option should be analyzed farther. Stakeholders at the GCC desired a path to meet ADA requirements where feasible, as well as accommodate road bikers, mountain bikers, runners, and ADA visitors.

Environmental

Some concerns for Route 1 include water run-off, and yearly path maintenance. As mentioned previously, this Canyon lies within a protected watershed; therefore, management of runoff from this Route will need to be evaluated further. This Route would require some deforestation during construction; therefore caution will need to be used so that the minimum amount of deforestation occurs and that reseeding of the natural seed will occur post-construction to help preserve the natural life of the Canyon. Due to the deforestation there will be an effect on the wildlife and potential issues will need to be considered, along with impacts caused during the construction. A consideration of different path types and their environmental impacts would help to mediate the total environmental damage. A boardwalk path and/or unpaved dirt path may be considered as alternatives to an asphalt-paved path in the name of environmental stewardship. A boardwalk is less destructive than a traditional paved trail because there is less land used for a boardwalk being supported above the ground.

11.2.4 COST ESTIMATE

The cost estimate shown below for this alternative was based on design by analogy using the Parley's Canyon Trail Feasibility Study completed in 2012 [9]. The proposed route will require two different widths. The two widths are recommendations from American Association of State Highway and Transportation Officials (AASHTO) and the estimates were developed using these recommendations. The 12-feet paved trail is for any grades that are less than 9%. The 14-feet trail is recommended from AASHTO to be used for any grades along the proposed trail location with grades greater than 9%. The first section of the trail from the Old Quarry Road origin to Tanner Flats will be 12-

feet wide for grades less than 9% and portions greater than 9% will be 14-feet wide in accordance with AASHTO guidelines.

Table 6 – Cost estimate of path construction from Old Quarry trail to Tanner Flats

From Start of the Old Quarry Trail to Tanner Flats			
	Cost (per lf)	**Length (per linear feet [lf])**	**Total Cost**
12-feet Wide Paved	$130.40	12,700	$1,656,000
14-feet Wide Paved	$465.60	9,000	$4,190,000
	Total		**$5.8 million**

Table 7 – Route 1 cost estimate of path construction with design details

Design Detail	Cost per linear foot (lf)	Total Cost
12-feet Paved Trail	$130.40 (for 15,800 lf)	$2,060,000
14-feet Paved Trail	$465.60 (for 8,700 lf)	$4,050,000
Two 6-inch Solid White Line (one/lane)	$0.70 (for 2,500 lf)	$1,750
Bicycle Rider Marker	$174.5 per marker (4)	$700
Pedestrian Bridge	$3,492 (for 200 lf)	$700,000
	Approximate Total Cost	**$12.6 million**

11.2.5 ALTERNATIVE EVALUATION AND PROPOSED BENEFITS

The benefit of this route is to minimize the conflict between vehicular and pedestrian path traffic. It will also give a better opportunity for families to use the Canyon in a safer environment away from traffic and in a more family–friendly environment. It keeps the uphill bicyclists off the road for the first half of the Canyon, keeping them away from the danger of moving cars and trucks as well as any informal parked vehicles along SR-210.

This alternative was proposed to reduce the interaction of pedestrian path users and vehicles in Little Cottonwood Canyon. This could also be improved with the connection of the Shoreline Trail across the Wasatch.

For the bike and pedestrian path, Route 1 is evaluated as the best option for Little Cottonwood Canyon. The ratings of this alternative are shown in Table 11 with explanations of the ranking given for each criterion. The rankings that were given are explained here for understanding how they were assigned. Cost for Route 1 was evaluated as a medium rating; this is because of the estimates of $12.6 million detailed in Table 6. The basis of the costs for creating the road was taken from the Parley's Canyon Trail Feasibility Study for the pricing of paving paths at various grades [9]. The 50-year life of the path was evaluated based on serviceability and mobility to enabling more recreators to use the Canyon for the expected population growth of the Canyon, so this was given a ranking of high. The environmental impact was rated as low for the disturbance of the Little Cottonwood Creek and the deforestation that would occur during the building process of the path. With the separation of the pedestrian and bike path for SR-210 the safety ranking was selected as high, for the reduction of conflicts between pedestrians and vehicles. Also, with the addition of making the trail ADA accessible in some areas, this enables a positive experience for people with disabilities using the Canyon. Aesthetics was rated medium from the environmental views of paving the trail by the creek bed but adds benefits of eliminating use of non-designated trails. With an overall rating of 2.05 out of 2.55, Route 1 is recommended as the superior option when compared to Route 2; see justifications and ratings for Route 2 in the following section.

11.3 BIKE AND PEDESTRIAN ROUTE USING SR-210

11.3.1 DESIGN DETAILS

11.3.1.1 LOCATION

The location for the proposed bike and pedestrian Route 2 within LCC will begin at the mouth of LCC, where 9400 South and Wasatch Blvd. converge toward Alta. This alignment will be integrated into the existing roadway, SR-210, as shown in Figure 25.

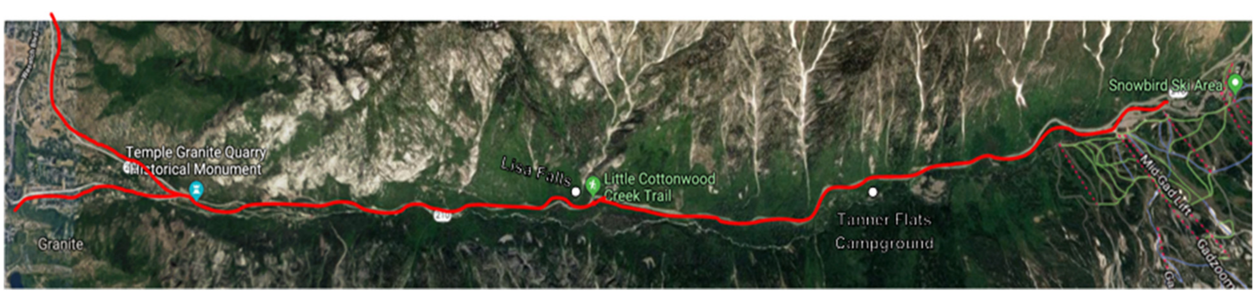

Figure 25 – Route 2 bike and pedestrian path along SR-210

11.3.1.2 DESIGN REQUIREMENTS

The bike and pedestrian route along SR-210 will accommodate uphill and downhill users. The two paths will need to be separated and will run with the flow of traffic. The desirable width of the uphill lane adjacent to the road is 4-feet, with downhill being 3-

feet according to AASHTO requirements but might require an even wider path for the unanticipated illegal parking on the roadside. Since vehicular and cyclists travel at similar downhill speeds it is anticipated for downhill bicyclists to travel in-line with vehicular traffic. In segments along this route with narrow passes, a cantilevered path may require additional investigation. Conflicts between the pedestrian path lane and the vehicular lane will be minimized but not solved. The bike lane will help manage and minimize the conflicts because the main areas of issue/conflict will be located around the trailhead access points. Informal parking conflicts can still be an issue unless the shoulder after the construction became smaller and vehicles are unable to park which would resolve the concern between the bike lane and the informal parking.

Design for this Route will require considerations for SR-210 improvements. For instance, the construction of this process will occur with the possible road widening and realignment of the current highway to make sure that the path will stay consistent.

11.3.2 POTENTIAL LAND ACQUISITIONS

The potential land acquisitions required for this Route includes ROW on both sides of SR-210. There are some sections of land that might travel on Forest Service land with the expansion of the road for bike use, which would also need to be acquired. Near the top of the Canyon, the Route travels through resort property and potential acquisitions may be needed.

11.3.3 CONSTRAINTS

Maintenance

In the wintertime, snow removal is the most common maintenance effort, which would need to be considered in the design of the path. During the spring through fall seasons debris will need to be removed, to make sure that the pedestrian path users stay on their designated areas and not encroach into the vehicle lane. Painting of the lines will need to be maintained to ensure that the lanes of vehicle and non-vehicle are clearly marked to minimize conflicts between them.

Existing Conditions

The existing conditions of the proposed location includes parking lots along the side of the road, trailheads with parking, and access to ski resorts. Some portions along the roadway have shoulders, while other parts of the roadway are along a steep cliff. There is one house and a private power plant that is located on the south edge of SR-210. Depending on how SR-210 is re-aligned and expanded where these two structures are located, a possible relocation or alternative method will be needed to avoid conflict with these structures and the pedestrian path. Towards the top of the route at Snowbird, there are two, three-way intersections that need to be navigated as well. Traffic will be more concentrated at the resorts and will need to be considered for the section of the path near the resorts.

Stakeholder Input

The best option for the bike path is to provide a separated path for the uphill and downhill users. From the Mountain Accord Transportation Recommendation, they stated that 87% of the public surveyed was in favor of the bike paths.

Environmental

The environmental impacts that will need to be considered for this Route are protecting the watershed by controlling and maintaining water runoff. Deforestation is another consideration with the expansion of SR-210 for the proposed bike lane.

11.3.4 COST ESTIMATE

The cost estimate shown below for this Route was based on the Parley's Canyon Trail Feasibility study completed in 2012 [9]. The trail will need to consist of two different widths. One trail will be 12-feet for any grades that are less than a 9% grade. Any portion of the grade that is 9% and greater will need to be 14-feet wide.

Table 8 – Route 2 cost estimate of path construction with design details

From Mouth of Canyon to Alta Ski Resort		
Design Detail	**Cost per linear foot (lf)**	**Total Cost**
12-ft Paved Trail	$130.40 (for 14,600 lf)	$1,904,000
14-ft Paved Trail	$465.60 (for 26,400 lf)	$12,292,000
Two 6" Solid White Lines (one/lane)	$0.70 (for 41,000 lf)	$28,700
Bicycle Rider Marker	$174.5 per marker (4)	$700
	Approximate Total Cost	**$14.2 million**

11.3.5 ALTERNATIVE EVALUATION AND PROPOSED BENEFITS

The purpose of the Route 2 is to provide a way of transport for pedestrian path users to go up and down the Canyon by minimizing conflicts with vehicles. This will minimize the impact on the surrounding environment because it will be built inside the ROW easement already designated for UDOT. It will be an extension onto the already existing and proposed construction of SR-210.

This Route attempts to provide specific bike lanes along SR-210 up Little Cottonwood Canyon. The bike lanes will run up and down the Canyon with traffic. These specific bike lanes attempt to reduce the risk of bikers traveling up and down the Canyon by providing a specific lane, giving more room to the bikers and new paint patterns.

Route 2 cost was given a low rating, due to the extra cost of widening and potential land cut and fills to widen to the road required to accommodate up and downhill users. Serviceability was rated at a medium because maintenance would include the general road maintenance of SR-210. The road widening would help to meet performance goals to reduce conflict between vehicles and bikers, while also meeting user demands. The environmental impact was given a low rating because of the extensive impact of construction on the surrounding environment. Construction activities may include land cut and fill, blasting of mountainsides, and road widening and paving. The possible effects of construction would include, but are not limited to, destruction of forestland, contamination of Little Cottonwood Creek, and reduction of natural mountainsides. Safety was rated as medium due to the fact that bikers and vehicles still share the road. While the additional bike lane may be on the same roadway as the vehicles, there are opportunities to introduce a protection barrier to mitigate the safety conflicts between bikes and vehicles. Aesthetics was rated as medium, as there is minimal change in views going up and down the Canyon and there would be some change in the mountainside and increased development will reduce the natural appeal of the Canyon. The final rating of this alternative was 1.50 out of 2.55.

11.4 INGRESS AND EGRESS AT RESORTS

11.4.1 DESIGN DETAILS

The desired intersections design is a box culvert that creates an exit from the ski and snowboard resorts to SR-210. The slope of the Canyon at the intersections will provide enough height for automobiles to enter and merge into the downhill lane of SR-210. The entrance of the tunnel will be situated at the exit from the resort, which then goes underneath the uphill lane. The exit of the box culvert would be situated in what is currently the suicide lane for automobiles to merge into the downhill lane.

11.4.1.1 LOCATION

For purposes of this feature, we will evaluate three intersections located near Snowbird Ski Resort; the intersection identifications and locations are listed below:

- Entry 1 is located at the intersection of SR-210 and Gad Valley Drive;
- Entry 2 is located at the intersection of SR-210 and Snowbird Center Drive; and
- Entry 4 is located at the intersection of SR-210 and Alta Bypass Road.

These locations are presented in Figure 26.

Figure 26 – Image of the intersections being studied

11.4.1.2 EXISTING CONDITIONS

Currently, the design of the intersection is comprised of a stop sign at each of the three entries. The intersections are skewed upward, which creates conflicts for merging traffic to identify incoming traffic upon exiting the resort. During peak periods, four officers are utilized to direct traffic for automobiles exiting the ski resorts. This causes congestion for automobiles traveling uphill and downhill, as they have to stop and wait for the vehicles leaving the ski resorts. Entry 2 may be closed based on the traffic flow and redirected to the other entryways, creating congestion at those locations. Entry 2 and Entry 4 have steep grades at the intersection, whereas Entry 1 has a grade not as steep. Additionally, Entry 1 has a physical barrier on SR-210 that allows left turning, downhill traffic to leave Snowbird and later merge with SR-210 traffic.

11.4.1.3 DESIGN REQUIREMENTS

The focus for the intersections is to create an alternative design to the exiting intersection that allows traffic to enter and exit the above-mentioned intersections in a manner that will:

- Maximize the safety of drivers by reducing potential crashes between pedestrians and automobiles; and
- Improve traffic flow for both directions in the Canyon.

Redesign of the existing intersections – within similar footprints – will reduce the environmental impact; therefore, the design will take into consideration the current disturbed area to help minimize impacts. The box culvert tunnel is considered simple for vehicles to access, as it will be located near the entryway to the ski resorts. We believe this design will assist with safety and easier merging on the road for traffic traveling down the Canyon.

11.4.2 POTENTIAL LAND ACQUISITIONS

There may be potential land conflicts, but at this stage in the Study it has yet to be determined since additional research will be required. There is also the potential for ROW reconfiguration.

11.4.3 CONSTRAINTS

Maintenance

During the wintertime, snow and ice removal is a necessity within the tunnels to increase the safety of the drivers and year-round use of the intersection. It is important to choose a structure with dimensions that allows for snow removal trucks to pass through, ensuring roadways are kept safe and drivable throughout the worst of winter conditions.

Stakeholder Input

The GCC is supportive of the intersection reconfiguration when it was mentioned during the January 25, 2018 presentation. UDOT has expressed interest in the box culvert design during a prior meeting. In addition, several public comments have indicated the need for reconfiguration due to uncertainty when leaving the resorts and potential accidents with other drivers.

Environmental

The environmental impacts need to be minimized in the development of the intersections, but this project will observe impacts due to construction activities. For instance, ground disturbance from heavy equipment would impact the area surrounding the intersection. However, by redesigning the intersections as close to the existing footprint, environmental impact will be less than constructing a new intersection. As observed by the Alta Marshall, drivers have an increased reaction time due to the steep grades and obscure angles, therefore increasing vehicle emissions produced. With this alternative, emissions would be reduced from lowered congestion at each of the intersections.

11.4.4 COST ESTIMATE

The cost estimate for this alternative is based on developing the box culvert tunnel design with a 20-foot by 20-foot cross section. This design would include a 12-foot wide lane going down the center with shoulders 2-feet wide on each side. A lighting system will also be implemented to illuminate the tunnel at night.

Table 9 – Cost estimate of precast concrete sectional box culvert cost per intersection

Conceptual Major Items	Cost per intersection
Concrete Box Culvert, Install, Backfill	$1,024,000
Cast-in-place concrete retaining walls	$200,000
30% contingency	$367,200
Approximate Total Cost	**$1.6 million/intersection**

11.4.5 ALTERNATIVE EVALUATION AND PROPOSED BENEFITS

Fixing the intersection skews at Snowbird Ski Resort entries will be beneficial in terms of traffic efficiencies and safety. In addition, developing an underground structure will allow for drivers leaving the Resort to merge with traffic moving down the Canyon in a more efficient manner, thus allowing more traffic movement throughout the Canyon and a reduction in congestion. Safety will be improved with less traffic leaving the entryways and less accidents occurring.

This feature was pursued to improve both safety and traffic performance. The first priority of this project would be to increase safety such that drivers have an ease of access through the resort entryways. The next priority is to improve traffic efficiency such that more people can transport themselves in a timely manner and enjoy the Canyon scenery.

Based on the selection criteria, the safety and aesthetics were graded as high. The purpose of the intersection is to improve safety for traffic leaving the ski resorts and moving down the Canyon. The design for the box culvert is simple and can incorporate any natural design input from stakeholders or parties involved.

From the selection criteria, the team chose the environmental impact to be in the medium category. The material and construction of the box culvert tunnel will impact the areas of the entryways. Emissions will be released from the vehicles needed for the construction development, but regarding the long-life span of the tunnel and the low maintenance required throughout the year, the impact of developing the tunnel is low.

Under the selection criteria, the team decided to grade the cost estimate of this feature to be medium. With the development of the box culvert tunnels, it is expected to have a long-life cycle of usage from vehicles from the materials involved.

11.5 BIG CURVE REALIGNMENT

11.5.1 DESIGN DETAILS

As traffic travels down the Canyon from Snowbird's Entry 1, vehicles merge with others heading down the Canyon on SR-210. Merging the two lanes creates a pinch point as traffic enters the Big Curve, which decreases safety and increases traffic congestion, shown below in Figure 27. Reconfiguring the Big Curve will allow safer merging for those trying to exit the Canyon.

11.5.1.1 LOCATION

The Big Curve, located on SR-210 just west of Snowbird Entry 1 will be evaluated for potential realignment. An aerial view of the Big Curve is shown below in Figure 27, while its relation to Snowbird Entry 1 is depicted in Figure 28. As stated above, the proximity of the Big Curve to the merge point creates safety concerns.

Figure 27 – Aerial image of merge point

Figure 28 – Aerial image of location of Big Curve in relation to Snowbird Entry 1

11.5.1.2 EXISTING CONDITIONS

Currently, the Big Curve radius is large and creates a pinch point for traffic that is merging from Entry 1 at Snowbird to SR-210. The pinch point occurs when automobiles traveling down the Canyon merge into one lane. As merging happens, the automobiles will need to brake, which causes a ripple effect further up the Canyon and thus causes slower traffic. Traffic accidents occur throughout the curve and need to be mitigated. From UDOT's Vehicle Collision data, there have been a total of twenty-four vehicular accidents between Entry 1 and Entry 4 during the timeline of January 1, 2014, to January 31, 2018. These accidents contribute to congestion of vehicular traffic uphill and downhill depending on the severity of the crash.

11.5.1.3 DESIGN REQUIREMENTS

The goal of the alternative is to straighten the Curve alignment to allow for easier merging of downhill traffic. By straightening the Curve, traffic efficiencies will improve by allowing vehicles to merge in a safer manner and eliminate a pinch point. It should be noted that when the Big Curve is realigned, existing design speeds should be maintained.

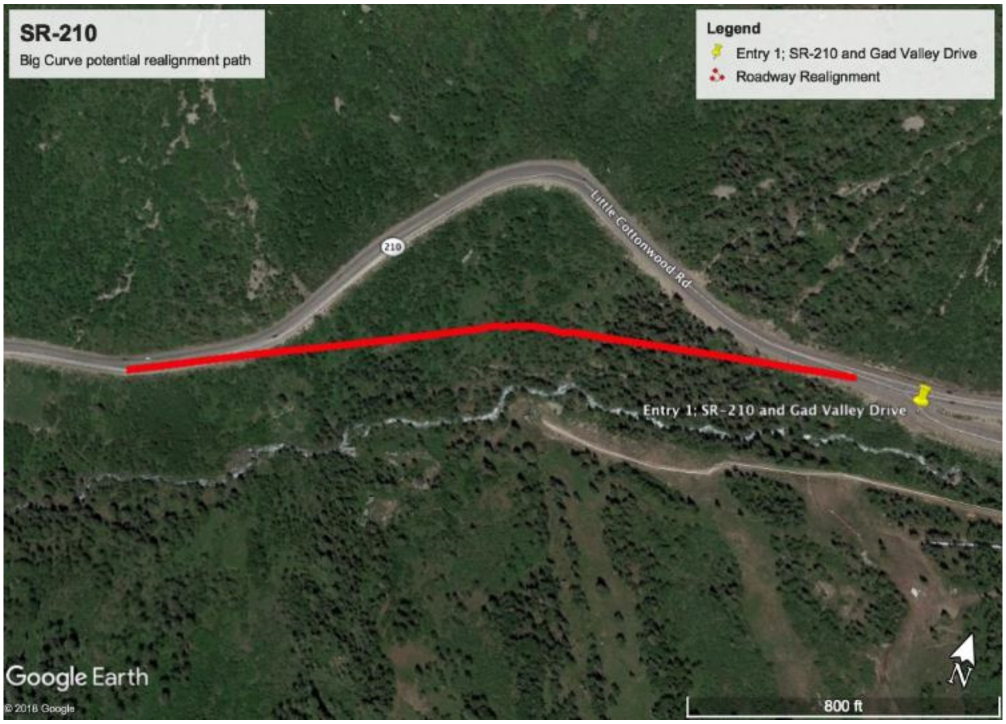

Figure 29 – Conceptual new alignment of curve

11.5.2 POTENTIAL LAND ACQUISITIONS

Land may have to be procured, but until preliminary design drawings have been completed, a decision cannot be made. Potential ROW acquisitions will need to be considered since the area of impact is not currently owned by UDOT.

11.5.3 CONSTRAINTS

Maintenance

The maintenance required for this re-alignment will focus on keeping debris, ice, snow, and other potential road hazards off the traveled way.

Stakeholder Input

When a representative from UDOT presented the project overview to the class, this was one of the big topics included with roadway configurations. Because this curve is a large safety hazard, it is a priority from the stakeholders.

Environmental

This could negatively impact the environment because the horizontal alignment will be pushed into the forest area, and fill will have to be transported into the Canyon for the roadway to remain at a constant vertical grade rather than changing at each of the new connection points. The new curve alignment would be designed in new horizontal, vertical alignment and sight distance under AASHTO Green Book Standard to make it safe and functional. Also, the existing creek should not be impacted by the realignment because it would cause impacts to aquatic life within the creek.

11.5.4 COST ESTIMATE

Table 10 – Cost estimate for Big Curve realignment.

Conceptual Major Items	Cost and Units	Total Cost
Hot Mixed Asphalt	$72.37 (for 4,800 tons)	$447,900
Base Course	$31.53 (for 2,800 yards)	$113,9000
Backfill	$30.00 (for 410,500 yards)	$16,008,000
Site Preparation (clearing and grubbing)	$3,810 (for 15 acres)	$74,300
Striping	$2.22 (for 8,700 linear feet)	$25,000
	Approximate Total Cost	**$16.7 million**

11.5.5 ALTERNATIVE EVALUATION AND PROPOSED BENEFITS

Realigning the curve will decrease down-Canyon congestion and improve safety by allowing traffic to merge more efficiently. Not only will drivers be able to commute out of the Canyon safer, but the town of Alta will also see less congestion during peak hours. By freeing up the roadway, it will also help move emergency vehicles through the Canyon if there is a need. This alternative of realigning the horizontal alignment of the Big Curve was pursued to improve the overall safety and traffic efficiencies of the roadway section.

The same criteria, as presented in Table 5, were used to evaluate this alternative. The cost will be very high to adjust the alignment and straighten out the curve. The volume of fills that must be brought in, along with the controlling cost of the feature are also expensive. Serviceability and safety will increase while environmental impacts and aesthetics will decrease.

12.0 SUMMARY OF ALTERNATIVES

Various methods have been developed to accomplish two main goals: roadway congestion and visitor safety. The proposed alternatives and features have been evaluated based on the rubric provided below which required that rankings be based on a low (1), medium (2), and high (3) criterion. Based on the values of our stakeholders, criteria were weighted according to their importance and ability to accomplish the performance goals of this study. A final count and ranking summary can be found in Table 11.

Table 11 – Selection criteria ranking of alternatives

Alternative/Feature →		Bike/Ped Path		Transportation Systems			Roadway Improvements			Ranking Guidelines		
Selection Criteria ↓	Weight of Criteria ↓	Sep. Path (Old Hwy)	Along SR-210	Auto-mated Veh. Ntwrk	Gon-dola	Inter-modal Hub	Resort Inter-section	Big Curve Realign-ment	Snow Sheds	HIGH = 3	MEDIUM = 2	LOW = 1
Cost Likelihood for life cycle costs (purchase, own, operate, maintain and dispose) are ***within budget*** and self sustaining	15%	M	M	M	L	M	M	M	H	Cost is within budget and life cycle costs are reasonable	Cost is near budget and life cycle costs sustainable	Cost is outside of budget and life cycle costs are unreasonable
		2	2	2	1	2	2	2	3			
Serviceability/Mobility Ability to ***meet the demands*** of the system both present and long term (50 years); Anticipated level of comfort and reliability	25%	H	M	M	H	H	H	M	H	Capable of meeting performance goals based; low level of complexity and enjoyable experience	Partially meets performance goals; ability to navigating system is somewhat complex	Feature cannot meet performance goals; high level of complexity and little reward for user's participation
		3	2	2	3	3	3	2	3			
Environmental Impact Likelihood for environmental impact to be ***minimized*** during construction and operation of feature or system	20%	M	M	H	M	H	H	M	H	Environmental impact is limited; little or no detrimental impact	Environmental impact cannot be mitigated; disturbance is considered to have low impact	Environmental impact cannot be mitigated; disturbance is highly detrimental to ecosystem
		2	2	3	2	3	3	2	3			
Safety Ability of the system or feature to ***increase safety*** for users, workers and bystanders	30%	H	M	H	H	M	H	H	H	Provides significant improvements to safety conditions	Maintains existing safety performance	Safety hazards increase for workers, users and bystanders
		3	2	3	3	2	3	3	3			
Aesthetics Potential for incorporation into the natural surroundings and nearby community	10%	H	L	H	L	M	M	H	M	Incorporates natural surroundings into design and does not adversely affect existing views	Limited incorporation of natural surrounding are provided and some existing views are impacted	Does not incorporate natural surrounding into the design and existing views are adversely affected
		3	1	3	1	2	2	3	2			
Overall Rating (out of 3)		**2.65**	**1.90**	**2.60**	**2.30**	**2.45**	**2.75**	**2.40**	**2.90**			

12.1.1 TRANSPORTATION SYSTEM

The three transportation systems were reviewed using traffic data acquired from UDOT and UTA resources while also including previous traffic reports completed by various studies performed within LCC. Due to limited traffic modeling and cost analysis, the proposed systems require further preliminary design to determine the feasibility of implementing the system.

12.1.1.1 3S GONDOLA

Based on our analysis and that of our constituents in the Central Wasatch Commission, we have determined that the construction of a gondola service to connect the Valley entrance to the resorts within LCC is a less desirable approach to mitigating the congestion. While the system has the potential to generate economic growth and serve as an additional attraction to the Canyon, the result of increased parking at the mouth of the Canyon would create additional congestion. Options have been suggested to move the base station further into the value, but land acquisition, aesthetics, impact on residential properties, and public opinion have been presented as likely conflicts.

12.1.1.2 MULTIMODAL HUB

The erection of a multimodal hub at 9400 South and Highland Dr. received positive feedback during the analysis process regarding its ability to support a growing population with diverse transportation needs as well as provide incentives and related information that encourages users to adjust current transportation patterns. The system supporting the multimodal hub and mass transit alternative does have uncertainties that present potential negatives to the approach: the structural design must incorporate a multi-use functionality within the building that incorporates pedestrian and social gathering activities as well as streamlined transportation. Some of the areas of concern are as follows: the surrounding roads and signaling would require minor adjustments to accommodate a change in demand pertaining to merging or turning lanes; multi-purpose planning would be required in order to generate sustainable revenue and reduce operating costs; and communication networks would require efficient response times between the system and users to ensure the reliability of the system.

Despite the complexity of the interworking within a multimodal hub, we believe this approach could accommodate a changing community with the incorporation of new technologies as well as enhancing the current public transit options.

12.1.1.3 INTELLIGENT TRANSPORTATION SYSTEM

An ITS with an automated vehicle network was evaluated based on theoretical analysis with a background in applying current models of automation into existing vehicles via renovations. We found that a variety of ITS have been developed but few have been integrated into society, which creates advantages and disadvantages for determining the practicality of implementing an ITS system within the Canyon Network. Ideally, we anticipated the advantages of a system that creates minimal environmental impact and maximizes roadway efficiencies by providing transit to the highest number of people in the least amount of space. Therefore, the system would have received the highest marks for its ability to meet the demands of the system, serviceability, and mobility, except for limited availability of the ITS within current time periods.

12.1.2 ROADWAY IMPROVEMENTS

12.1.2.1 AVALANCHE MITIGATION

The snow sheds and snow barriers were evaluated separately to determine the advantages of each independently. Snow barrier could act as directional devices that control the path of the avalanche. While both methods have the goal of reducing or eliminating the use of live ammunition avalanche control, we understand that avalanche control is an integrated process within the Canyon and a unified system would maximize effects anticipated from the implementation of snow shed or snow barrier structures.

The cost analysis for both options varied depending on the placement of the structures. We believe that by analyzing areas of high priority chutes in combination with the current terrain, an affordable plan is possible that incorporates snow shed structures on the road and barriers that direct avalanches to those areas. Concerns for the aesthetics and operational issues concerning ice and snow build-up near the entrances and exit points of the snow shed would require design consideration, but we believe they can be remedied with design features to create a safe and environmentally friendly atmosphere.

Both features were evaluated under serviceability and mobility for their ability to mitigate the effects of an avalanche and maintain accessible roadways. Snow sheds are expected to have a greater ability to withstand a larger mass avalanche slide, due to their ability to redirect the flow verses the barrier and trench, which function as a catch basin and slight redirection of flow.

The serviceability and mobility criteria also account for the feature’s ability to reduce road closures due to avalanche control. We also note that the process of snow removal greatly affects the time needed during road closures, and we anticipate that sections of the road covered by a snow shed would allow for less time required for plowing. By reducing the time required for the avalanche road closures, the congestion within the Valley will see significant improvements.

12.1.2.2 EGRESS AND INGRESS AT RESORTS

Our analysis found that the proposed changes to the resort exits proved to be a cost-effective way for increasing safety and reducing congestion while maintaining limited environmental impact. Therefore, the reconfiguration of select resort exits received a high overall score with our evaluation process. Further analysis is required to determine the amount of land required to keep interchanges at acceptable grades for speed and weather conditions.

12.1.2.3 BIG CURVE REALIGNMENT

Due to frequent congestion issues along the downhill transportation line of the Canyon due to speed, merging, and curve alignments, improvements to the curve are anticipated to have high returns regarding increased safety and serviceability of the feature. The cost and environmental impact were less clear due to a need for further investigation into alternatives for roadway widening verse roadway reduction, which eliminates the overlap of the merging section with the sharp turning points that were not explored at this point. Overall, adjustments to the curve would directly achieve the key performance goals of this study.

12.1.3 BIKE AND PEDESTRIAN PATH

The two alignments for a safer bike and pedestrian path were evaluated side-by-side to determine the more desirable option. While some areas of the SR-210 provide adequate space for expansion, various factors were presented that deemed this a less sustainable option for future demands and lasting safety. Along the roadway, deterring issues such as illegal parking, future developments on roadway, and areas that required substantial land acquisition were among the deciding factors. The alternate route along the Old Quarry Road received positive feedback in most areas except for environmental concerns that addressed the effects of construction near the existing creek bed. Supporting comments were received in the areas of increased safety, increased economic growth due to providing an ADA compliant path, and low anticipated costs compared to the benefits of the additional safety it creates.

13.0 RECOMMENDATIONS

Based on the evaluations presented herein, we recommend the following concepts be further developed and priced in the preliminary engineering report prepared by SEA.

1. We recommend an intelligent transportation system (ITS) be developed that includes an autonomous vehicle network (AVN). We believe that such a system can be developed without the need of significantly widening or increasing the roadway footprint within the Canyon. We do not recommend significant widening of the Canyon roadway to support a dedicated high occupancy vehicle (HOV) lane. We believe such a lane is largely unnecessary, has the potential to degrade the Canyon's ecosystem, and is expensive (approximately $80 to $120 million) based on similar projects in mountainous terrain.

2. We recommend multimodal hubs be established to support the ITS and AVN. These can become a focal point of transit and allow for more disseminated out-of-canyon parking. We recommend that the first hub be established at 9400 South and Highland Drive. We do not recommend a Gondola System for implementation at this time. This system has cost and operational issues that make it challenging to implement. While the system has the potential to generate economic growth and serve as an additional attraction to the Canyon, the result of increased parking at the mouth of the Canyon would create congestion. Also, it is not known if system revenue will pay for the initial capital cost and future operational costs.

3. We believe that several roadway improvements are necessary to improve safety and traffic operations in the Canyon. These include:
   - Snow sheds;
   - Improvements to ingress/egress at the resort parking lots;
   - Minor alignment changes and widening to improve sight distance, merging, and passing; and
   - Shoulder improvements to improve cyclist safety.
4. We recommend a dedicated bike/pedestrian path be established within the lower limits of the Canyon. We recommend part of this trail be paved for ADA access. Such a path might be incorporated with a new visitor center constructed near the mouth of the Canyon.

We envision that the successful implementation of these recommended systems and safety features will allow Little Cottonwood Canyon to continue to provide a natural and inviting destination for people with diverse interests and hobbies to safely experience Utah's Wasatch Mountains. We believe this can be accomplished by protecting the Canyon's sensitive ecosystem and by minimizing the footprint of future transportation systems operating within the Canyon boundaries.

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APPENDIX A – GRANITE COMMUNITY SURVEY ON MOUNTAIN ACCORD TRANSPORTATION ISSUES

Granite Community Survey
On Mountain Accord Transportation Issues

1. What issues related to transportation in Granite and Little Cottonwood Canyon concern you the most? Please list/describe them in your order of importance from most to least:

Answers (4/29/14):

Dimple Dell Road! We are expecting our first baby and live right on that road. We need speed bumps or other methods of reducing speed as we have no sidewalks, curbs or gutters that run continuously along the road. It's a major safety issue!

More traffic/speeding on side streets Congestion up/down canyon

Environmental impacts, including air quality, of existing vehicular traffic and future increases. Need for incentives to increase carpooling & bus usage. Need to reduce/eliminate shoulder parking to improve bicycle safety. Need to improve bus transit time and bus service. Need to increase parking for hikers where feasible.

Traffic control of automobiles & parking, preservation of canyon environment

The ability to get up-canyon easily & swiftly on stormy winter days, by public transportation. Wildlife deaths due to vehicles. The large amount of car traffic going through the neighborhood in both directions during winter.

Heavy traffic on weekends and big powder days, especially in the morning after the parking lots are full forcing people to drive cars and after 4:00 with everyone leaving at once. I've experienced 2 hour drive times from Alta to the canyon mouth. Clearly there isn't enough park and ride parking. I feel it would be detrimental to the canyon environment to construct a TRAX rail or aerial tram.

We are concerned about the harmful effects of implementing Trax up the canyon and don't believe this is a good idea. We support an improved shuttle system, tolls for private vehicles, penalties for 1 person occupants in autos, etc. Trax would be unattractive, and potentially harmful to wildlife and the environment. Also detrimental to the property values of the homes who would border the Trax line. Feel it will bring graffitti and crime to a beautiful area. We also feel increasing people visiting the canyons is detrimental to the environment. They are already at capacity.

Congestion Environmental impact Fire Safety

Through road proposed for Carriagehouse Lane (linking Little Cottonwood to 9800)

Pollution- sound, light, air, and water Change in the natural character of the mouth of the canyon Traffic and safety of LCC Rd.

I do not want to see TRAX up to or into the canyon! I want to see access imited similar to what they do in Zion!

- traffic during ski season - speeding up little cottonwood road - loud (motorcycles) driving up little cottonwood road

Not being able to get home or have the school bus pick up kids because traffic is backed up when the canyon is closed. It has been significantly better the past few years with the road being closed at wasatch but was a big problem before.

the number of actual vehicles as this directly translates to a negative environmental impact upon the canyon.

Buses will not be a viable alternative until they start running from the Little Cottonwood Park and Ride by 7:30am or shortly thereafter so that one can arrive early enough for first tram. Second, for buses to be a viable alternative, they must run continuously throughout the ski day with no longer than 20 minute intervals between buses.

1. Intersection of Wasatch and Little Cottonwood Roads.

Access to lift-served skiing areas. Access to back-country skiing and hiking through the Canyon Pollution and other environmental impacts to the Canyon

Speeding cars on Dimple Dell Road

1. Too many cars and not enough carpooling and bus use. 2. Adequate and safe parking at trails and points of interest. 3. Noise Pollution (motorcycles) 4. Safety for Bikes

I would like to see mass transit of either a rail or aerial tram

Traffic on snow days that hinders the granite residents from getting to and from their homes

Make transportation out of gravel pit at the mouth of Big Cottonwood

Restricting transportation will severely harm the tourist business. Utah should impose better restrictions in car exhausts like California. Helps much more than asking people to restrict driving.

Continue to protect the environment, and preserve the natural setting of the Wasatch Mountains.

The idea of a train up the canyon Increased traffic Environmental impact on the canyon

1. Eliminate all private vehicles except service vehicles and property owner vehicles. 2. Charge canyon visiting fees for all but property owners and resort employees. 3. Develop bigger park and ride lots at points along the main routes of travel in the flatter portions of the Salt Lake Valley that will be points of embarkation for busses that will be the only personal transportation into the canyon. 4. Make safety improvements to the road up LCC in its exact footprint. 5. Avalanches are a natural condition that must be lived with. Busses can be more easily controlled

than the thousands of cars in the winter. 6. Provide bus stops at major sightseeing, hiking trailheads, picnic and camping sites and at the resorts. 7. Provide local shuttle services in, between and around the two ski resorts as well as to Albion Basin.

Limit canyon traffic

Air quality, congestion

2. What are your priorities for Little Cottonwood Canyon? For example, how important are:

–	Most Important –	Important –	Least Important –	Total –
– Increasing recreational canyon use (skiing, other)?	13.89% 5	22.22% 8	63.89% 23	36
– Limiting canyon recreational use to current levels or modest increases?	55.26% 21	23.68% 9	21.05% 8	38
– Allowing canyon traffic to increase?	10.81% 4	8.11% 3	81.08% 30	37
– Making efforts to decrease canyon traffic?	52.63% 20	28.95% 11	18.42% 7	38
– Other:	66.67% 4	16.67% 1	16.67% 1	6

3. Please rank what is most important to you, from 1 to 4 (1 is most important):

–	1 –	2 –	3 –	4 –	Total –	Average Ranking –
– Growing the economic value of the canyon	7.69% 3	15.38% 6	10.26% 4	66.67% 26	39	1.64
– Protecting the canyon environment	76.92% 30	12.82% 5	5.13% 2	5.13% 2	39	3.62
– Improving transportation in the canyon	15.38% 6	48.72% 19	35.90% 14	0.00% 0	39	2.79
– Improving recreational uses of the canyon	0.00% 0	23.08% 9	48.72% 19	28.21% 11	39	1.95

4. *Parking and personal vehicle uses*: Please rate the following possible solutions to parking & transit problems in Granite and Little Cottonwood Canyon:

–	Desirable –	No Opinion –	Undesirable –	Total –
– Expand existing parking lot: Orgill Trailhead (east of Wasatch)	54.05% 20	18.92% 7	27.03% 10	37
– Expand existing parking lot: Park & Ride lot at mouth of canyon	65.79% 25	7.89% 3	26.32% 10	38
– Establish new parking lot: Geologic View Park	42.11% 16	18.42% 7	39.47% 15	38
– Establish new parking lot: Grit Mill	37.84% 14	40.54% 15	21.62% 8	37
– Establish safe shoulder parking: East of Orgill Trailhead Pkg Lot	31.58% 12	31.58% 12	36.84% 14	38
– Establish safe shoulder parking: East/west of Grit Mill	28.95% 11	34.21% 13	36.84% 14	38
– Enforce no parking on road	68.42% 26	18.42% 7	13.16% 5	38
– Parking fees for high use areas	46.15% 18	30.77% 12	23.08% 9	39
– Install pull-outs for sightseeing	52.63% 20	23.68% 9	23.68% 9	38
– Improve parking at ski resorts	53.85% 21	28.21% 11	17.95% 7	39
– Increase carpooling incentives for canyon employees	89.47% 34	5.26% 2	5.26% 2	38
– Increase carpooling incentives for canyon recreationists/visitors	82.05% 32	10.26% 4	7.69% 3	39
– Provide more park and ride lots for canyon employees/visitors	84.62% 33	10.26% 4	5.13% 2	
Other:	66.67% 4	16.67% 1	16.67% 1	

5. Please rate the following transportation suggestions:

–	Desirable –	No Opinion –	Undesirable –	Total –
– Expand bus service in Little Cottonwood Canyon	84.62% 33	7.69% 3	7.69% 3	39
– Provide bus rapid transit (BRT) up Little Cottonwood Canyon	73.68% 28	15.79% 6	10.53% 4	38
– Implement shuttle service from Park & Ride lots	82.05% 32	15.38% 6	2.56% 1	3

6. Please rate the following possible alternatives:

–	Desirable –	No Opinion –	Undesirable –	Total –
– Implement TRAX line from new transit hub near mouth of Big Cottonwood Canyon along Wasatch to mouth of Little Cottonwood Canyon.	30.77% 12	12.82% 5	56.41% 22	39
– Implement TRAX line from Sandy to mouth of Little Cottonwood Canyon	30.77% 12	7.69% 3	61.54% 24	39
– Implement rail up Little Cottonwood Canyon	23.08% 9	7.69% 3	69.23% 27	39
– Implement aerial tram up Little Cottonwood Canyon	34.21% 13	13.16% 5	52.63% 20	38

To send survey to others, have them click on this link:
https://www.surveymonkey.com/s/9DZCVW6

APPENDIX B – LITTLE COTTONWOOD CANYON STUDY PRESENTATION, JANUARY 25, 2018

Little Cottonwood Canyon Study
by Student Engineering Associates (SEA)

January 25, 2018

Agenda

1. Identify the Issue
2. Conceptual Solutions
3. Features or Technologies
4. Feedback

Identifying the Issues

Congestion

- **Road Closures & Residential Life**

Gridlock neighborhoods on Wasatch, Alta & others

- **Trailhead & Valley Parking**

Capacity issue, illegal roadside

- **Roadways: Curves, Merging, Intersections**

Blind spots, bus crossings and right-a-way

- **Hitchhiking & Recurring Delays**

Safety

- **Avalanche Mitigation & Threat**

Shot technique & 100% shut down of Alta
“No Stopping-Avalanche Threat” signs ignored

- **High Traffic with Bikers and Joggers**

Unprotected lanes and sharp curves

- **Single Access Point In & Out**

Residents, user and emergency vehicles

Awareness

- Full parking,
- Snow conditions
- Biker/jogger on bind turn
- Safe & environmentally conscious recreation

Underlying Principles

1. Promote **economic** growth while maintaining the **integrity** of canyon’s landscape.

2. Incorporate modern **technologies** that enhance the **efficiency** and experience within the canyon.

3. Provide **conservation** and historical **education** for the visitors and local community.

Re-thinking Little Cottonwood Canyon with **Conceptual System** Planning/Design

- Imagining the possibilities
- Planning for the future
- Designing a Sustainable and Environmentally Conscious System

Gondolas

Rail

Gondola

- Connecting city with the mountains
- Eliminating transport issues
- Environmental footprint

Identifying challenges

- Capital investment
- Base station area
- Residents dependent on road

The towers of the Emirates Air Line cable car, from the north bank of the River Thames.

Image credit: Nick Cooper // CC BY-SA 3.0 Source: https://howwegettonext.com/cable-cars-are-changing-the-world-61f2b803c129

Gondola

Gondola designs in Per Bergström Jonsson's office.

Image credit: Duncas Geere

Railways

Funicular/Light/Cog rail options

- Environmental
- Tourist attraction
- Safe!

Source: valldenuria.cat

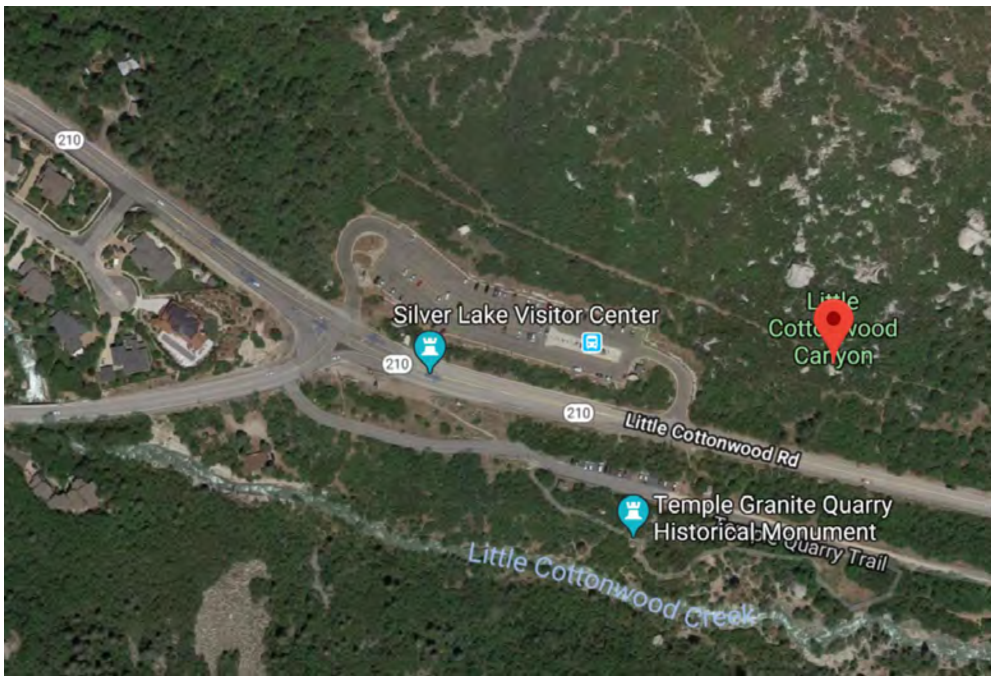
Features or Technologies for the System

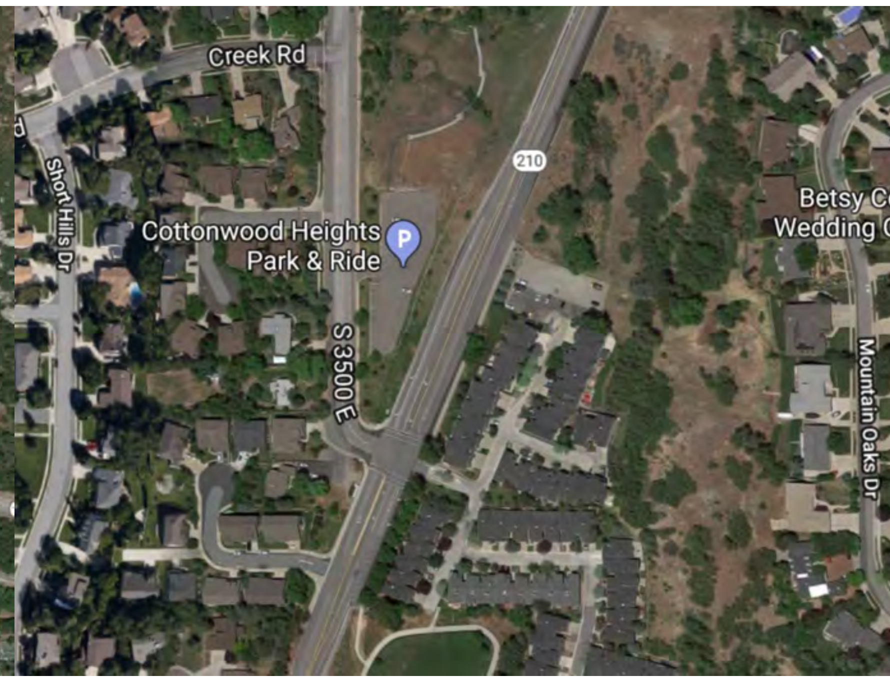
1. Intersections
2. Parking Structures
    a. "Y" or mouth of the canyon
    b. Swamp Lot
3. Roadway Widening and Intersection Configuration
    a. Hard to do only portions without creating a bottleneck
4. Snow Sheds
5. Bike Paths
    a. Traditional
    b. Protected
    c. Cantilevered
6. Pedestrian
    a. Tracking System
7. Trailheads
8. Heated Pavements
    a. a look at Holland's snowmelt system

Intersection and Lane Configuration

Parking Structures and Visitors' Center

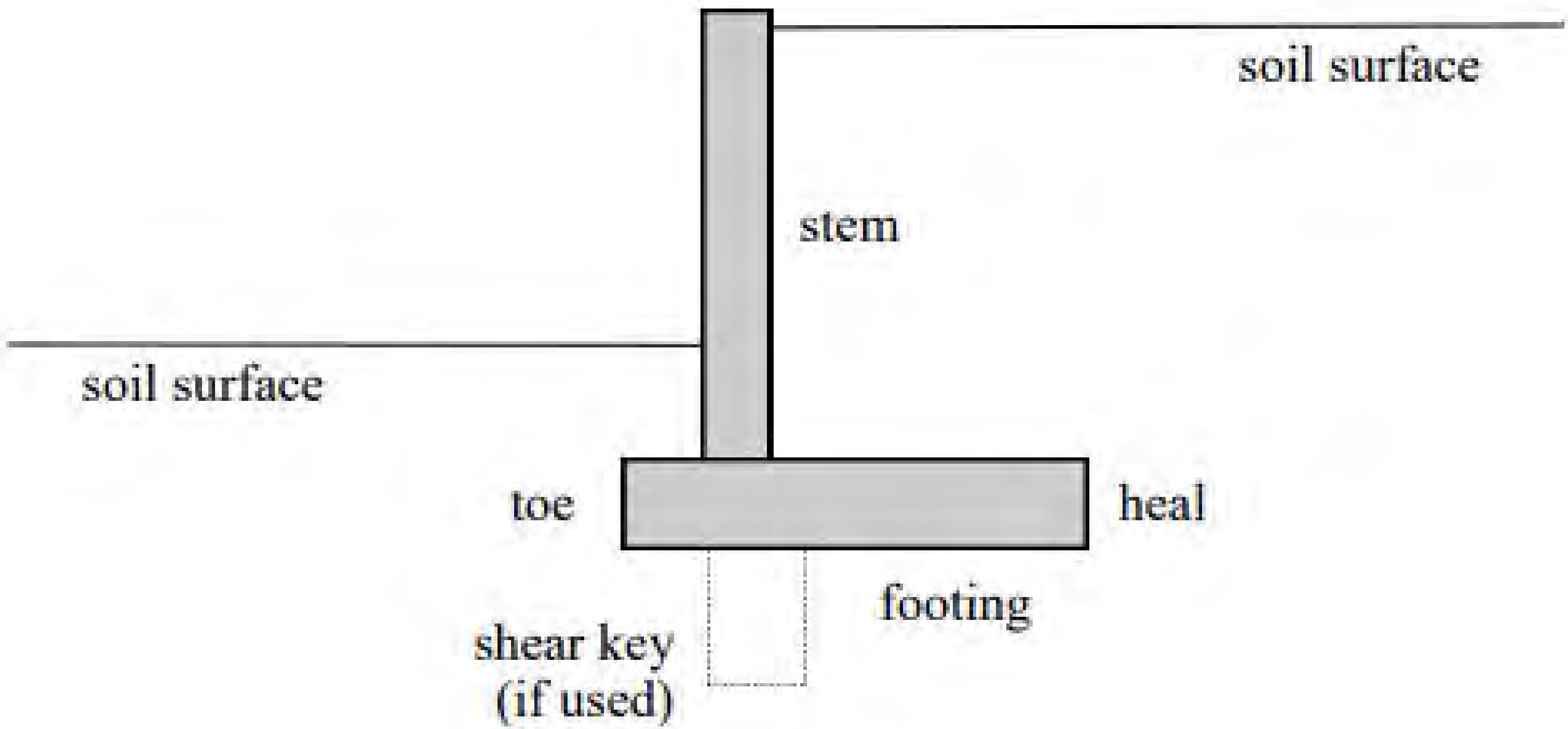
- "Y"-Intersection
- "Swamp-lot" on 35th E





Roadway Widening

- Retaining walls and fill as an alternative to blasting.

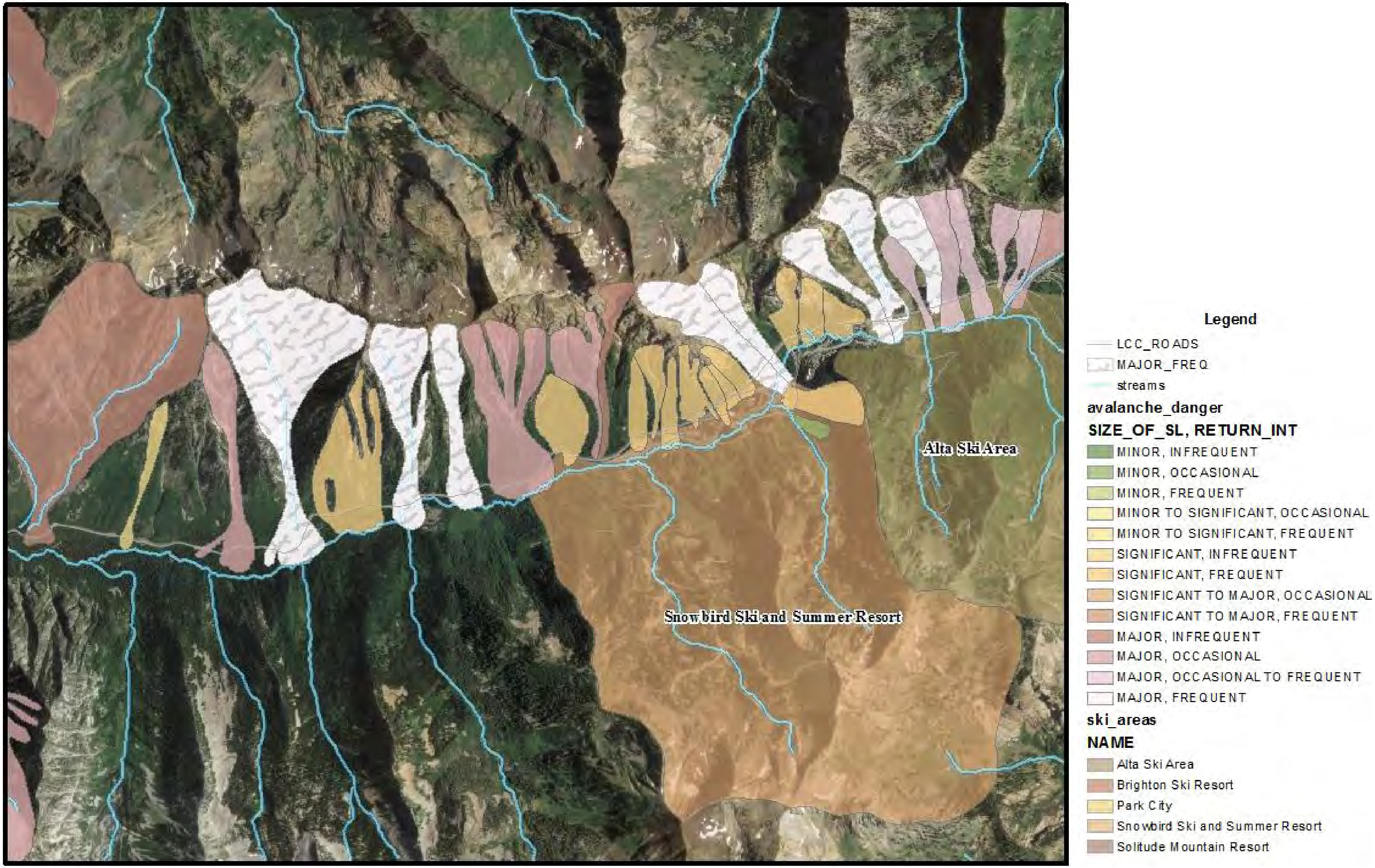


Challenges

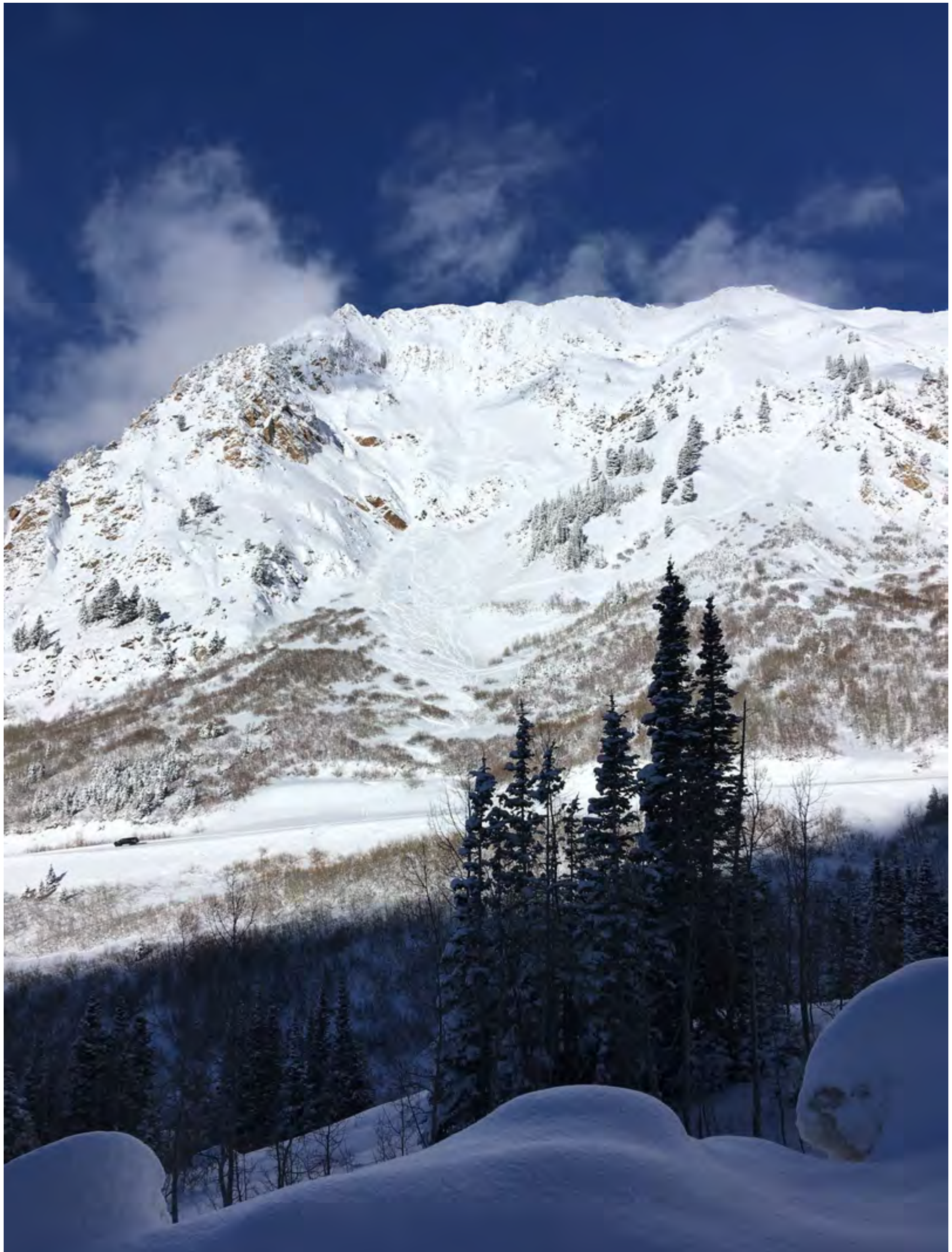
- Steep slopes

Avalanche Mitigation

snow sheds



Alta Ski Area
Snowbird Ski and Summer Resort
Legend
LCC_ROADS
MAJOR_FREQ
streams
avalanche_danger
SIZE_OF_SL, RETURN_INT
MINOR, INFREQUENT
MINOR, OCCASIONAL
MINOR, FREQUENT
MINOR TO SIGNIFICANT, OCCASIONAL
MINOR TO SIGNIFICANT, FREQUENT
SIGNIFICANT, INFREQUENT
SIGNIFICANT, FREQUENT
SIGNIFICANT TO MAJOR, OCCASIONAL
SIGNIFICANT TO MAJOR, FREQUENT
MAJOR, INFREQUENT
MAJOR, OCCASIONAL
MAJOR, OCCASIONAL TO FREQUENT
MAJOR, FREQUENT
ski_areas
NAME
Alta Ski Area
Brighton Ski Resort
Park City
Snowbird Ski and Summer Resort
Solitude Mountain Resort



Avalanche Mitigation type	Av.	Rock fall	Debris slide	Debris flow
Avoidance				
Minor changes	green	yellow	green	yellow
Removal				
Typically N/A	green	red	red	yellow
Stabilization				
SZ Support	green	green	yellow	green
Gas exploder	green	red	yellow	yellow
Hand charges	green	red	yellow	yellow
Launcher	green	red	yellow	yellow
Artillery	green	red	yellow	yellow
Protection				
Shed/gallery	green	yellow	green	green
Bench/catchment	green	green	green	green
Berm	green	green	green	green
Wall	green	yellow	green	yellow
Splitter	green	green	green	yellow
Mounds	green	green	green	yellow
Nets	green	yellow	green	yellow

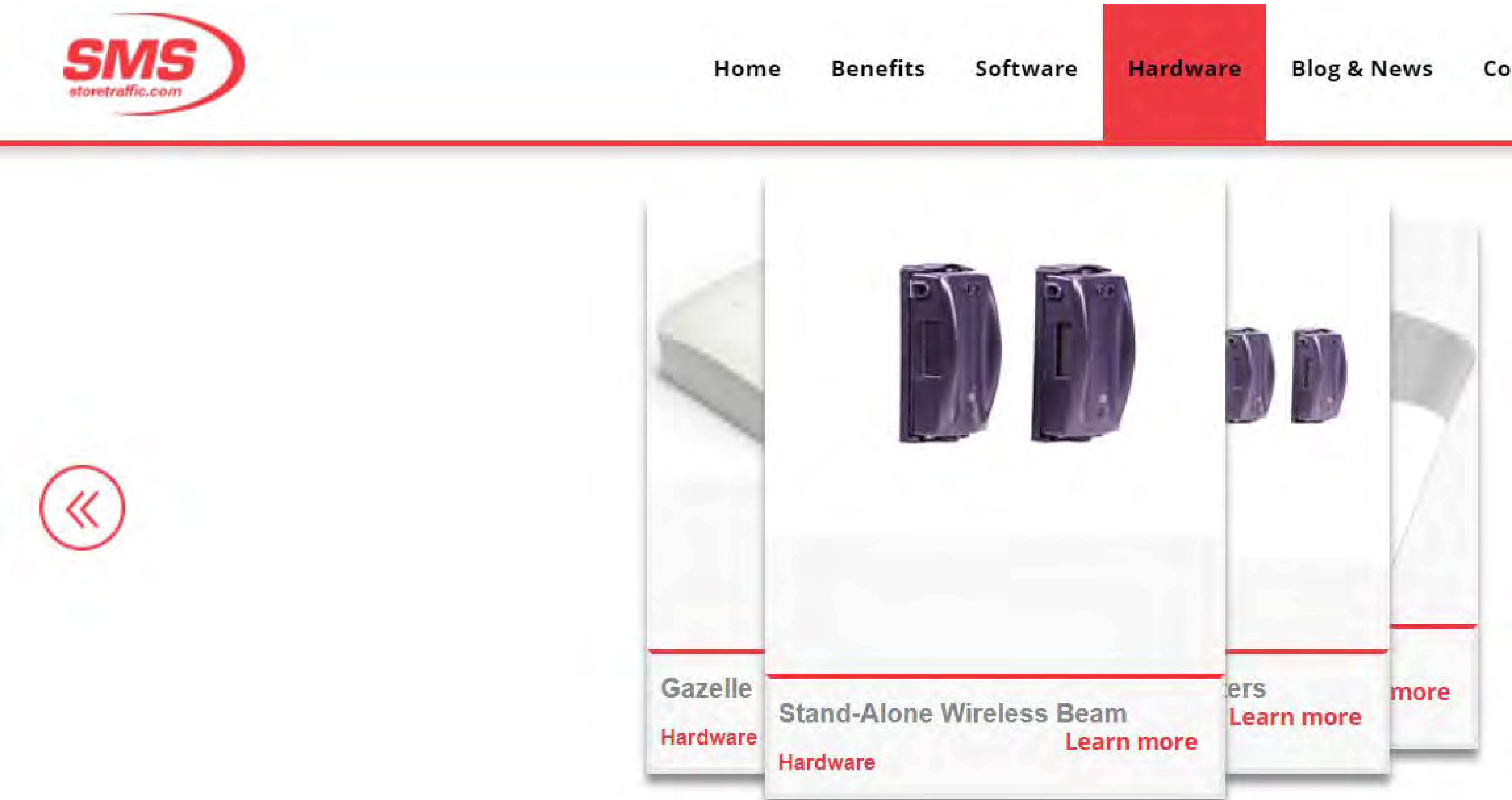
Fig. 4: Comparison of mutually beneficial (green), deleterious (red), and neutral (yellow) avalanche mitigation measures, relative to rock fall, debris slide, and debris flow.

Traditional Bike Path

Protected Bike Path

Cantilevered Bike Path

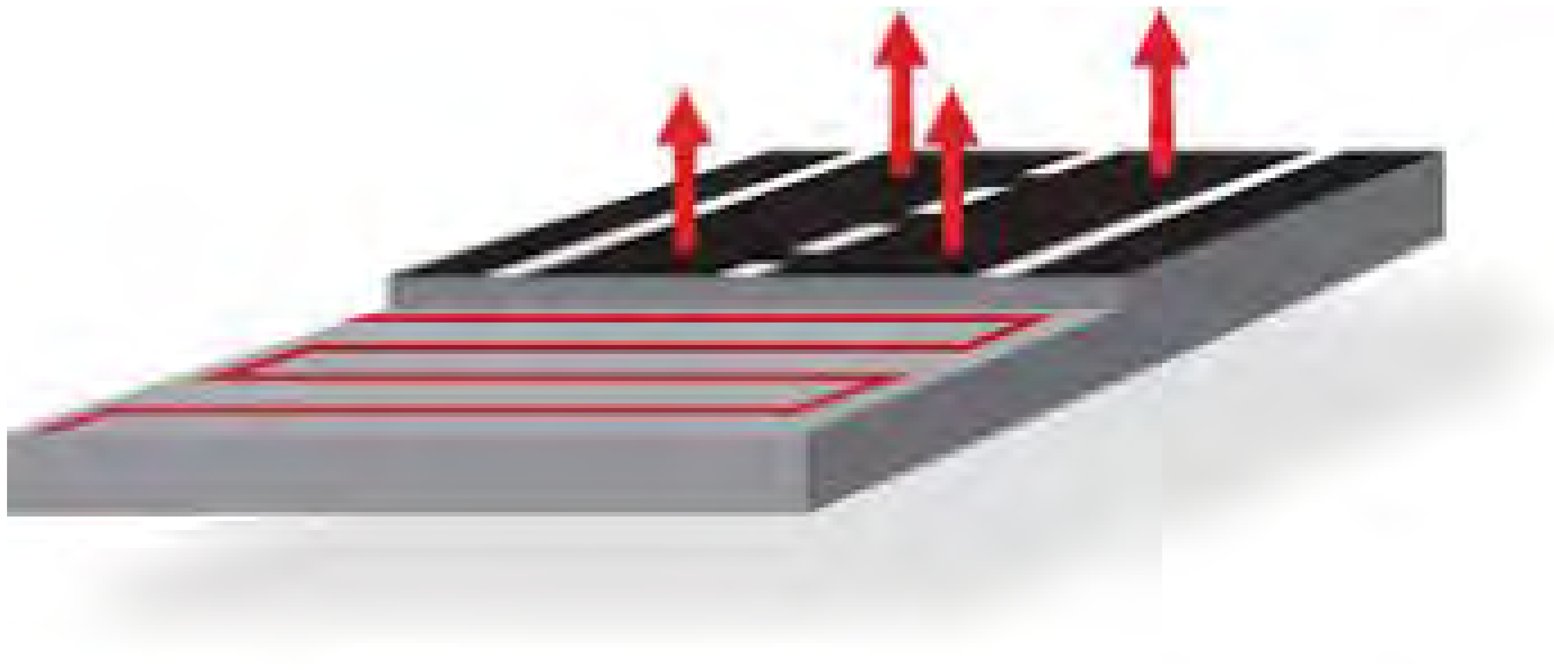
Pedestrian Tracking System



Trailheads

Scan This...
Use your smart phone's QR reader to access trail information before you begin your hike.
Get This...
- trail map saved to your phone
- Up to date trail description
- Tips for a safe hike

Snow Removal



Snowmelt System

No salt, sand or de-icer needed ■ No plowing ■ No slipping or sliding ■ No snow tracked into stores
Extended pavement life ■ Increased winter activities in downtown ■ Sidewalks aren't prone to frost heave

Source: https://www.cityofholland.com/streets/snowmelt

Snowmelt System

Source: http://www.holland.org/snow-free-holland

Snowmelt System

16 **Snowbird Ski and Summer Resort** Snowbird, UT

OVERVIEW: Snowbird Ski and Summer Resort sprawls across 2,500 acres in Snowbird, Utah. In 1987, the growing resort became too large for the utility's 25-kilovolt (kV) power line that runs up the mountain. Instead of paying for a line upgrade, the company decided to turn to on-site power generation and installed a 2-MW CHP system at a cost of $3.5 million. An additional $2.2 million was required to build a natural gas pipeline to the facility. With an overall efficiency of 75 percent, the CHP results in energy savings of $815,000 per year and ensures a reliable source of power for the facility. In the winter, heat from the CHP system is used for space and pool heating and melting snow on walkways. In the summer, some of the heat is still used for space and pool heating, but the rest runs a Carrier absorption chiller for the lodge's air conditioning.

SECTOR: Hotels, resorts

OPERATION START: 1987

TECHNOLOGY: Reciprocating engine

FUEL: Natural gas

MANUFACTURERS: Caterpillar, Carrier

CAPACITY: 2 MW

INSTALLED COST: $5.7 million

OVERALL EFFICIENCY: 75%

ENERGY SAVINGS: $815,000/year

REPORTED PAYBACK: 7 years

OTHER BENEFITS:
- Reliability

Source: U.S. Department of Energy, Intermountain Clean Energy Application Center, *Snowbird Ski and Summer Resort*, Project Profile, 2011, available at http://www.intermountaincleanenergy.org/profiles/Snowbird-Project_Profile.pdf.

Source: https://www.nrdc.org/sites/default/files/combined-heat-power-IP.pdf

Snowmelt System

imagine your bike path,
with heated pavement in the winter,
as you ride up Little Cottonwood Canyon...

….free of snow, ice, and slush

Source: https://parkcitypeople.com/mountain-biking-la-sal-mountains-the-whole-enchilada-trail/


Questions

APPENDIX C – OTHER FEATURES

AVALANCHE MITIGATION

Braking Mounds

Avalanche protection dams are another type of avalanche mitigation structure that could possibly be used within Little Cottonwood Canyon. These dams include deflecting dams that may be used to deflect the avalanche flow, or braking mounds used to retard the kinetic energy of the avalanche thus reducing its speed. There is also an excavation area for the avalanche debris to collect. Finally, these dams would include a catching dam that would collect all of the deflected avalanche debris protecting the roadway and vehicles. Figure 1. is an example of an avalanche protection dam.

Figure 1. Two braking mounds and a catching dam at the bottom of the slope to protect Neskaupsstaður, Iceland.

These mounds could possibly be placed on the Superior Chute as the slope is not within Twin Peaks Wilderness Area to protect SR-210 and Snowbird. The advantages of this system are that mounds and a dam could be made of natural loose deposits in the area, which would cut the costs of construction and from SR-210, these mounds could appear apart of the natural landscape, therefore making them aesthetically pleasing. The disadvantages of this system are the environmental impacts of excavating or repurposing the deposits for the mounds and in the event of an avalanche the mounds and the dam could reach capacity. A second avalanche could then pass over the catching dam.

Additional information on braking devices used to control avalanches has been presented in Avalanche Control, Volume 5 of the Food and Agriculture Organization of the United Nation's Conservation Guide. Of interest are Chapters V (Structures for Deviating, Breaking, and Containing Avalanches) and VI (Structures for Stabilizing Snow in the Avalanche Starting Zone). The website to the document is (last accessed March 6, 2018):
http://www.fao.org/docrep/006/AD075E/AD075e00.htm#cont

Snow Barrier

Design Details

Snow barriers are designed to stop snow from hitting the road by using both a trench and a barrier to stop the snow. The trench must be periodically cleared of debris from the avalanches.

Location

Probable locations include avalanche chute/no stop avalanche roadway sections including the following chutes: Superior, East Hellgate, #10 Springs Face, and White Pine Chutes. Snow barriers may also supplement areas where snow sheds have not been constructed.

Existing Conditions

See Existing Conditions for Snow Shed analysis.

Performance Goals and Design Requirements

Large and strong enough to withstand typical avalanches. See Figure 2 for China wall/berm located at White Pine.

Figure 2 – China Wall and snow berm at White Pine

Potential Land Acquisitions

While construction could not extend into the Twin Peaks or Lone Peak Wilderness areas, extending the easement between UDOT roadway and Forest Service land would be necessary in order to provide sufficient trench space. Figure 3 shows the Twin Peaks Wilderness area and Lone Peak Wilderness area in relation to the SR-210 roadway.

Figure 3 – Twin Peak Wilderness and Lone Peak Wilderness areas outlines in red.

Constraints

Maintenance

Avalanche debris would require removal as it builds up behind the snow barrier. This would require equipment, monitoring and personnel.

Stakeholder Input

Snow barriers may provide a cheaper alternative for locations where snow sheds would be less desirable due to cost, environmental impact or terrain constraints. Barriers could also work in unison with a snow shed structure and further investigation would be needed in order to determine commonly effected areas of impact (i.e. parking and pedestrian areas).

Environmental

Land alterations would require the consideration of effects to the watershed and natural habitat.

Cost Estimate

Cost varies due to constraints for construction within canyon boundaries. We do not expect an unreasonable price for construction but further preliminary design to determine the size of trench and wall is required in order to provide an estimated cost analysis.

Alternative Evaluation and Proposed Benefits

The proposed benefits of avalanche berms would be the reduction in avalanche debris reaching the roadway. The avalanche berm would collect the debris within the excavated area and the wall would ensure that none of the avalanche debris reached the roadway. This would reduce the time of closure and the amount of congestion outside of the canyon because the canyon as there would be less snow on the roadway for plows.

The selection criteria for avalanche berms were cost, serviceability, environmental impact, safety, and aesthetics with ranking from high, ideal conditions, to low, least ideal conditions. In the limited examination of snow barriers, we found cost to rank high, ideal, in comparison to its alternative, snow sheds. Serviceability and safety were rated as medium because in an event where a trench is at capacity and an avalanche should breach the wall, the roadway and users would be at risk. We anticipate the design reduce the risk of overflow within a reasonable factor of safety. Environmental impact was rated as low due to excavation required for the berm and trench which would require alteration of forest service land. Aesthetics were rated as medium because they could be made to look natural with natural shrubbery, trees and a sculpting of the wall's façade.

PARKING

Swamp Lot (3500 East and Wasatch Blvd.)

Common Elements / Design Consideration

Congestion up the canyon is problematic and extends all the way to I-215 via SR-210 and on SR-209 (unknown length) in peak hours during ski season. A primary goal of the design is to reduce congestion and promote flow of traffic in all directions on those roads.

Summary

According to representatives from the Granite Community Council (GCC), congestion up LCC during peak hours stretches along SR-210 all the way back to I-215, and requires traffic going up BCC from Fort Union Boulevard to cross LCC congested traffic. The existing Park & Rides (P&R) along SR-210 have limited capacity (approx. 60-70 stalls each), and reach their maximum on relatively low-demand days, having a minimal impact on the congestion problem. A potential parking structure in either location could relieve traffic and provide more flexibility as well as a convenient transition from personal vehicles to the UTA Ski Bus or future transit alternatives.

Overview and Site Map

Design Details

Location

The alternative location is on the North side of the intersection between South 3500 East and Wasatch Boulevard (SR-210). There is an existing Park and Ride (P&R) in the location with an adjacent wetland lot functioning as a green space for residents in surrounding areas. In Figure 4 below the lot is shown in the north direction, the snow in the background covers the preserved wetland and is located next to residences as shown and on the other side of the road (left). Wasatch Boulevard, seen on the right, connects Interstate-215 ('Belt Route') with the mouths of BCC and LCC and becomes frequently congested. The existing parking covers 0.46 acres (1,900m^2), while the total area confined by the roads and residences is 3.18 acres (12,900m^2). On the east side of Wasatch Boulevard there is an undeveloped area at the foot of the slope, potentially available to use for additional parking and bus transit stop.

Figure 4 – Image taken Jan. 23. at the 3500 east and Wasatch Blvd. location.

Figure 5 – Overview of 3500 East and Wasatch Blvd. intersection and Park & Ride

Performance Goals and Design Requirements

The primary goal of the parking structure is to relieve congestion on LCC Road by providing an attractive and convenient transition from personal vehicles to mass transit UTA Ski Buses. The structure must be accommodating a significant number of vehicles such that it alleviates SR-210 congestion. A cost-benefit analysis is recommended to evaluate the effectiveness of constructing a facility at this location.

The design must be aesthetically compliant with the architecture of the surrounding residences.

The design must incorporate an efficient means of transporting parking users to the canyon. A bus station may be integrated with the parking structure to provide shelter on the side of SR-210, and should have frequent departures to make transit attractive to canyon users.

Potential Land Acquisitions

Salt Lake County owns the land at 3500 E and Wasatch Blvd.

Constraints

Maintenance

The structure should be designed such that minimum maintenance is required

Existing Conditions

The current P&R reaches capacity on relatively low-demand days. It is used for both transit users as well as people parking to carpool.

Stakeholder Input

The Granite Community Council (GCC) has voiced concerns that the congestion on SR-210 isolates certain families in their homes in the area. During our meeting on the 01/25-2018, the GCC representatives showed some reluctance to the alternative as being a solution to the congestion problem. Some concerns about the location are that it is on the congested section of the road and is not large enough to mitigate the peak volume of vehicles alone, and a large structure may be intrusive to residents and or limited by zoning allowances for height and structure type. The façade of the structure would need to be adapted to the neighborhood architecture and style

Environmental

Construction of a conventional parking structure is not considered environmentally friendly for several reasons: the lot is located in a residential area and there is a green patch (swamp) for the community where wild life and people recreate. From an environmental standpoint, the lot should be better integrated in the canyon transportation system, as it cannot provide P&R services for any significant number of visitors without compromising the ecological health of the local community.

Cost Estimate

The unit price used for estimating cost of the parking structure was $75/sqft and 250sqft/stall. A two-story structure covering the whole lot will provide approximately 800 stalls (slightly reduced due to the odd shape of the lot) and is estimated to be $19.6 million utilizing most of the area. Due to the residential zoning of the location it is likely that the full area cannot be utilized.

Alternative Evaluation and Proposed Benefits

The lot is easily accessed for up canyon traffic as it is located on the right side of the road. It is a convenient location for people to park their vehicles and meet up to car pool or go on the ski bus.

To increase ridership on the ski buses and provide convenient parking for skiers and other users of the canyon. Convenience is frequently referred to as the most important trait of a system when trying to increase ridership in public transit, and the location at 3500 East provides, arguably, the most convenient alternative parking not considering in-canyon parking.