AVON **CLONE**

COLORADO'S QUAKING ASPEN

A MODEL FOR A SYSTEM OF MOUNTAIN MAGLEV STATIONS

SCOTT HOOK

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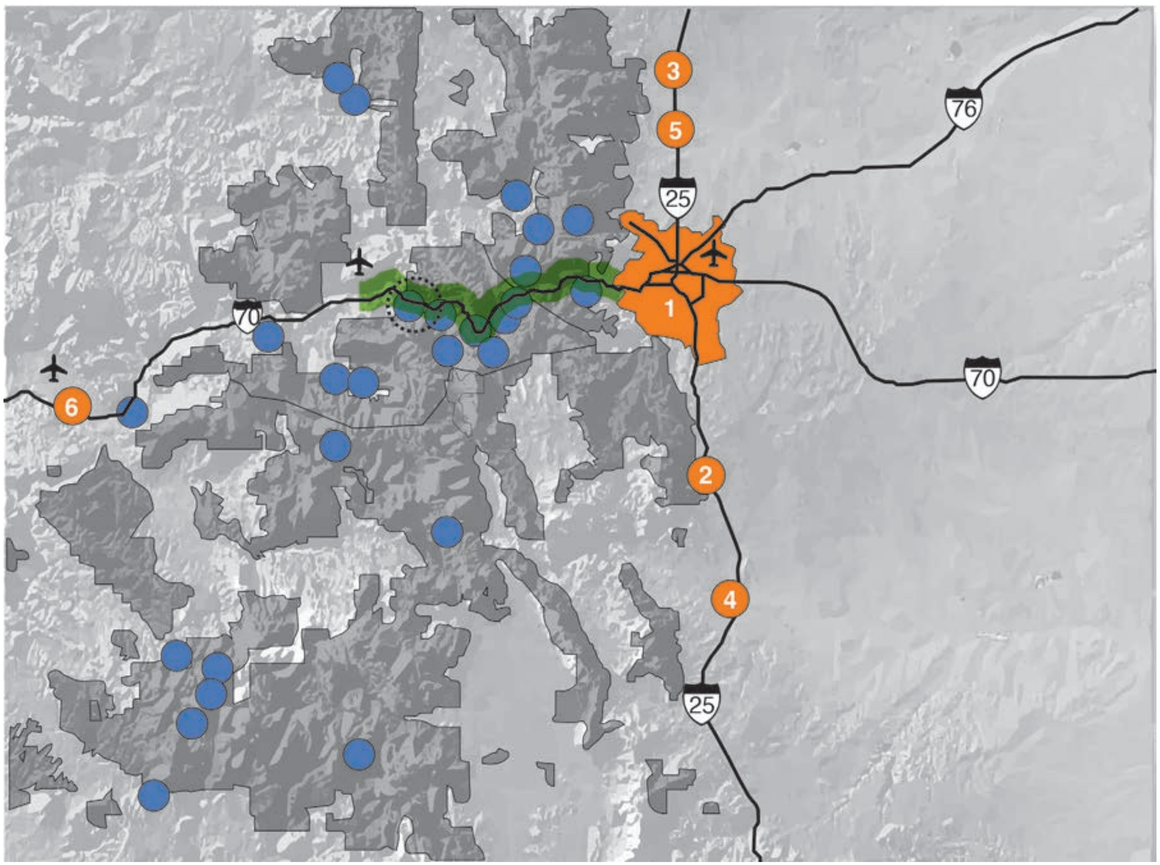
A MODEL FOR A SYSTEM OF MOUNTAIN MAGLEV STATIONS

A thesis presented to the Faculty of NewSchool of Architecture + Design

In partial fulfillment of the Requirements for the Degree of
Master of Architecture

By Scott Hook

San Diego, 2014



1 DENVER METRO AREA
2 COLORADO SPRINGS
3 FORT COLLINS
4 PUEBLO
5 LOVELAND
6 GRAND JUNCTION

POPULATION CENTERS (70%)
TRAIN ALIGNMENT
SKI AREAS
NATIONAL FORESTS
PROJECT SITE

FIGURE 1 - COLORADO OVERVIEW

Problem

The Rocky Mountains of Colorado are home to numerous activities and industries that significantly contribute to the state's economy (Fig. 1). However, traffic congestion along Interstate-70, the main corridor through the mountains, limits growth of these mountain industries and severely impacts the state's economy as a whole. In order to relieve the congestion, a High-Speed Rail system must be constructed and the highway expanded. However, passenger rail has had limited success in the United States since the mid-1950's, and ridership projections indicate difficulty in enticing drivers to switch to transit.

Method

This thesis optimizes the station typology for Transit Oriented Developments (TOD's) throughout the mountain corridor by proposing a station design template that can be adapted to the unique scenarios for intermediate stations along the alignment. The goal of this template is to establish organizational commonality between community centric stations, while accommodating aesthetic individuality appropriate to each site's context and specific history. The template is then adapted to the Colorado Department of Transportation's identified site for a station in the town of Avon.

This process is modeled after the iconic native aspen, which grow in groves known as clonal colonies that are comprised of genetically identical trees sprouting from a shared root system. Like these aspen, each station in this system shares a common genetic template, but develops differently due to varying environmental influences. The result is a system of functionally identical yet physically distinct stations.

Results

Ridership figures for the I-70 MAGLEV system can be expected to increase if stations are incorporated at the center of Transit Oriented Developments within one half mile of the station. Through careful master planning and the successful separation of automotive, transit and pedestrian traffic, a pedestrian friendly and transit-centric station area results. This creates an attractive condition for a symbiotic relationship with surrounding mixed-use developments, which results in a cohesive transit enabled community. The proposed design for the station at Avon attempts to create this condition, but is naturally challenged by the pre-identified hilltop site, which limits densification in the vicinity. Fortunately, the tremendous Village at Avon development largely falls within a one half-mile station catchment, and the station will ultimately provide convenient access to the populace of Avon and their corridor neighbors in the towns of Edwards and Eagle-Vail.

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Scott Hook

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Kurt C. Hunker, Director of Graduate Programs and
Chair , Graduate Department of Architecture

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Jorge Ozorno, Thesis Advisor

_________________________ date _____________

Vuslat Demircay, PhD., Research Advisor

DEDICATION

To my lovely wife and the great state of Colorado

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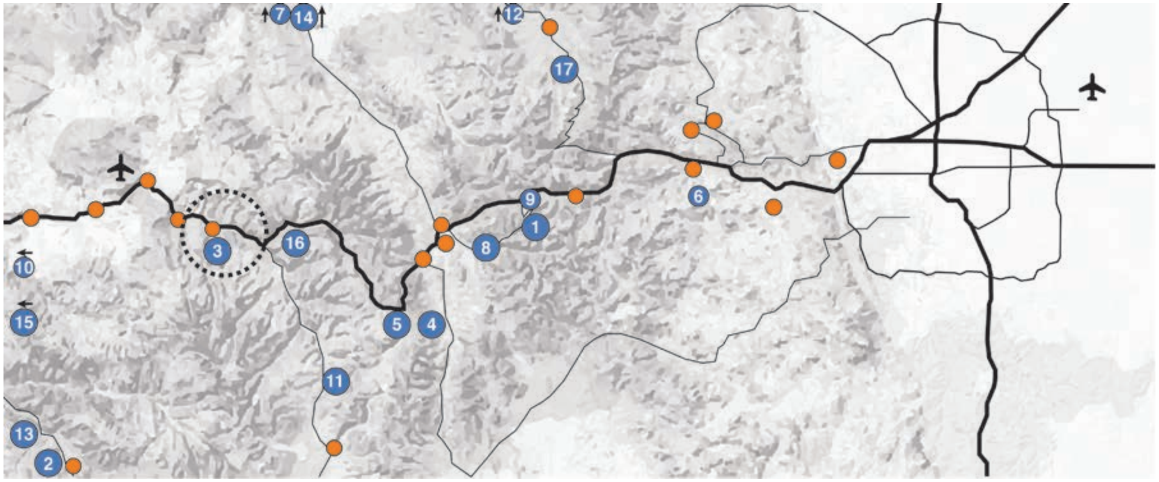
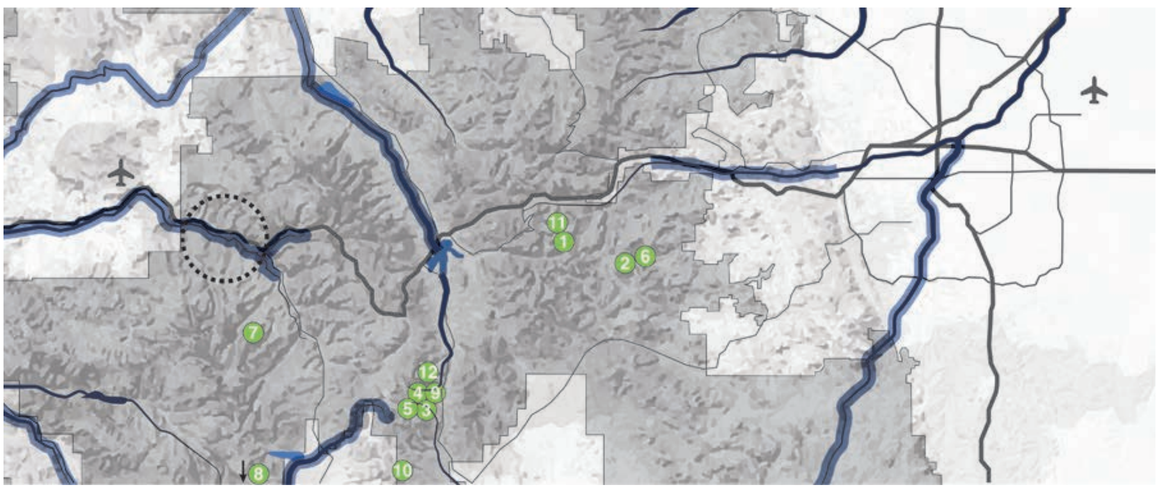


1 ARAPAHOE BASIN
2 ASPEN
3 BEAVER CREEK
4 BRECKENRIDGE
5 COPPER
6 ECHO MOUNTAIN
7 HOWELSEN HILL
8 KEYSTONE
9 LOVELAND
10 POWDERHORN RESORT
11 SKI COOPER
12 GRANBY RANCH
13 SNOWMASS
14 STEAMBOAT
15 SUNLIGHT
16 VAIL
17 WINTER PARK

TOWNS
SKI AREAS
PROJECT SITE

FIGURE 2 - CORRIDOR SKI RESORTS

20 MILES



1 GRAYS PEAK
2 MT. BIERSTADT
3 MT. BROSS
4 MT. CAMERON
5 MT. DEMOCRAT
6 MT. EVANS
7 MT. OF THE HOLY CROSS
8 MT. MASSIVE
9 MT. LINCOLN
10 MT. SHERMAN
11 TORREYS PEAK
12 QUANDARY PEAK

14,000' MOUNTAINS (12 OF 54)
RAFTING RIVERS
NATIONAL FOREST
PROJECT SITE

FIGURE 3 - MOUNTAIN ACTIVITY

20 MILES

1.1 Introductory Narrative

Colorado is the gateway to the Rocky Mountains, one of the country's most spectacular mountain ranges. Its jagged wilderness is amongst nature's most alluring destinations, and is the heart of Colorado's identity. Children grow up learning that "West" is synonymous with mountains, and mountains are synonymous with adventure. Year after year the number of visitors grows, and the more popular the outdoors become.

Colorado is the number one ski destination in the United States, staking a claim to 19.4% of the national market in 2012 (Colorado Travel Year, 2013). Yet it may be of some surprise to discover that the most popular outdoor pursuit in the state is not skiing. In fact, skiing is only enjoyed by 6% of visitors to the state, which doesn't even rank the sport amongst the top three outdoor activities (Impact of I-70 Congestion, 2007). Those positions are claimed by: visits to national and state parks (21%), hiking and backpacking (20%), and visits to historic sites (19%). Together these four activities keep the Rocky Mountains bustling throughout the year.

As is the case with mountain ranges, though, accessibility to these activities can be limited. Interstate-70 is the only continuous East/West connection across the state, and is the main artery for commerce, tourism, and shipping through the mountains. As such, the I-70 Mountain Corridor contains a higher concentration of outdoor activities than elsewhere in the state. 17 of the 26 ski resorts as well as the country's two most visited national forests, White River Forest and Arapahoe-Roosevelt National Forest, are immediately accessible from I-70 (Fig. 2-3). In addition, of the fifty-four 14,000 foot mountains in Colorado, "which are popular destinations for tourists and residents" (Impact of I-70 Congestion, 2007) twelve are located along I-70.

1.2 Background, Statement of Problem, and Importance of Problem

Due to activity and travel throughout the I-70 Mountain Corridor, though, the region is suffering from economically suffocating traffic congestion. "From 1990 to 2002, increases in Colorado highway capacity lagged increases in vehicular travel by 8%" (Impact of I-70

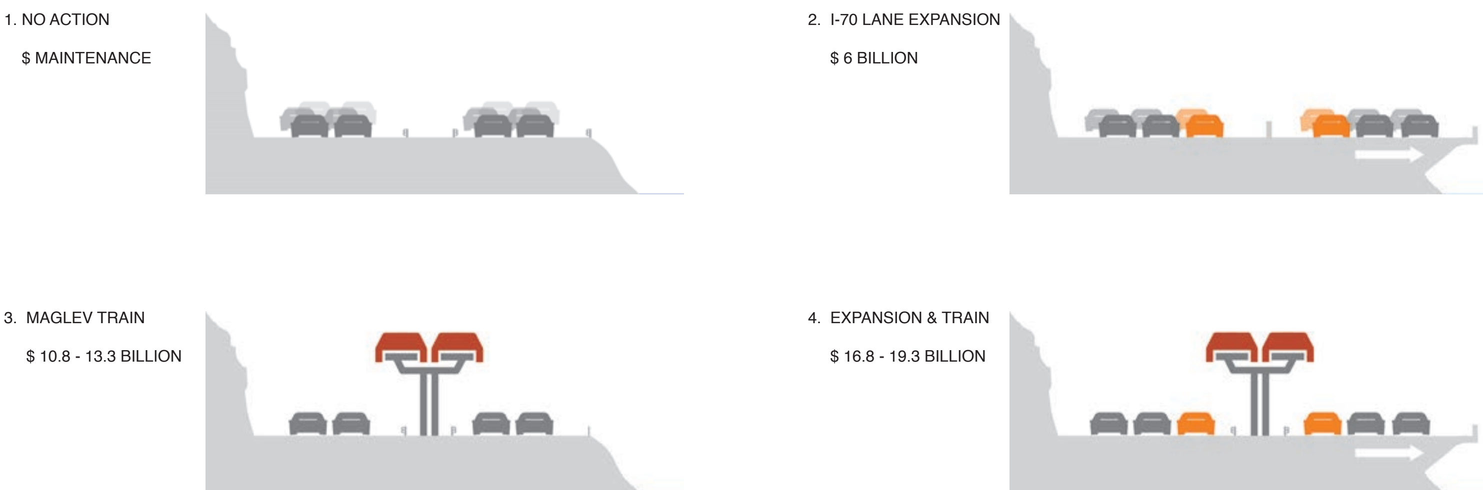
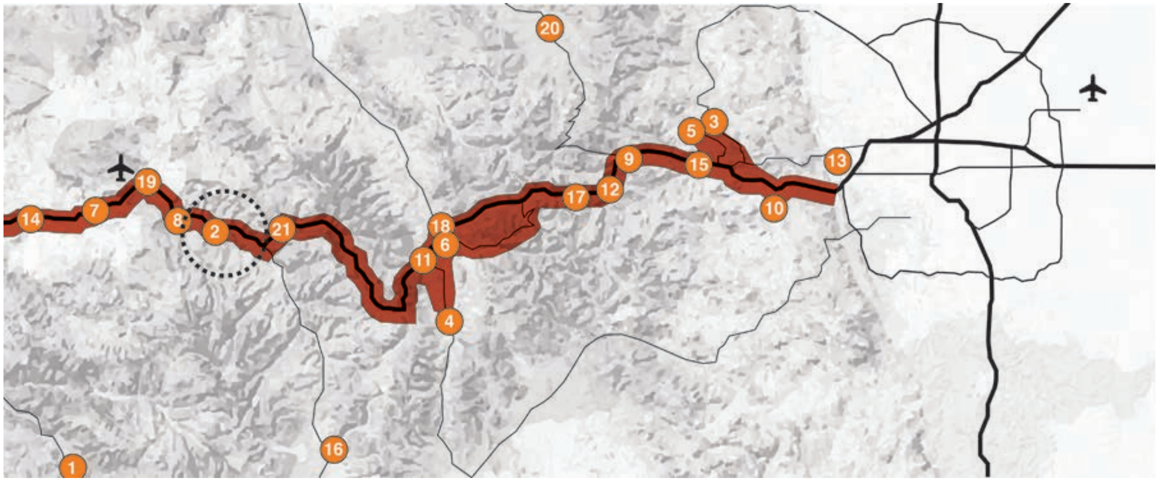


FIGURE 4 - CONGESTION ACTION ALTERNATIVES



1 ASPEN
2 AVON
3 BLACKHAWK
4 BRECKENRIDGE
5 CENTRAL CITY
6 DILLON
7 EAGLE
8 EDWARDS
9 EMPIRE JUNCTION
10 EVERGREEN
11 FRISCO
12 GEORGETOWN
13 GOLDEN
14 GYPSUM
15 IDAHO SPRINGS
16 LEADVILLE
17 SILVER PLUME
18 SIVERTHORNE
19 WOLCOTT
20 WINTER PARK
21 VAIL

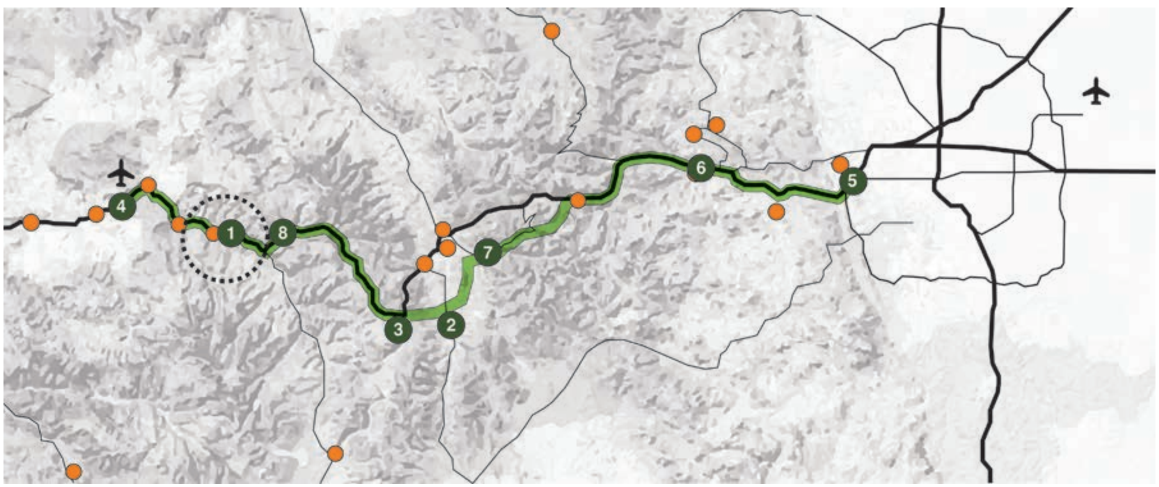
I-70 MOUNTAIN CORRIDOR

MOUNTAIN TOWNS

PROJECT SITE

FIGURE 5 - MOUNTAIN CORRIDOR TOWNS

20 MILES



1 AVON
2 BRECKENRIDGE
3 COPPER MTN SKI AREA
4 EAGLE COUNTY AIRPORT
5 GOLDEN / JEFFERSON COUNTY
6 IDAHO SPRINGS
7 KEYSTONE SKI AREA
8 VAIL

MOUNTAIN TOWNS

HYBRID MAGLEV ALIGNMENT

STATION

PROJECT SITE

FIGURE 6 - HYBRID MAGLEV ALIGNMENT AND STATIONS

20 MILES

Congestion, 2007), but due to the route's narrow canyons and high mountain passes, capacity expansion is limited. The cost of doing nothing, however, far outweighs the cost of the alternative solutions (Fig. 4-5). Models predict that, "by 2035, all Action Alternatives, except the Minimal Action Alternative, [will] meet or surpass a Gross Regional Product of approximately $45 billion per year. The No Action Alternative [will] depress the Gross Regional Product by nearly $10 billion per year" (Final PEIS, 2011). Common to all of these action alternatives is High-Speed Rail (HSR) in one form or another to be built from Denver through the I-70 Mountain Corridor to the Eagle County Airport.

Yet acknowledging the need for HSR is significantly easier than implementing it. HSR is unproven in the United States, and passenger rail expansion is risky in a nation still in love with the automobile. Critics and proponents alike recognize that convincing travellers to switch from auto to transit is amongst the largest challenges to US HSR (multiple sources). Baruch Feigenbaum, an opponent to HSR implementation in the United States, says, "Since transit usage is one of the greatest indicators for rail success, ridership is important", but concludes that, "high-speed rail will never be an appealing transportation choice to most travelers (Feigenbaum, 2013). Recent reports appear to support Feigenbaum's assertion. In 2011 the Rocky Mountain Rail Authority released its HSR Feasibility Study indicating that a system could draw 7 to 8 million riders per year. However, early reports from the ongoing Interregional Connectivity Study (ICS), which began in 2012, warn that these, "earlier expectations of the number of people who would use such a system were over estimated by more than 100 percent (Nath, 2013). Most recently the Advanced Guideway System (AGS) Feasibility Study predicted ridership to be between 2.5 million and 6.3 million people per year depending on route alignment, stations served, and technology chosen (Fig. 6) (AGS Draft, 2014). These varying ridership projections indicate that the overcrowded freeway will continue to worsen if ridership projections cannot justify the construction and operation of HSR.

1.3 Thesis Statement

Ridership concerns are neither isolated to Colorado's situation nor new to HSR systems. In recent years the world's rail infrastructure has undergone a "Station Renaissance" via station renewals and the construction of new stations. Concepts set forth by Peter Calthorpe in Transit Oriented Development (TOD) and New Urbanism are often incorporated into station designs today. TOD is defined as, "a compact, mixed-use community, centered around a transit station that, by design, involves residents, workers, and shoppers to drive their cars less and ride mass transit more" (Peters, 2012). The goal of TOD is to boost ridership and, as a result, revenue (TCRP, 2004).

This thesis optimizes the station typology for Transit Oriented Developments (TOD's) throughout the mountain corridor by proposing a station design template that can be adapted to the unique scenarios for intermediate stations along the alignment. The goal of this template is to establish organizational commonality between community centric stations, while accommodating aesthetic individuality appropriate to each site's context and specific history. The template is then adapted to the Colorado Department of Transportation's identified site for a station in Avon.

This process is modeled after the iconic native aspen, which grow in groves known as clonal colonies that are comprised of genetically identical trees sprouting from a shared root system. Like these aspen, each station in the system shares a common genetic template, but develops differently due to varying contextual influences. The result is a system of functionally identical yet physically distinct stations.

1.4 Statement of the Method of Investigation

The nature of the problem is significantly more complex than what has been discussed thus far. Chapter Two will delve deeper into the history of HSR, which impacts its use today. Those HSR systems will then be compared to the unique context for the I-70 Mountain Corridor system. This analysis will confirm the viability, feasibility, and benefit of the mountain HSR proposal. A rail technology will then be chosen, and a TOD station designed.

2.1 – The History of High Speed Rail

The use of High Speed Rail throughout the world has set the foundation for its use in the United States. These precedents have not been without their problems, which complicate the decision to fund HSR in the I-70 Corridor. To understand this difficulty a history of HSR technology and proliferation is necessary.

2.1.1 – Defining 'High Speed'

HSR was born out of a need for increased capacity on existing rail lines between high-density urban centers (Feigenbaum, 2013). Moshe Givoni notes that, "the direct increase in capacity offered by the HST [High Speed Train] line is due to the higher frequency, which is feasible due to the higher speed, relatively short headway between trains, and long trains with high seat capacities" (Givoni, 2005). Of these three factors (speed, headway, and seating) speed garners the most attention because it is the most complex. The quantifier for "high speed" increases as time goes on, but still varies between regions. The European Union, for example, considers high speed to be greater than 155 miles per hour on a dedicated track and 125 miles per hour on upgraded existing lines (Givoni, 2005). Surprisingly, the Federal Railroad Administration in the US is more generous, and counts speeds in excess of 90 miles per hour as high speed (RMRA, 2010). Yet these figures aren't representative of what is actually achievable. The Madrid-Barcelona line operates at 217 miles per hour with a wheel on rail system (Givoni, 2005), while the new Chinese magnetic levitation (MAGLEV) train connecting Pudong Airport with Shanghai runs at 268 miles per hour (Shanghai MAGLEV Train, 2013). With new innovation, we may see speeds of 760 miles per hour if Elon Musk's Hyperloop proposal becomes a reality (Fig. 7) (Milian, 2013). Yet the evolution of HSR will show that speed is in itself the result of many factors including technology, network organization, and terrain.

2.1.2 – Birth in Japan

In1964, Japan began HSR service on the Tokaido line between Tokyo and Osaka (Fig. 8). The line's first Shinkansen train, famously known as the "Bullet Train", operated at 155 miles per hour on a dedicated track, thereby reducing travel time by over 64% (Givoni, 2005). Japan's terrain makes HSR construction expensive, though. Stability at speed requires a longer distance between bogie wheel axles. These longer bogies (the pivoting wheel units at either end of a rail car) result in larger turn radii. Large turn radii make terrain following

FIGURE 7 - HIGH SPEED COMPARISON

impossible, and forces route straightening in the form of expensive tunnels, which comprise over 30% of the total length of Japanese HSR lines (Givoni, 2005). Despite the cost and difficulty of construction in Japan, transit demand makes the Tokyo-Osaka line one of only two profitable HSR lines in the world (Feigenbaum, 2013).

2.1.3 – Proliferation in Europe

After the introduction in Japan, the spread of HSR was slow, and 17 years passed before the world's second HSR line began operation between Rome and Florence in 1977 (Feigenbaum, 2013). The Italian design chose to use conventional tracks to reduce construction costs. However, conventional tracks do not bank enough for HSR to be comfortable for passengers in high G turns, and speeds are limited. This problem was partially overcome in 1988 with the introduction of the Italian Pendolino train, which tilts the cars themselves during a turn. The tilting mechanism allows centrifugal force to pass through the longitudinal axis of the body, which simply presses passengers into their seats rather than knocking them about from side to side. Although comfort is improved, maximum speeds are still limited to 155 miles per hour (Givoni, 2005).

The third line to be constructed, and the only other profitable HSR line in the world, was France's Paris-Lyon TGV line, which began operating in 1981 (Fig. 9) (Feigenbaum, 2013). "The most significant difference between the TGV and the Shinkansen is probably the ability of the former to operate on conventional tracks as well, which allows the TGV to use the conventional lines as it enters and leaves the city centre" (Givoni, 2005) otherwise the train operates on a dedicated track. Germany's ICE (Inter-City Express) train follows the TGV method, but operates on a shared track with conventional passenger and freight trains (Fig. 10). "This feature turned out to be a disadvantage since it led to high construction costs (to support the higher load of freight trains) and low utilization of the lines (since freight trains operate at much lower speeds)" (Givoni, 2005). Capacity of Germany's ICE train is therefore limited due to the interrelationship of speed and frequency (Feigenbaum, 2013).

2.1.4 – The Advent of Magnetic Levitation (MAGLEV)

HSR's slow start eventually accelerated. "Worldwide, HSR grew from approximately 3,100 to 6, 200 miles between 1997 and 2009" (Nichols, 2011). New technologies were implemented during that time as well. In 2004, China opened the first MAGLEV line connecting Pudong Airport with Shanghai (Fig. 11). Whereas all other HSR trains use a wheel on rail system or a variant thereof, MAGLEV uses magnetic force to levitate and power the train. This frictionless technology

FIGURE 8 - SHINKANSEN TRAINS, JAPAN

FIGURE 9 - TGV TRAINS, FRANCE

allows for operating speeds up to 300 miles per hour (RMRA, 2010). However, "MAGLEV lines are probably the most expensive HST infrastructure" (Givoni, 2005). The cost of MAGLEV has been the downfall of many proposed projects throughout Europe and Asia, and the only proposal actively being planned is Japan's Chou Shinkansen line between Tokyo and Osaka (List of MAGLEV train proposals, 2013). There are tremendous advantages that offset this cost, though. The wheel-less trains are significantly quieter, with noise pollution from wind only becoming a problem over 185 miles per hour (Givoni, 2005). MAGLEV is also environmentally sensitive, running on electricity with a minimal footprint due to elevated tracks (I-70 Coalition, 2009). Finally, MAGLEV can ascend steeper grades than other HST's and has better all weather capability (RMRA Final Report, 2010).

2.1.5 – The United States' Conspicuous Absence

Amidst the worldwide growth of HSR was the conspicuous absence of the United States. The fiscal failure of Amtrak, the government owned passenger rail company, has made US investors and taxpayers wary of a new rail system (multiple sources). Due to rising gas prices, population growth, and environmental concerns, though, the US HSR industry may start to take off. "The U.S. Congress established the current high-speed rail program framework in the 2008 and 2009 Appropriation Acts: The Passenger Rail Investment and Improvement Act of 2008 (PRIIA) and the American Recovery and Reinvestment Act of 2009 (ARRA)" (Feigenbaum, 2013). Of the thirteen routes proposed by the ARRA, those in California and the Northeast Corridor are most likely to come to fruition (Nichols, 2011). These states have the highest perceived demand, but other states, such as Ohio, Wisconsin, and Florida have already returned $3 billion of Congress's planning money (Fuller, 2011) citing fiscal prudence as the reason for not pursuing HSR (Renne, 2013). Complicating the case for Colorado is the fact that none of the White House's funded routes pass through Colorado. (High-Speed Rail, Jobs, and the Recovery Act, 2013). Only the more aggressive plan proposed by the U.S High Speed Rail Association incorporates the state. Their plan envisions 17,000 miles of HSR, more than double the length of track that currently exists in the rest of the world combined, constructed by 2030 (US High Speed Rail Assc, 2013). In the end, though, the California system will likely act as the litmus test for future routes throughout the country.

2.1.6 – Lessons Learned from Asia and Europe

Despite US waffling, the 49-year history of Asian and European HSR systems have much to teach the burgeoning American market. In sum, they teach that new systems should incorporate the following physical

FIGURE 10 - ICE TRAINS, GERMANY

FIGURE 11 - MAGLEV TRAIN, CHINA

features: dedicated tracks, elevated tracks, G compensation, and electric propulsion. Route planning, terrain, and weather also contribute to the appropriateness of one system over another. Straight sections allow for faster speeds, but may require expensive tunneling. The cost of tunneling for a wheeled HSR may be the same as the cost of MAGLEV over steep grades (AGS Draft, 2014). Route planners now have a choice to go 'up and over' vice 'through'. Technology choice can also be informed by travel time goals, which are tied to the train's average speed rather than its maximum operating speed. Routes with many stops require faster speeds and accelerations to keep travel time low, but direct routes can afford slower average speeds and still achieve the same travel times (RMRA Final Report, 2010). Finally, signaling and control systems can reduce headway times between trains to improve capacity. Smaller trains that run more frequently and closer together are capable of carrying the same number of passengers as larger trains running less frequently (Givoni, 2005). In regards to rail station design, these factors determine the size and type of train that needs to be accommodated, the frequency at which trains may arrive, and the number of people arriving or departing.

2.2 – Challenges Inherent to HSR

Although these physical lessons are positive, the economic lessons are less so. Only the Tokyo-Osaka and Paris-Lyon lines have managed to turn a profit, which is attributable to urban density and high travel demand along the route, otherwise all other routes require government subsidies to operate (Feigenbaum, 2013). As stated in the introduction, HSR success is ultimately a matter of ridership, but studies conducted throughout the world have determined many of the causes behind low ridership, which can be addressed in future lines.

2.2.1 – Population Density

Low density near rail stations is a frequent cause of low ridership, and also a major concern for HSR implementation in the United States. "While the Los Angeles metro area has the highest U.S. population density, it is dwarfed by European and Asian cities… Extending HSR to places without the ability or desire to encourage high

FIGURE 12 - HAUTE-PICARDIE TGV "BEET STATION", FRANCE

densities is unlikely to be successful" (Feigenbaum, 2013). Multiple studies have shown that the presence of a rail station in and of itself is not sufficient to create needed densification (Givoni, 2005). Rather urban planning, zoning, and public policy in advance of rail service are required. This is demonstrated by the rural Haute-Picardie station on the Paris-Lyon TGV line that, "became known as a"Beet Station," and remained surrounded by sugar beet fields even after TGV opened" (Fig. 12) (Nichols, 2011). The density problem is already found in US rail stations. A 2013 study of all US rail stations revealed, "that in 22 of the 35 regions in this study, less than 5 percent of the population live within rail precincts" (Renne, 2013). The most common solution for stations where additional density is needed has been to incorporate Transit Oriented Developments (TOD). "Research shows residents living near stations are five to six times more likely to commute via transit than are other residents… the principal aim of TOD and joint development is to boost ridership and thereby, boost revenue income" (TCRP, 2004).

2.2.2 –Transit Networks

Even in areas of high density, though, ridership can falter if the connecting transit system is insufficient. Feigenbaum notes that, "riders who begin their commute by car are more likely to drive or fly than riders who begin their commute by transit" (Feigenbaum, 2013). Low US gas prices contribute to the American preference for driving vice riding. The challenge, then, lies, in getting travellers out of their cars as early as possible. The Paris and Tokyo lines previously mentioned are successful in part to the inter-modal transit system emplaced. 25% of travel in Paris and 60% in Tokyo is via transit, but in the United States New York tops the list at only 15% (Feigenbaum, 2013). It is of no surprise then to discover that train stations have to re-emerge as, "new, inter-modally connected spaces that link the various parts of the city" (Peters, 2012).

2.2.3 – Competing Modes

Ticket prices and travel mode competition can also reduce ridership. Feigenbaum is vehement in his assertion that HSR cannot compete with air travel, citing numerous examples in Europe and Asia where ticket price and travel time for air travel is less than that of rail (Feigenbaum, 2013). Yet Moshe Givoni disagrees stating, "in general, on routes of around 300km [186 miles], evidence shows that the introduction of HST services almost leads to a withdrawal of aircraft services...many airlines chose to replace the aircraft with the HST on some routes, leading to a real mode substitution" (Givoni, 2005). Feigenbaum concedes, but with the caveat, "that HSR can only be competitive on routes that are between 200 and 500 miles in length" otherwise buses are cheaper and offer comparable travel times for distances less than 150 miles (Feigenbaum, 2013).

2.2.4 – Challenges for HSR in Colorado

The history and precedents of HSR naturally raise many challenges concerning a Colorado system. These questions create a historical framework for designing the I-70 Mountain Corridor HSR system. At the heart of these still lies the challenge of achieving ridership. They are:

1. *How do low densities and populations along the route affect ridership?*
2. *How is HSR demand generated amidst low density and population?*
3. *How can HSR compete with other modes of transportation?*
4. *How is HSR justified without existing rail demand?*
5. *How do multi-modal transit systems support HSR?*
6. *How do topography and environment affect route and technology selection?*
7. *How can HSR serve as a tourism destination by itself?*
8. *How does HSR ridership impact the environment?*
9. *How can rail car, rail station, and station area design improve ridership?*

FIGURE 13 - TOPOGRAPHICAL CONSTRAINTS FOR IDAHO SPRINGS, COLORADO

1/4 MILE

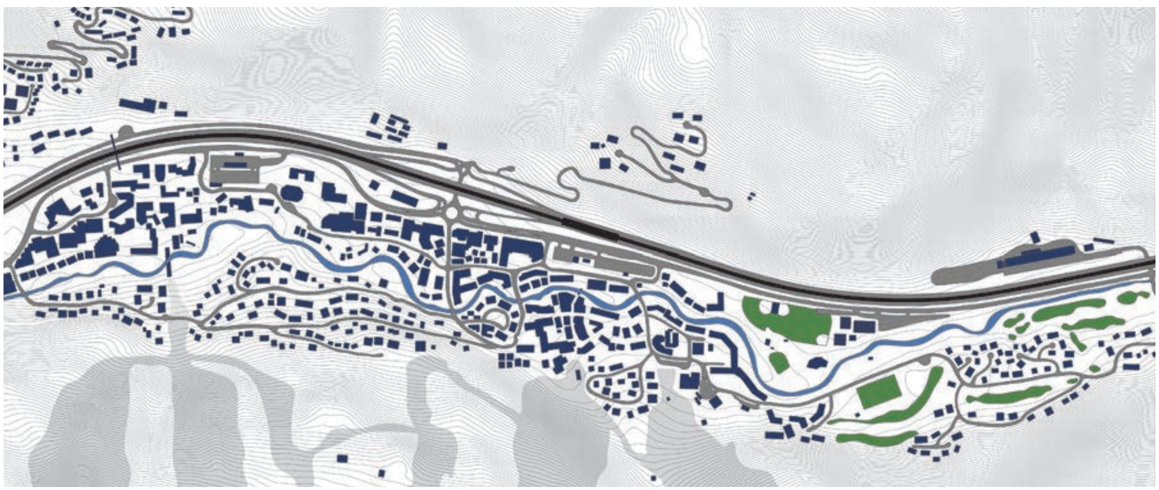


FIGURE 14 - TOPOGRAPHICAL CONSTRAINTS FOR VAIL, COLORADO

1/4 MILE

2.3 – The I-70 Mountain Corridor Context for HSR

In the case of the I-70 Mountain Corridor many of these questions can be answered through the existing context of the problem. The topographic, geographic, meteorological, economical, societal, and civic structure of the corridor is unique amongst existing HSR routes, and therefore defies direct comparison to any one precedent.

1. How do low densities and populations along the route affect ridership?

If Colorado's HSR were decided by the population size of the Mountain Corridor towns alone, it would never be entertained. Precedents have shown that HSR has been successful or even justified only when connecting some of the largest urban centers on the planet. These cities have populations in the millions. The towns along the I-70 Corridor, however, are each less than 10,000. Vail and Avon, neighboring towns in Eagle County, have permanent populations of 5,253 and 6,345 respectively (Census Bureau, 2012). However, the Denver Metropolitan area has a population of 2.6 million, which is half of the state's 5.2 million, (Census Bureau, 2012). When compared to Paris at 2.2 million, an HSR line from Denver through the mountains is more palatable.

Growth and tourism are other factors that alter population sizes, "the Mountain Resort Region population is expected to increase 62% from 2005 to 2025" (Impact of I-70 Congestion, 2007). Many of the people living in the region are not permanent residents, either. In 2006, for example, 49% of housing units in Eagle County were second homes, a number that is expected to increase with the retirement of the baby boomer generation (Impact of I-70 Congestion, 2007). Enter tourism into the equation, and Vail's 35,000 beds provide tremendous capacity for overnight visitors (I-70 Coalition, 2009). These resorts also attract a work force. "By 2020, the [Mountain Resort Region] is estimated to have a shortage of almost 65,700 workers and the number of commuters is expected to double from 1997 to 2020" (Impact of I-70 Congestion, 2007). An I-70 line is not intended to serve the population of its permanent and seasonal residents alone, though. The I-70 Coalition Land Use Planning Study determined that, "development at a transit station on the I-70 corridor will look different than what has been described in the case studies. The communities on the I-70 corridor are not large urban centers and do not rely on increased density to support transit as much as urban areas, but instead will mostly rely on tourism and employment" (I-70 Coalition, 2009). For perspective, 2012 saw a record 14.6 million overnight visitors to Colorado on marketable leisure trips and a record 30.8 million day trips throughout the state (Colorado Travel Year, 2013). Although these statistics are not broken down by region, it can be assumed that a significant portion were destined for locations throughout the Mountain Corridor given the density of tourist destinations in the region. Therefore, it is not only the population growth of the region, but rather the number of visitors and employees, that HSR ridership will be drawn from.

2. How is HSR demand generated amidst low density and population?

The I-70 Coalition assertion that HSR success is not directly dependent upon density still warrants discussion. In Feigenbaum's opposition to U.S. HSR he states that, "the U.S. has a different spatial structure than most countries. U.S. core cities, where people are most likely to board HSR trains are substantially less dense than European or Asian cities" (Feigenbaum, 2013). This is difficult to argue against since it is well established that U.S. urban sprawl is a result of land availability, low gas prices, and uncontrolled development. The Mountain Corridor by its topography alone is not susceptible to traditional urban sprawl, though. I-70 follows a route through narrow canyons and mountain valleys, which limits developable land and adds a premium to prices (Fig. 13-14). Vail, for example, is largely contained within a half-mile wide strip along six miles of I-70 (Google Earth, 2013). As a result, the town is very walkable with retail and activity hubs located at the Vail Village and Lionshead centers, both of which restrict automobile access. Control via topography does not mean that sprawl is non-existent. Rather, mountain sprawl simply follows I-70 and expands into developable valley floor lands. Towns such as Avon and Edwards to the West of Vail are susceptible to this as is evident by the presence of big box stores and the Eagle County Regional Airport. HSR stations should be designed to encourage densification and to maintain the small town identity for which the mountain towns are known. This is frequently echoed in community feedback contained in the I-70 Coalition Land Use Planning Study (I-70 Coalition, 2009 & AGS Feasibility Study, 2014).

3. How can HSR compete with other modes of transportation?

The topography and existing traffic congestion also alleviate concerns of competition from alternate modes of transit. The distance from Denver International Airport to the Eagle County Airport west of Vail is 155 miles (Google, 2013). This falls into the distance that Feigenbaum considers optimal for bus transit. Buses may reduce the number of cars on I-70, but they will not be able to alleviate congestion or improve travel times. Freeway capacity and congestion are not directly related, and latent or unmet demand can cause continued congestion despite increases in capacity. Latent demand, "occurs when travelers want to make a trip but choose not to because of severe congestion, long travel times, or other unsatisfactory conditions" (Final PEIS, 2011). Increases in freeway capacity, whether they stem from lane expansion or passenger consolidation in buses will not relieve congestion because latent demand immediately fills the added capacity and leaves congestion unchanged (Final PEIS, 2011). All feasibility studies for the Mountain Corridor HSR agree that congestion will only be relieved with the addition of a train. Buses, therefore, contribute little to solving the existing problem, and neither do aircraft. Eagle County Airport outside of Vail is the largest of three regional airports serving the Mountain Resort Region (Fig. 15). The terminal only accommodates 10 aircraft, and in all of 2012 only 337,383 passengers flew through the Eagle Airport (Airport Statistics for Eagle County, 2013). By comparison, the Vail and Beaver Creek ski resorts had 2.65 million visitors during the 2010/2011 ski season (Vail and Beaver Creek, 2013). The likelihood of the I-70 HSR losing ridership to an alternate mode of mass transit is therefore highly unlikely.

FIGURE 15 - EAGLE COUNTY AIRPORT

4. How is HSR justified without existing rail demand?

Historically, HSR has been implemented in areas of existing high rail demand. as was demonstrated by the Tokyo-Osaka and Paris-Lyon examples. Although Amtrak offers limited conventional passenger service through the corridor, the service does not have the demand to justify HSR by itself (RMRA Final Report, 2010). It has been shown previously, though, that the factors within the I-70 corridor are interrelated, and the demand for increased travel capacity in general makes this rail demand prerequisite for HSR largely irrelevant. To demonstrate, this can be evaluated in terms of the value drivers assign to their own time. "With no congestion, the route from the City and County of Denver to Copper Mountain [east of Vail] takes roughly one hour and 14 minutes. With congestion on I-70, travel time increases to two hours and ten minutes" (Impact of I-70 Congestion, 2007). This equates to a 75% increase in travel time due to congestion alone. The Colorado Department of Transportation also estimates that by 2025 congestion will encourage 27% of winter motorists and 10% of summer motorists not to travel (Impact of I-70 Congestion, 2007). HSR offers dependability and timeliness to an otherwise unpredictable journey, which creates a demand for HSR in the absence of a demand for Amtrak.

5. How do multi-modal transit systems support HSR?

A larger transit system capable of feeding HSR stations cannot be explained away by topography or other existing conditions. Rather inter-modality is an essential component to HSR success. The reasons for expanded transit networks are many, and they directly affect future station design and station area planning. The propensity for drivers to keep driving once in their cars rather than transferring to an alternate mode has already been discussed. Another reason for inter-modality is the, "'congestion conundrum': the fact that nodal development around a transit station increases spot congestion" (TCRP, 2004). Parking garages are an unavoidable necessity (Feigenbaum, 2013), but light rail and bus networks can alleviate traffic in the station area and improve pedestrian safety and accessibility (TCRP, 2004). Fortunately, both Denver and the ski resort towns along I-70 have high functioning transit networks with plans for the expansion of both. "The Regional Transportation District (RTD) rail network includes an existing 35-mile light rail network and a multi-billion dollar transit expansion plan designed to integrate new transit modes into a comprehensive region-wide system" (State Rail Plan, 2012). The expansion will add 63 more miles of light rail and 94 miles of commuter rail, which will offer higher speeds and fewer stops (State Rail Plan, 2012). For those mountain towns that aren't already walkable in their entirety, bus networks are already in place. Summit County, home to the Breckenridge, Copper Mountain, Keystone, and Arapahoe Basin ski resorts, operates the free Summit Stage bus network, which connects the resorts with commercial hubs and residential areas (Summit Stage, 2013). Similarly, Eagle County, home to the Vail and Beaver Creek ski resorts operates the county wide ECO transit system, which charges $4 per ride (ECO Transit, 2013). To accommodate HSR these existing networks will need to increase capacity and establish transit hubs at station locations (Nichols, 2011).

6. How do topography and environment affect route and technology selection?

Similar to the discussion on speed, choices for technology and route are interconnected and multi-faceted. The I-70 freeway from Denver to Vail is narrow, windy, and steep. It runs, "over several mountain passes including the highest point of the U.S. Interstate System just east of the Eisenhower-Johnson Memorial Tunnel (EJMT). Because of its location, I-70 in the Mountain Resort Region is prone to avalanches, rockslides, and can often be closed due to the adverse weather conditions and traffic accidents" (Impact of I-70 Congestion, 2007). These factors are major causes of automobile congestion, but pose difficult design problems for rail systems. The Programmatic Environmental Impact study states, "the selection of a transit technology will depend on the limitations of transit technologies, such as seat capacity, speed, power needs, and ability to handle higher grades and curves" (Final PEIS, 2011). With this in mind, and by using information established previously, a series of causal relationships can be established that inform technology and route selection.

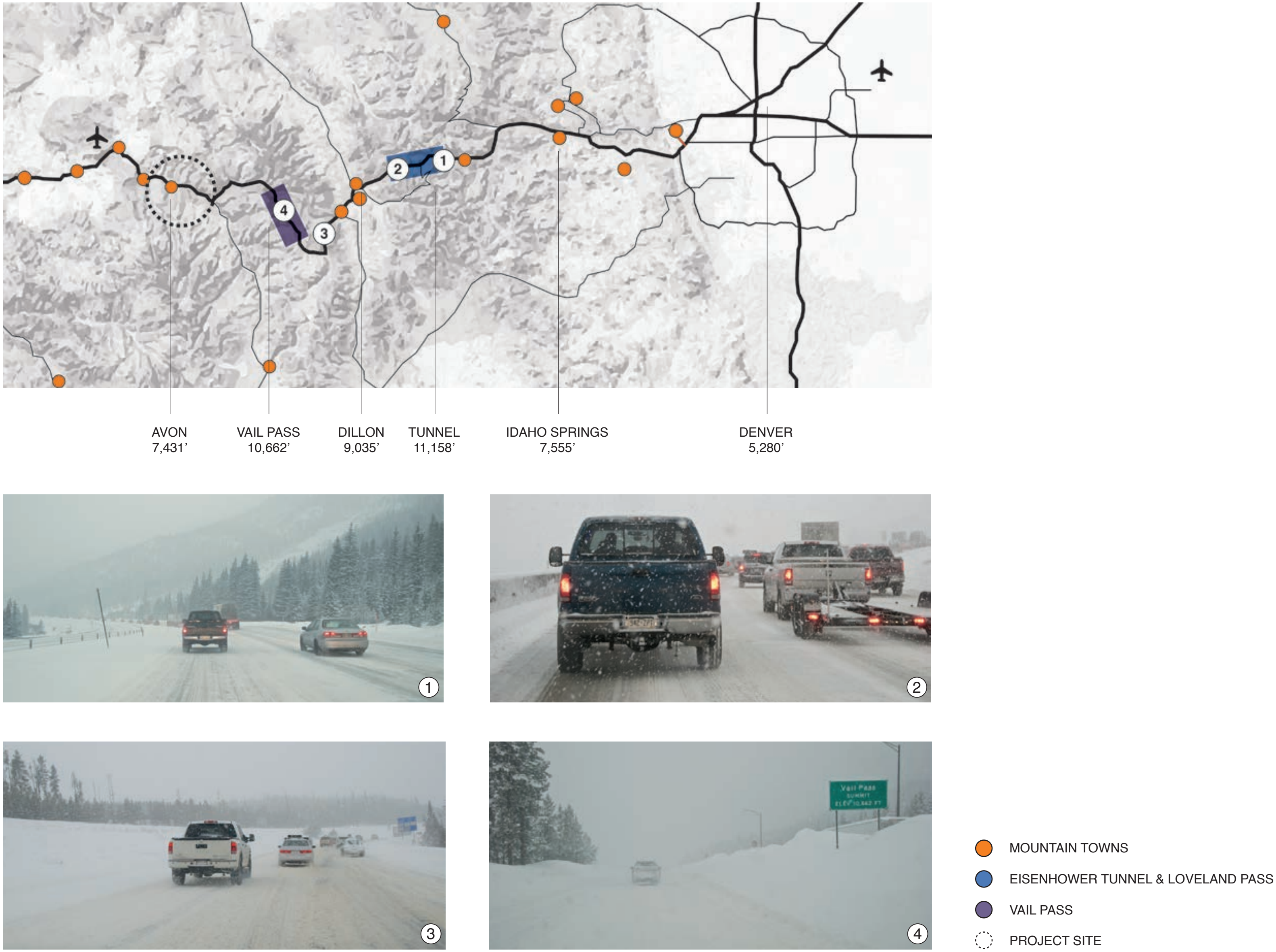


FIGURE 16 - MOUNTAIN PASSES, WEATHER, AND CONGESTION

The Italian and Japanese systems show that speed is a product of the directness of the route. They also show that speed is a by product of capacity and a requirement for reducing travel time. Joining these observations reveals that a circuitous route, like I-70, will mandate a decrease in speed, which leads to a decrease in capacity and frequency. A solution to regain capacity and frequency is to reduce travel times while simultaneously operating at slower speeds. The only way to do this is to reduce the number of stops. Unfortunately, eliminating stations has unfortunate economic implications for the towns that lose them (Givoni, 2005). With all of these factors taken into consideration, two main configurations are revealed. The first is a system that provides direct service to destinations along circuitous routes with potentially steep grades in smaller trains operating at slower average speeds (60-70mph (RMRA Final Report, 2010)) (AGS, 2014). The second is a system that provides service to multiple stations along straighter routes with lower grades in larger trains operating at high speed (120-200mph) (RMRA Final Report, 2010). These two configurations create categories for a range of options proposed for the I-70 AGS (AGS Feasibility Study, 2014). Those routes with steeper grades require a MAGLEV or similar technology, while shallower grades can use more traditional wheel on rail trains. Severe weather also influences technology selection (Fig. 16). Wheeled systems are more susceptible to weather due to moving parts, but MAGLEV, which doesn't use moving parts for propulsion, is more tolerant (AGS Feasibility Study, 2014). In the case of Colorado, only MAGLEV's max speed potential will go unused because none of the proposed routes are straight enough to achieve top speeds safely or comfortably. These interwoven relationships explain why technology choice is difficult, and why a final decision has yet to be made (AGS Feasibility Study, 2014)

Multiple agency studies have provided route and technology recommendations, though. In the most recent AGS Feasibility Study, route alignments are proposed to accommodate the range of technology choices. AGS is the umbrella term encompassing the range of high-speed technologies and track systems. High Speed Routes, those using High Speed Rail or High Speed MAGLEV have the greatest tunneling requirements and greenfield demands. Slower routes using smaller vehicles stay closer to the I-70 right of way. Hybrids of the two provide a compromise between travel time and construction costs. (AGS Feasibility Study, 2014) The gamut of vehicle technologies range in speed from 90mph to 200mph+, with capacities between 2 – 960 passengers. General Atomics, Transrapid, and others propose 2-10 car MAGLEV consists (a consist being the set of vehicles comprising a full train). Swift Tram and PPRTC on the other hand suggest single car direct service low passenger MAGLEV systems. Other corporations are promoting vacuum/air pressure, hydrogen, as well as traditional wheel on rail propulsion systems (AGS, 2012). Although the AGS Feasibility Study does not delineate a preferred technology, the balance of cost, capacity, and travel time suggest the likely choice to be a Hybrid High Speed MAGLEV alignment using the Transrapid technology already in use in Shanghai. Each Transrapid consist will be comprised of 2-10 vehicles with capacities of 140-960 people, speeds around 120 mph, and corridor travel times of 73 minutes. This technology will deliver passengers and freight to eight in line stations, and is estimated to cost $13.3 billion (significantly less than the estimated $32.4 billion for traditional HSR). (AGS Feasibility Study, 2014).

7. How can HSR serve as a tourism destination by itself?

With a purely quantitative analysis, ridership remains a problem, but the technology will also be influenced by more subjective criteria. The technology itself is capable of attracting riders who would have otherwise driven. The PEIS states that an, "Advanced Guideway System is the most attractive to riders of the transit technologies considered and, thus, attracts approximately 500,000 more riders" (Final PEIS, 2011). The psychological affect fostered by state of the art technology is therefore believed to be considerable. This is supported historically with a look back at the emergence of passenger rail over a hundred years ago. Stations and trains, "were instantly loaded with symbolic meanings as the new 'palaces of modern industry'" (Peters, 2012). Since China opened the Shanghai-Pudong line and Japan began planning the Chou Shinkansen line, MAGLEV has become synonymous with 'state of the art', making it a preferred technology for ridership attraction.

Ridership can also be increased by marketing HSR as a tourist attraction. There is an existing precedent of scenic railroads in Colorado.

"Given Colorado's railroad history and the state's natural beauty, [eight] scenic railroads provide tourist-oriented service" (State Rail Plan, 2012). Two of these are directly accessible from I-70: the Georgetown Loop Railroad and the Leadville Scenic Railroad (Fig. 17). The Colorado Railroad Museum is also along I-70 at the base of the foothills in the town of Golden (Colorado & Southern Railroad History, 2013). Given the beautiful context of the Rocky Mountains, it is likely that HSR will draw from the same pool of tourists who are destined for one of the state's scenic railroads.

The alignment may also have the potential to attract and maintain ridership due to its context beside the congested freeway. Make no mistake, though, the previous discussion of scenic railroads still holds true along I-70, which is an extremely beautiful freeway route despite the congestion. Riders can enjoy this beautiful scenery while elevated above the freeway. As trains course through the mountains at predictable and reliable speeds, riders will see the traffic congestion below. This may serve as a reminder that the ticket price is worth the convenience, speed and stress free alternative to driving. Riders will be reaffirmed of their decision to switch modes with every car they pass.

8. How does HSR ridership impact the environment?

Ridership, technology, and route are interrelated in regards to the environment as well. In this regard the development of HSR through the Mountain Corridor is more of an ethical responsibility on the part of the developers and state than a reason to attract ridership. Nevertheless, passenger concern over pollution may attract riders to HSR similar to how hybrid cars attract drivers.

In terms of energy, the majority of technology proposals are electrically driven. Feigenbaum argues that, "rail only reaps environmental benefits if it is electrified. Otherwise it is no less polluting than modern cars or planes" (Feigenbaum, 2013). This is quantified in a study on California's HSR (CAHSR), which states that, "a car with 5 passengers is energy-equivalent to CAHSR with 1011 passengers and HRT [Heavy Rail Transit] with 298 passengers" (Chester, 2009). These numbers will change due to Colorado's terrain, but the concept is sound. However, greenhouse gas emissions have the potential to increase if HSR ridership does not fill HSR capacity. Appropriately sizing consists will ensure that maximum occupancy is achieved, and efficiency is

FIGURE 17 - GEORGETOWN LOOP RAILROAD - GEORGETOWN, CO

optimized. Otherwise, GHG emissions related to power generation can be minimized with solar. The potential to accomplish this exists since Colorado ranks fourth in the nation for new energy potential (Colorado by the Numbers, 2013).

The environmental implications of HSR go well beyond power generation. Impact upon greenfields and ecosystems, right-of-way usage, footprint, and habitat disruption are important factors that should be addressed from an ethical rather than financial perspective. Of all proposals the I-70 ROW alignment analyzed in the PEIS gives the most attention to these environmental impacts. It should be noted, though, that, in addition to the AGS, the PEIS calls for expansion of I-70 to six lanes since a rail line alone would not alleviate congestion from latent demand (Final PEIS, 2011). That being said, the, "Advanced Guideway System has the smallest direct impact due to its smaller footprint" (Final PEIS, 2011). This footprint is a result of the elevated guideway, which is supported intermittently along its length. This is in contrast to conventional HSR, which requires an at grade track to carve through the terrain and be bordered by protective fencing. With the AGS, wildlife can pass beneath the track, therefore reducing the need for wildlife bridging. The ALIVE MOU also calls for extensive bridging throughout the corridor to reduce animal-vehicle collisions on the freeway (Final PEIS, 2011). Finally, the more right-of-way land that can be used the less greenfield is needed.

9. How can rail car, rail station, and station area design improve ridership?

Even though this thesis aims to focus upon station and station area design, the discussion thus far has focused largely upon the rail line and technology itself. An essential means to an end, the selection of route and technology inform station design decisions including site selection, station size, intermodal connections, and programmatic composition. With the complex nature of the problem understood, the discussion can turn to how the design of stations themselves can improve ridership.

Sir Norman Foster is quoted as saying, "the way in which a train station 'engages' itself as a gateway for its city is a very important question for that city's future. It is an indicator for the city's quality and for its quality of life," (Peters, 2012). Foster recognizes a return to the golden age of rail commonly referred to as the "Station Renaissance" that, "includes construction of new stations conceived as a part of urban development projects and station renewal" (Kido, 2005). Urban planners, such as Deike Peters and Johannes Novy, and station architecture experts, such as Julian Ross, stress the importance of quality station design in successful rail systems and community developments around the world. "Apart from the real, on-the-ground physical restructuring effects, the re-emergence of centrally located railway stations as focal points for urban activity carries strong symbolic meaning: it further solidifies European cities' break with…car-oriented settlement patters" (Peters, 2012). This renewed interest in rail stations signifies a return to pre-World War II ideals, which saw grandiose train stations, the "palaces of modern industry", destroyed only to be rebuilt smaller and less extravagant (Peters, 2012). Now, rather than indicating an arrival of the 'golden-age of technology', there is a desire for station architecture to communicate a new 'era-of-optimism' (Hebbert, 2006). New challenges in visual communication and a new found realization that amenities and design can attract riders has inspired rail companies to hire high profile architects such as Foster and Calatrava rather than continuing to design stations in house (Kido, 2005). This holds true in the case of Colorado. A renovation of Denver's 119-year-old Union Station by SOM is nearing completion. The design's fabric canopy over the platform is reminiscent of the canopy at the Denver International Airport, and suggests a commitment to multimodal transport throughout the Denver Metro area and beyond (Hook, 2000).

While the station architecture serves as a visual beacon for a new era of transit, it is the planning around the station that makes the entire system successful at drawing ridership. Urban planning through Transit Oriented Development (TOD) can create entirely new transit oriented communities or reinvigorate communities in need of a revival. This method has proven successful around the world, and can be applied to a range of scales and economic contexts. SOM's Union Station project in Denver, and Moule and Polyzoides Del Mar Station design in Pasadena represent two distinct scales of successful station area development, and will be reviewed as case studies. Many broad reaching studies have analyzed the qualities of Transit Oriented Developments leading to both financial, community, and transit success.

2.4 – The Case for Transit Oriented Development

2.4.1 – Understanding Transit Oriented Development

In 1995 the New Urbanist Peter Calthorpe coined the term Transit Oriented Development (TOD) (Calthorpe, 1995). He describes the concept as, "a modern version of the traditional town [with] the convenience of the car and the opportunity to walk or use transit … blended in an environment with local access for all the daily needs of a diverse community" (Calthorpe, 16). Over the course of the next two decades his concept evolved into today's understanding of a TOD as, "a compact, mixed-use community, centered around a transit station that, by design, invites residents, workers, and shoppers to drive their cars less and ride mass transit more'" (Peters, 2012). Stemming from an unhappiness with low density and auto dependent suburban developments, it is a concept that has taken root in the United States and is actively employed in both new and old developments (Landis, 1995) ranging in scale from small intercity bus systems up to large intercity rail centers (TCRP, 2004). It is convenient for this thesis that Peter Calthorpe's firm, Calthorpe Associates, was chosen to design the new Denver General Plan, "which examines the links between land use and transportation from a citywide perspective" (Calthorpe, 2013). This 2002 plan indicates a community and citywide commitment to adopting integrated transit strategies, which include TOD. Yet, "it bears noting that TOD is hardly a new concept. A century ago, highly walkable, mixed-use communities blossomed around most streetcar and interurban rail lines in the United States. The subsequent uprooting of these systems in favor of roads and super-highways witnessed the gradual disappearance of transit-oriented communities" (TCRP, 2004). What was also forgotten about these early TOD's is that the trolleys and trains that served them, "were privately developed for the express purpose of bringing potential suburbanites to new subdivisions."(Landis, 1995) However, TOD's are but one end of the development spectrum, and the1,640 TOD stations in the U.S. represent only 37.3 percent of all stations (Renne, 2009). The remaining 62.7 percent are TAD's (Transit Adjacent Developments) or TOD/TAD hybrids. "A TAD…is typically [found] in an auto-dominated, industrial and/or segregated land use environment" (Renne 2009). Through urban planning, rezoning, and aggressive redevelopment TAD's and Hybrids are being transformed into TOD's. Common to these transformative projects is, "TOD's key challenge,… the successful co-location of activity centres and residences close enough to either end of a transit trip to make rail (or, alternatively, bus rapid transit) a viable and attractive alternative to the motorcar "(Peters, 2012).

2.4.2 – Economic Benefits of Transit Oriented Development

Indeed, the goal of TOD is to increase transit ridership, but the economic benefits of TOD make these developments possible. Multiple studies have been conducted on the economic effects of TOD. "In the best cases, HSR has had strong positive benefits on the economic vitality of cities, increasing property values, creating jobs, and attracting new private investment" (Nichols, 2011). Many of these studies show that most transit developments have a mix of economic benefits. The Transit Cooperative Research Program (TCRP) determined, "that development near transit stops enjoys land-value premiums and generally outperforms competitive markets. This generally holds for residential housing (especially condominiums and rental units) as well as office, retail, and other commercial activities" (TCRP, 2004). Another study, which analyzed five California transit systems, argued that premiums were seen in residential values but not commercial ones (Landis, 1995). Finally, an examination of every American Transit Precinct by John Renne and Reid Ewing, found, "the opposite of gentrification (TODs were more affordable, had lower median incomes and a higher share of renters)" (Renne, 2013). Gentrification is of great concern to communities in the Mountain Corridor. With an ever-growing number of second homeowners, greater valley access will have a negative effect on affordable housing as baby boomers begin to buy more remote property (Final PEIS, 2011). The I-70 Coalition supports this prediction, stating, "properties within a 5 or 10 minute walk of a transit station are valued at 20-25% higher than comparable properties further away. People are willing to pay higher property values to avoid traffic congestion and to live a higher quality of life" (I-70 Coalition, 2009). Fortunately, urban experience suggests that preemptive zoning, code refinement, and public policy can prevent affordable housing loss. Despite these differing conclusions developers generally look upon TOD opportunities positively. This is especially true in areas where traffic congestion continues to worsen and where an affinity for TOD exists in the community, which is the case with the Mountain Corridor (TCRP, 2004). On average, developers give TOD a 5 out of 7 rating for economic performance, and, "savvy developers increasingly understand that profiting from TOD is a long-term process" (TCRP, 2004).

Financial benefits are not limited to TOD property values alone, though. Renne argues that even though most TOD residential units are rented by people with incomes $17,000 less than their TAD counterparts, both groups have similar expendable incomes due to TOD household savings for housing and transportation (Renne, 2009). If this can be manifested in the Mountain Corridor, ski resorts will be able to finance affordable employee housing projects at TODs thereby improving the lifestyles of their employees without increasing resort payroll costs. Another economic benefit occurs at the corporate level. Successful TOD's have demonstrated an ability to act as catalysts for further development and densification. In the Lyon area of France, for example, "many companies decided to move their offices from elsewhere in the city to the premises of the new station in order to benefit from the easy access to TGV. Agglomeration economies take hold, further attracting many new activities including hotels. The station area of the TGV station therefore became a major center of economic activity, which is the cornerstone of the economic expansion of the city" (Deakin, 2009). Co-locating larger companies with transit stations also encourages the employees of those companies to live close to a stop on the same transit line. Again, this is predicted to be the case in the Mountain Corridor where ski resorts, the largest employers in the area, will receive HSR stations. With careful planning, densification and growth at these stations can become self-sustaining similar to Lyon.

2.4.3 – Social Benefits of Transit Oriented Development

The financial premiums associated with TODs are accompanied by social premiums as well. Having learned from the mistakes of uncontrolled development in the past and with the input from the Context Sensitive Solution processes, TOD developers are realizing the social benefit of their mixed-use complexes. These come in the form of happier lifestyles since, "the less desirable features of sprawl – automobile dependence, congestion, excessive amounts of time behind the wheel, and a feeling of isolation from cultural offerings – are prompting more and more Americans to leave the suburban edge and head to transit-served sub city nodes" (TCRP, 2004). They are also seen in the form of increased community interactions. Elizabeth Deaken and Cornelius Nuworsoo, in their paper 'Transforming High Speed Rail Stations to Major Activity Hubs: Lessons for California', envision HSR stations as new city centers bustling with cultural activity (Deakin, 2009). Ultimately those stations most successful at fostering rich social interactions, "emphasize 'place making': creating attractive, memorable, human-scale environs with an accent on quality-of-life and civic spaces" (TCRP, 2004). In the case of something as high profile and technologically impressive as an HSR system, "policy makers and urban designers… should take advantage of the opportunity to create memorable urban places, with new parks and open spaces as well as residential and commercial growth" (Nichols, 2011). Ewa Kido, on the topic of 'Context Sensitive Design for Railway stations', adds that these stations can serve a number of functions including that of urban landmarks (Kido, 2005). Peters supports Kido's assertion by stating that HSR stations are a, "key fact in the rebranding of the entire station area, with stations often being (re)developed as high-profile 'flagships', signaling the transformation of the entire area to visitors on arrival. This would ideally include a comprehensive upscaling of the 'quality of place' of the entire area" (Peters, 2012).

2.4.4 – Balancing Economic and Social Benefits of Transit Oriented Development

A challenge is presented in finding a balance where both financial and social benefits are optimized. In some cases, development profitability is placed too far above social benefit. In these cases stations, "are effectively transformed into massive 'shopping malls on rails' – often to the point of being largely stripped of their civic character" (Peters, 2012). Peters also notes that overdeveloping stations often results in the neglect and closure of others. This was seen in Germany, where, in 2009, "The German Railway company DB was aiming to sell 2,400 stations across the country, seeking to keep only a core portfolio of 600, with lesser stops already being degraded into non-places without proper roofs or electronic information systems" (Peters, 2012). The maltreatment of these smaller stations is detrimental to ridership and damages the effectiveness of the transit system as a whole. Finally, branding strategies that overstate the centrality of HSR to a TOD could affect development negatively. The TCRP states, "the fact that a project is directly tied, symbolically and figuratively, to a transit facility seems to detract from its value" (TCRP, 2004). Fortunately, the precedents for over commercialization problems such as these are largely isolated to Germany and Japan, and are easily addressed in community development policies and strategic HSR branding.

2.4.5 – Ridership Benefits of Transit Oriented Development

Those aspects of TOD whose strategies cannot be overused are those related to increases in transit ridership. Study after study has determined quantifiably that Transit Oriented Developments improve transit ridership. One such study reported that concentrated development at TOD's resulted in, "an average of 44% fewer daily vehicle trips" (I-70 Coalition, 2009). Likewise, studies have shown that the share of commuters traveling by transit is directly related to the share of jobs and population within a half-mile catchment of a station (Renne, 2009). U.S. TOD's, for example, observe 3.5 times more people commuting via transit, bicycle, or walking than TAD's, and also have half the level of vehicle ownership of TAD's (Renne, 2013). It should not be overlooked, though, that TOD's are the result of careful planning and zoning practices. These practices provide enough data that it is possible to derive common characteristics amongst successful Transit Oriented Developments.

2.5 – Transit Oriented Development Commonalities

A review of numerous TOD studies shows that commonalities amongst TOD's can be divided into three categories: accessibility, density, and planning. It is likely that new developments that focus upon balancing the commonalities within these categories will succeed in fostering intermodal, physical, economic, and social improvements while also achieving the primary objective of increasing transit ridership. (Deakin, 2009)

2.5.1 – Station Accessibility in Transit Oriented Development

The locations for transit stations and the accessibility to them from surrounding developments is of the utmost importance to TOD success. Previous examples showed that a central location is required for a transit station, "to provide a fast and convenient door-to-door travel experience" (Nichols, 2011). Nichols emphasizes that these centrally located station buildings should be highly visible from both trains and the developments themselves, but also recognizes that station area growth requires easy pedestrian access, customer convenience, and heavy foot traffic (Nichols, 2011). Accessibility, therefore, is of equal importance to location. Visitors and transit riders must be able to access stations via foot, bicycle, bus, or car, and if this accessibility is compromised the TOD will suffer. "Residents living within 1⁄4 mile of a transit station arrive by foot or bicycle; however, this share plummets markedly if there are significant physical, symbolic, and psychological barriers to bicycle and pedestrian traffic like wide, busy roads and incomplete sidewalks" (Fig. 18) (TCRP, 2004). This observation is confirmed by Renne who argues that, in addition to station proximity, the number of four way stop intersections around a station have the strongest influence on transit use by pedestrians and bicyclists (Renne, 2013). Fortunately, TOD developers recognize this, and generally make sure, "that the walk between a project and a station portal is safe and reasonably attractive" (TCRP, 2004) Yet the importance of establishing TOD stations as hubs for intermodal transit networks is essential for bringing commuters from outlying developments to rail stations. Intermodality introduces challenges that sometimes conflict with pedestrian and bicycle access, though. These, "often result in station and road designs and parking layouts that detract from the quality of walking. More fundamentally, this represents a conflict between the role of a station as a functional 'node' and a desirable 'place'" (TCRP, 2004). This is further complicated by the original problem of convincing American drivers to choose riding over driving. As 'Choice' transit users, these individuals are sensitive to the quality and frequency of transit service and seek travel modes that minimize the need to transfer (TCRP, 2004). Deakin echoes the importance of transfer ease between intermodal connections (Deakin, 2009). Successful TOD accessibility plans, therefore, must provide seamless transitions between transit modes without impacting safety or accessibility for those pedestrians and bicycles originating within a ½ to ¼ mile station catchment. Transit Oriented Developments must also balance place making and design visibility with transit node functionality, which requires careful attention to parking and road design.

2.5.2 – Planning for Transit Oriented Development

Planning in advance of HSR arrival is a key element to optimizing accessibility and TOD success as a whole. This planning involves accommodating Transit Oriented Developments in new citywide master plans, modifying zoning and building codes, and building upon existing economic momentum. There are many successful TOD networks throughout the U.S., including San Diego and Denver, but several Metro stations in Washington D.C. are amongst the best examples of transit stations where success has been attributed to significant advanced planning. These Metro stations have become major employment and activity centers (Deakin, 2009). In particular, the TCRP reports, "many local observers attribute Arlington County's success at adding over 15 million square feet of office space, 18,000 housing units, and several thousand hotel rooms [in] the Rosslyn-Ballston corridor since 1970 to [an] early vision" (TCRP, 2004). Since the publication of this report, the Metro system has opened new TOD stations that have coincided with beneficial change. Of particular note is the Navy Yard-Ballpark station serving Nationals Park, which has played a central role in transforming the troubled neighborhood along South

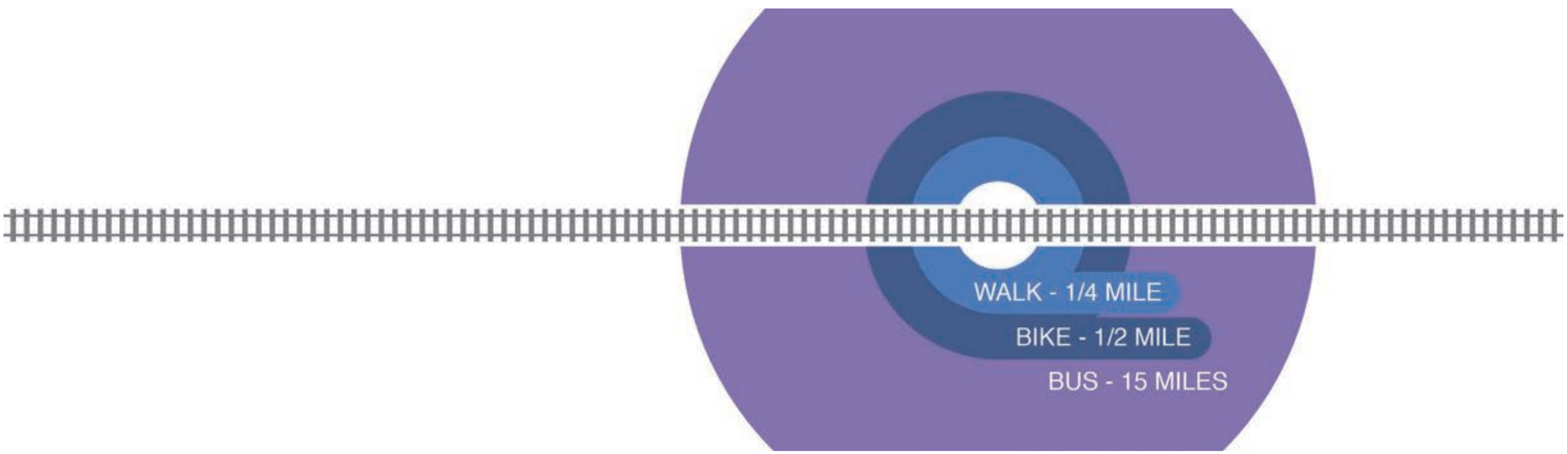


FIGURE 18 - STATION ACCESSIBILITY IN TRANSIT ORIENTED DEVELOPMENT

Capitol Street. Yet the importance of advanced planning cannot be understated.

Experience elsewhere has proved that a rail station alone does not manifest Transit Oriented Development. Amongst other things, TOD requires land use changes to support development (Feigenbaum, 2013). Again, without advanced planning, land use changes alone do not spur development. This was demonstrated with, "land use changes at four (representative) San Diego Trolley stations between 1980 and 1994: proximity to a Trolley station was not found to be a significant determinant of vacant or developed land use change" (Landis, 1995). The earlier discussion of TGV beet stations aligns with this observation. Another TGV station, Le Creusot, lacked existing business activity, which deterred new business and prevented the station area from fulfilling the vision of becoming a new activity center (Deakin, 2009). The assumption of "if you build it, they will come" at Le Creusot was further compounded by poor accessibility (Nichols, 2011). Additionally, for successful planning to be effective, "the presence of a buoyant local economy that can take advantage of the new opportunities offered by the high-speed rail accessibility [is required]" (Givoni, 2005). In order to capitalize on this existing economic strength, cities must alter their zoning policies to, "allow higher-than-average densities and a land-use program and mix that satisfy market demands" (TCRP, 2004). Additionally, parking space requirements need to be relaxed so that developers can encourage transit use should they so choose. "Many developers relate to the idea that parking standards should be lowered to the degree that significant numbers of residents, shoppers, and workers ride transit. On the other hand, many have embraced the principle that parking is an effective marketing tool" (TCRP, 2004). Regardless of the position developers take on parking, cities need to enable developers to create the most effective developments possible within a more flexible zoning and code framework. Advanced planning, prior to the arrival of HSR, therefore, is the lynch pin for TOD creation and community betterment. Cities are encouraged to modify their zoning and code policies, to incorporate HSR and TOD into their master plans, and to support economic momentum where HSR stations are expected to be located.

2.5.3 – Population Density for Transit Oriented Development

The last TOD commonality category to discuss is density. Density was mentioned earlier in regards to HSR ridership requirements, but is appearing again in regards to TOD development. Fortunately, density at TOD's is the least convoluted or controversial element in the equation. Simply put, "residents of higher residential density areas are more likely to walk than drive to transit, and residents of 'traditional neighborhoods' with a greater mix of land uses are more likely to utilize transit than are residents of conventional suburban neighborhoods" (Renne, 2013). Renne's study also established that all TOD's have at least 30 jobs or residents per acre, a mix of residential and commercial land uses, and block sizes less than 6.5 acres (Renne, 2013). The TCRP adds that FAR's in excess of 1.0 are not uncommon, and relaxed parking requirements have been adopted by the most aggressive TOD developments (TCRP, 2004). Conveniently the 30+ density requirement is becoming more attractive to residents seeking to escape automobile congestion and the lack of social interaction found in low density areas. 40 percent of the entire population and 80 percent of Generation Y (people born between 1980 and 2000) state a desire to live in TOD's (Renne, 2013). Projected population growth through 2050 indicates that densification at rail stations is required if the expected 100 million new Americans are to have transit accessible places to live (Renne, 2013). By incorporating design and planning into this inevitability, a station area can create, "a vibrant activity center or hub for social interaction and entertainment" (Deakin, 2009). Thus, it can be concluded that higher density mixed-use developments built upon larger block sizes will sustain Transit Oriented Developments and their transit ridership requirements. Although achieving a 30+ density in the corridor towns is unlikely due to context sensitivity, actively seeking higher densities than existing will still improve ridership.

2.6 – Transit Oriented Developments in the I-70 Mountain Corridor

Are TOD's appropriate for the I-70 Mountain Corridor? The bulk of the evidence as well as community feedback indicates that they are. The I-70 Coalition reported, "corridor communities recognize through their community visions and planning policies that future transportation systems should be inclusive of transit options, that transit and bike/pedestrian connectivity is essential, and that land use development practices will influence whether transit service is effective in reducing automobile trips" (I-70 Coalition, 2009). Looking back at our discussion of TOD's throughout the world, we see that the Mountain Corridor is, in fact, ideal for TOD incorporation.

2.6.1 – Transit use in the Mountain Corridor

For this discussion the Vail-Avon area of Eagle County will again be used as an example (Fig. 19). "The County is home to both resort-oriented communities in the eastern portion of the County, and local resident-based communities in the western half of the county. This development pattern has resulted in a strong east-west commuter travel demand within the County" (I-70 Coalition, 2009). These commuters are broken into two groups, the local work force and tourists/second homeowners. Congestion along I-70 West of Vail is significantly less than it is to the East of Vail, but this does not mean that the east-west commuter travel will remain auto-dominated after the arrival of the AGS. Parking within the Vail and Beaver Creek resorts is limited, and many commuters rely upon the existing ECO bus service to get to work. The location of future stations in Vail and Avon will determine to what extent these commuters continue to rely upon the bus network or are able to transition to rail.

As it stands, stations in Eagle County are proposed for Vail, Avon, and the Eagle County Airport (AGS Feasibility Study, 2014). The Vail station would allow direct pedestrian access to the ski slope, while the Avon station will require a transfer to the bus network to deliver tourists and commuters to the Beaver Creek Area. The Vail location would be most beneficial to tourists, while Avon would primarily benefit valley residents and the work force (Coalition, 2009). In light of the primary goal for the I-70 HSR to relieve congestion coming from Denver, it seems that the Vail location would be most successful at removing the greatest number of drivers from the busiest portion of I-70, and would eliminate an unappealing mode transfer for those 'choice'

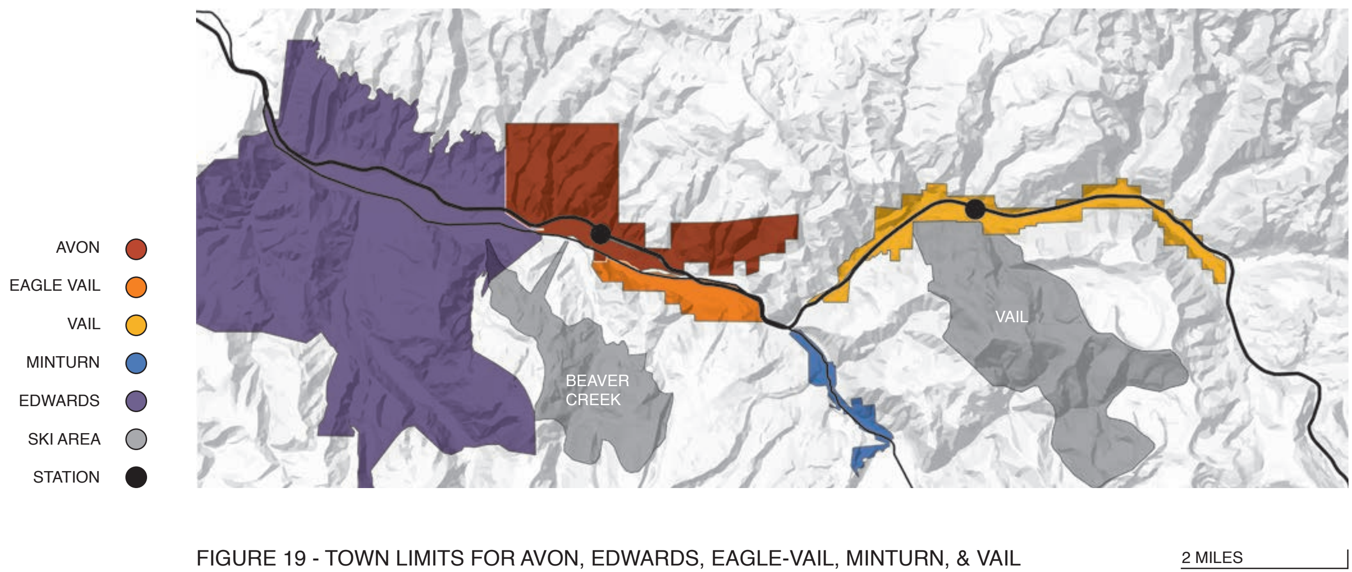


FIGURE 19 - TOWN LIMITS FOR AVON, EDWARDS, EAGLE-VAIL, MINTURN, & VAIL

riders travelling to the resorts. Regardless of station location, each must be intermodal, and intermediate towns without stations would need to bolster their existing bus hubs and networks to integrate with the larger network.

2.6.2 – Affordable Housing Shortage in the Mountain Corridor

A major concern of community members is how transit can, "take Eagle County residents and employees to employment and help address affordable housing issues present in resort communities" (I-70 Coalition, 2009). Affordable housing is of equal concern to resort owners. "Because of the shortage of affordable housing in and around resort communities, many employers are forced to either increase salaries to cover commuting costs or to work with local officials to provide housing options for their employees. Vail Resorts and Aspen Skiing Company, two of the largest employers in the Mountain Resort Region, are currently expanding their employee housing options… If congestion continues to worsen, employers will need to either add more housing or increase salaries to avoid employee shortages" (Impact of I-70 Congestion, 2007). Through amendments to the code, portions of new TOD's could be reserved for affordable/employee housing. The influx of the resort work force at TOD's will provide necessary density numbers and will contribute to the development of TOD's as social activity centers, while increasing transit commuting rates. Finally, resort employees will see savings in their transportation and housing costs, and a corresponding improvement in lifestyle via an increase in observed expendable income.

2.6.3 – Consolidating Density in the Mountain Corridor

The density prerequisite for TOD's is not only a benefit to commuters, but to the cherished mountain environment as well. By updating master plans and incorporating overlay zoning, towns along I-70, such as Avon and Edwards, can limit mountain sprawl and concentrate development around pre-planned activity nodes. Current planning policies in towns throughout the Mountain Corridor welcome TOD developments in their towns. For example, "current Planning Policies and Zoning Regulations in Vail support further densification, a viable mix of land uses and an overall multi-modal transportation approach. Plans and policies are based on the concept of walkable villages with critical transit services linking all parts of the village" (I-70 Coalition, 2009). In keeping with TOD requirements, Vail's Land Use Plan calls for densities from 18-20 dwelling units per acre for multi-family developments and up to 50 dwelling units per acre for hotels within the mixed-use core area (I-70 Coalition, 2009). Avon has plans to be similarly organized, but requires significantly greater development to establish a TOD around the station. Vail has limited buildable area, but that area is in immediate proximity to the village and existing transit hub (AGS Feasibility Study, 2014).

Although this argument focused upon Vail and Avon, the context is comparable to the other towns throughout the corridor. The socioeconomic composition of the Mountain Corridor is staged for AGS arrival and the development of TOD's. Community planning will determine whether these TOD's will achieve requisite densities, while design will determine their success in place making. The remainder of this thesis will focus upon the design of a station template that can be modified and applied to any of the six intermediate stations along the alignment.

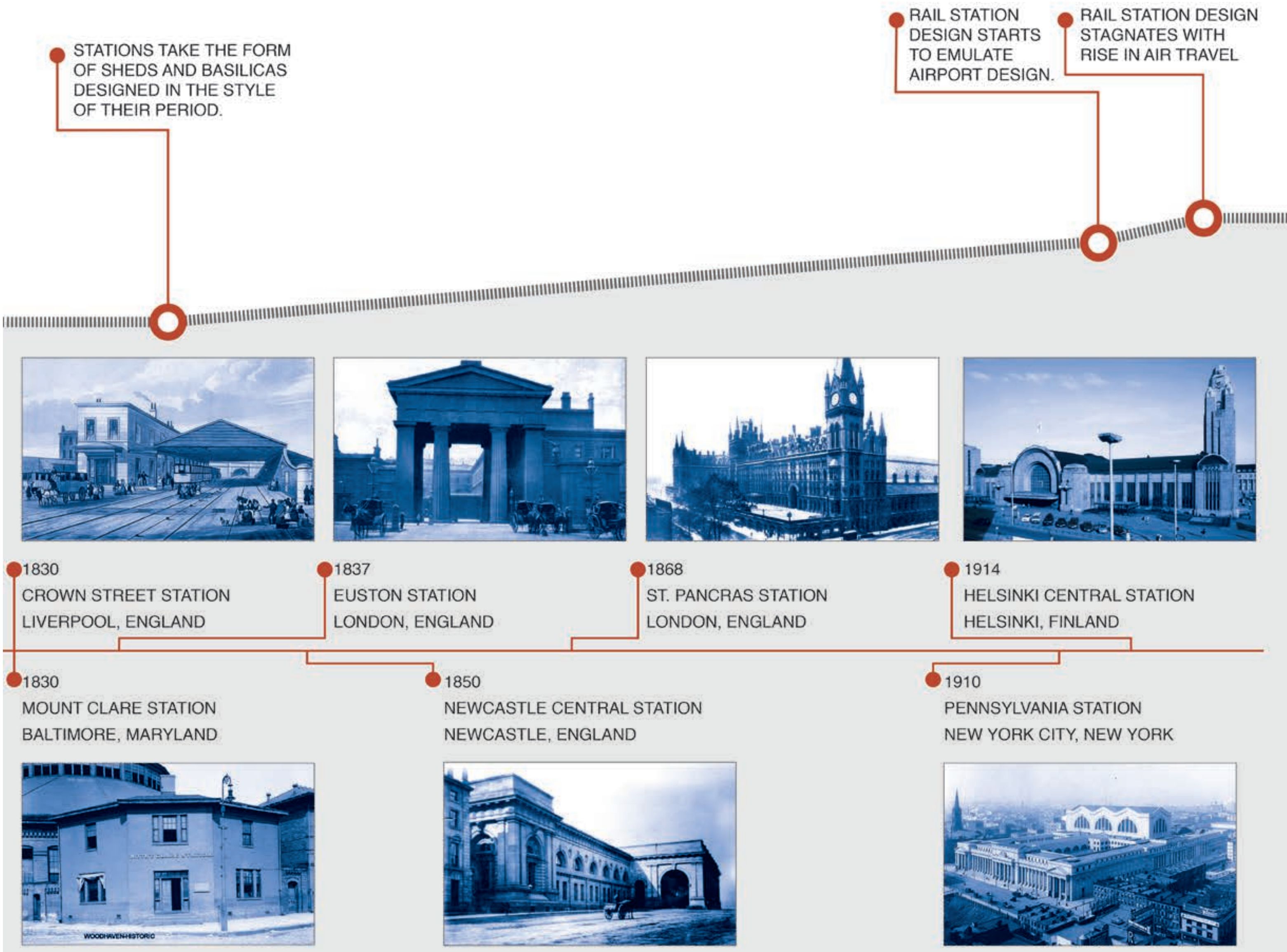
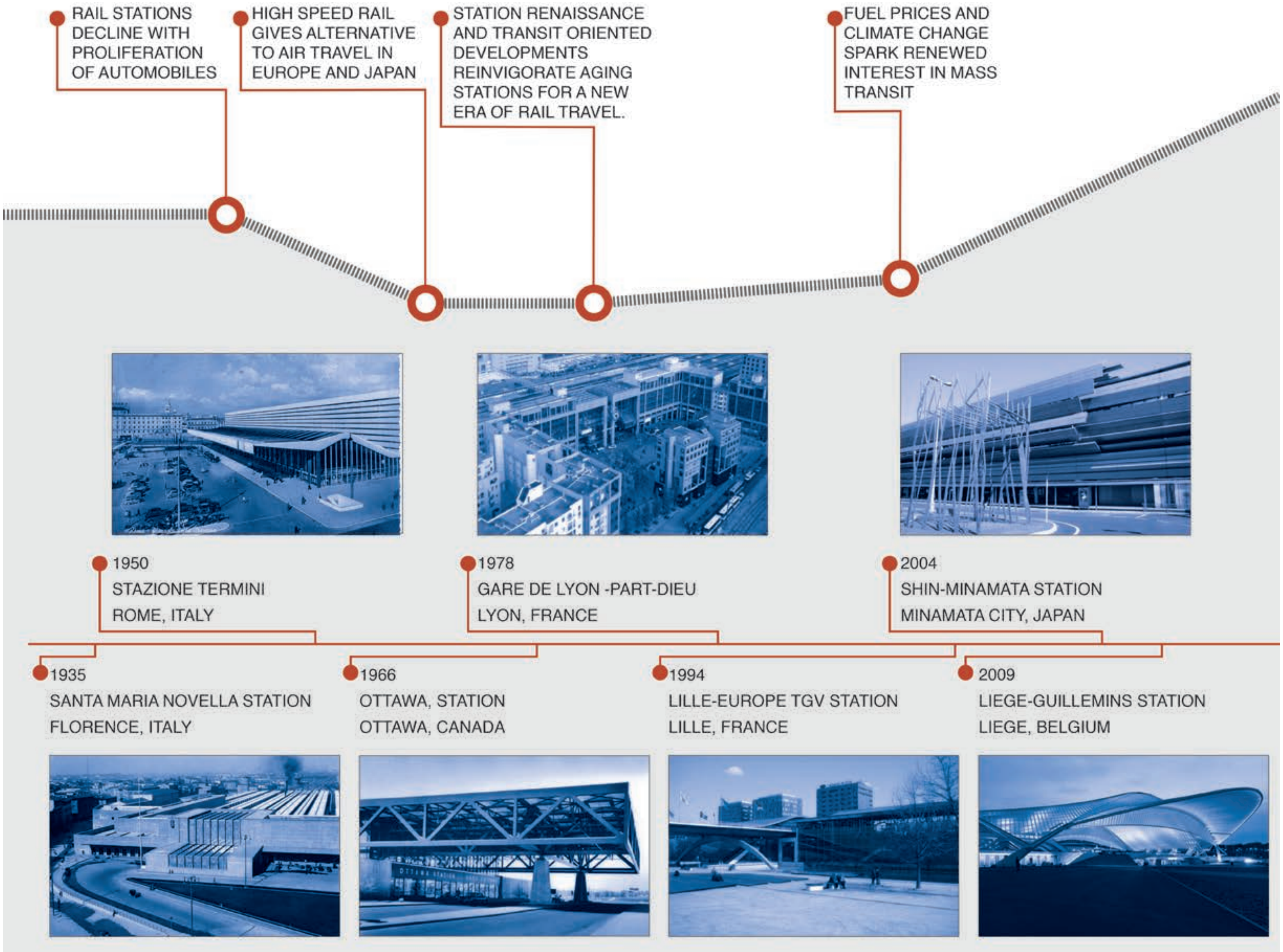


FIGURE 20 - STATION TYPOLOGICAL HISTORY


RAIL STATIONS DECLINE WITH PROLIFERATION OF AUTOMOBILES
HIGH SPEED RAIL GIVES ALTERNATIVE TO AIR TRAVEL IN EUROPE AND JAPAN
STATION RENAISSANCE AND TRANSIT ORIENTED DEVELOPMENTS REINVIGORATE AGING STATIONS FOR A NEW ERA OF RAIL TRAVEL.
FUEL PRICES AND CLIMATE CHANGE SPARK RENEWED INTEREST IN MASS TRANSIT
1950
STAZIONE TERMINI
ROME, ITALY
1978
GARE DE LYON -PART-DIEU
LYON, FRANCE
2004
SHIN-MINAMATA STATION
MINAMATA CITY, JAPAN
1935
SANTA MARIA NOVELLA STATION
FLORENCE, ITALY
1966
OTTAWA, STATION
OTTAWA, CANADA
1994
LILLE-EUROPE TGV STATION
LILLE, FRANCE
2009
LIEGE-GUILLEMINS STATION
LIEGE, BELGIUM

3.1 - Theoretical

Chapter two in large discussed the theory and research behind TOD's. Chapter three will focus more directly upon the station design itself. Historically, station design follows the most progressive and emblematic style of the time, but application of style is often haphazard due to competing priorities between engineering and design (Fig. 20). The result is often manifested in high style facades masking purely functional train sheds. Perhaps this is why engineer and architect Santiago Calatrava has had such great success in transportation architecture. The engineer in him is able to recognize that the station itself is simply an agglomeration of egress and circulation that must function with tremendous efficiency, while the architect in him understands the importance of iconic design, light and space. Calatrava's work will not be used as case studies for this thesis, however, due to their scale and footprint, which are not appropriate for Colorado mountain towns. The Japan HSR station designs of Makoto-Sei Watanabe, on the other hand, are comparable in function and design, but minimize the building footprint (Jones, 2006). These will be discussed as case studies further on.

3.1.1 – Right of Way Restriction

The approach for this thesis design is to locate as much of the program within the 40' Right of Way as possible. The 40' ROW was chosen because it is the constant site attribute between all of the stations, and staying within that area as much as possible will reduce overall land costs. By catering to the restrictive 40' ROW a common station plan can be developed and applied to a greater number of stations with minimal alteration. The more common the plan amongst stations the better each station will function. If passengers are able to depart a station in a similar circulation pattern as they arrived, their familiarity with the plan will improve the flow of circulation and egress (Griffin, 2004). The less time passengers spend deciphering way finding features and interpreting the plan, the fewer bottlenecks will arise and the platform and terminal will feel less crowded. The 40' restriction is most applicable to the towns of Vail and Idaho Springs. Vail has no available land to build upon, and the station must be built in the highway median or as a bridge over the highway from the existing transit hub (AGS Feasibility Study, 2014). Idaho Springs has more developable land for the station, but the town itself has expanded to its physical limits. The more land that can be saved from station development the more land can be redeveloped as a profit generating TOD.

3.1.2 – Circulation and Egress

The ROW restriction heightens the importance of efficient circulation and egress. This project seeks to arrange vertical circulation elements in a manner that will distribute passengers appropriately whether they are arriving or departing. This is a reaction to those stations, such as Rome's Termini Station or Florence's Santa Maria Novella Station, which depend upon horizontal circulation to distribute passengers. In these stations, passengers arrive at the end of the platform and must walk the length of the train to get to the end vehicle. This results in high congestion at the throat of each platform where it intersects the terminal. The vertical circulation in this thesis project uses the (blasphemous) concept of symmetry to overcome this problem. Passengers arrive at the center of the terminal and use mirrored sets of escalators, stairs, and elevators to ascend to the platform. The stairs and escalators draw passengers away from the center of the station and deliver them to the junction between the second and third car from each end of the consist. The elevators are centrally located near the terminal entrance to accommodate those individuals with special needs and delivers them to the center car of each consist. The result is the natural distribution of passengers along the entire length of the train while reducing congestion. Descending works in reverse and funnels passengers to a ground level terminal that can be significantly shorter in length than the platform. Passengers will be within close proximity to ancillary program and all intermodal connections as well as a terminal plaza, which will be integral to a TOD design. This funneling works well for multiple station plan scenarios, including those that will have to direct passengers to a tunnel or bridge across the highway, as is the case in Vail.

3.1.3 – Enabling Transit Oriented Development

In regards to TOD incorporation a number of goals are implemented into the station template. The first is the separation of transit modes in a manner that protects pedestrian and bicycle access. Parking garage access and passenger drop-off areas are therfore located on the backside of the terminal adjacent to the highway. In a sense the terminal is turning its back on the automobile in preference for mass transit and pedestrian traffic while still providing vehicle users with equally convenient access. This removes most of the traffic from the street in front of the terminal. Streets surrounding the station are limited to two lanes (one in each direction) with wide sidewalks separated by a row of trees. All intersections are to have four way stops or round-a-bouts with pedestrian activated crosswalk lighting. This ensures that what traffic remains in front of the station is not a danger to pedestrians. To encourage TOD progress, the transit plaza will be shared by appropriate program for the site, which may include retail, hotel, mixed-use, and place making features such as ice skating rinks. The terminal parking garage will also be shared with the TOD program in order to limit the amount of land dedicated to parking elsewhere.

3.1.4 – Foundation for Architectural Language

With a common platform plan, circulation pattern, and requisite TOD elements set, the remainder of the design can focus upon the architectural elements that will make each station a unique icon for its respective town. This is a similar approach to Watanabe, who uses unique envelopes to differentiate stations with similar plans (Jones, 2006). For these envelopes and many others throughout the world it is commonplace for the visual language to draw from the vehicles themselves by communicating motion. Watanabe's Kashiwanoha-Campus and Shin-Minamata Stations, Calatrava's Lyon Airport Station, and Foster's Singapore Expo Station all communicate motion or flight (Uffelen, 2010). Although the requisite long station buildings lend themselves to the motion metaphor, it is all too commonplace, and generally fails to speak to the context of the area. This is ironic since the architecture is communicating an action at the one point in time that the vehicle is actually stationary. In the case of Watanabe's and Calatrava's stations, the architecture envelops the trains, and is thereby compelled to externally communicate the action of the vehicles inside. This is unnecessary. This thesis proposes a central enclosed platform with the trains located outside on the periphery. This arrangement has a number of benefits including space savings and energy conservation, but more importantly allows the train to become part of the exterior. There is no need to emulate train motion through design, when the train motion is already part of the design. What better way to promote MAGLEV than to place it on display for the world to see? These are not dirty and loud locomotives. They are silent and polished arrows of the most advanced technology in the world so let them be seen and help in the ultimate goal of attracting ridership.

In the case of Colorado, the motion concept in envelope design should be secondary. Yes, the motion of MAGLEV is exhilarating and awe inspiring, but passengers are not riding the train for the thrill alone. They are riding so they can enjoy destinations that continue to thrive because of their history and mountain context. By communicating history and nature architecturally, the stations no longer speak to technology, but rather to the greater reason for using the technology in the first place. This concept is rare in examples of transportation architecture since most are located in dense urban areas, and not small rural towns like Colorado. For this reason one has to capture the contextual sensitivities of an architect like Peter Zumthor (were he to design a station).

The theoretical design concept for each of the Colorado stations is to challenge the common expectations for a station by inverting them. This begins by moving the trains outside and to the periphery of the station. Passengers awaiting a train can still see approaching trains from the platform, but the best viewing area is actually outside, which turns the transit plaza in front of the terminal into a platform of its own.

The application of these theoretical concepts as they apply to the Avon station is discussed in Chapter 4.

3.2 – Psychological

Since platforms and terminals are predominantly composed of circulation and egress elements, one of the major challenges involves controlling and optimizing pedestrian flow within large enclosed spaces. Research spearheaded by Dirk Helbing and Peter Molnar on the subject of pedestrian self-organizing behavior is of great use in this matter. Their research showed that in moderate densities people begin to move as a fluid. They move in the most direct path possible, and naturally create a border with people moving in an opposite direction while only rarely crossing into the oncoming flow. Furthermore they showed that a row of columns creates a virtual wall across which pedestrians are unlikely to cross when moving in a parallel direction. (Helbing, 1998 & 2001). Architecturally, we view columns in plan, and therefore assume they are permeable and have little impact on flow unless directly obstructing the direction of travel. However, people do not experience columns in plan, and when standing to the side of a row of columns the column widths visually join to block the view to the other side of the column row. This can be seen in highway designs where thin fins are attached to concrete medians every few feet. Drivers are prevented from seeing across the median at an oblique angle, while the perpendicular view is unobstructed. When this concept is applied to station design the columns can be placed in reference to desired pedestrian flow rather than by simple structural necessity. In the Avon station design, for example, the platform columns are placed so as to separate departing and arriving passengers congregating at escalators and stairways, which prevents congestion. Likewise, the columns near the elevators are arranged to create areas of sanctuary where people can congregate without feeling like they are blocking an aisle.

This concept is complimented by the psychological impact of ceiling height, which has multiple influences on movement. Research from the University of Minnesota shows that ceiling height influences how people think. High ceilings inspire open thinking and a sense of freedom while lower ceilings inspire detailed thinking and a sense of confinement (University of Minnesota, 2007). In a physical sense, ceiling height also has the ability to direct movement like the invisible hand of the architect pushing people where they should go (Ballast, 1992). When applied to station design a varied ceiling height can compliment the effects of column arrangement. High ceilings encourage people to stand and to think about where they are going, and what they should be doing. This makes high ceilings good for circulation routes by drawing people into high ceilinged areas and encouraging them to think. Low ceilings encourage people to sit and to focus on one thing at a time. Open platform edges are thus well served by lower ceilings, as are information display areas, vending areas, and waiting areas.

Through subtle psychological manipulation via design the potentially chaotic open areas of platforms and terminals are able to encourage passengers to organize and move in accordance with the purpose of the building.

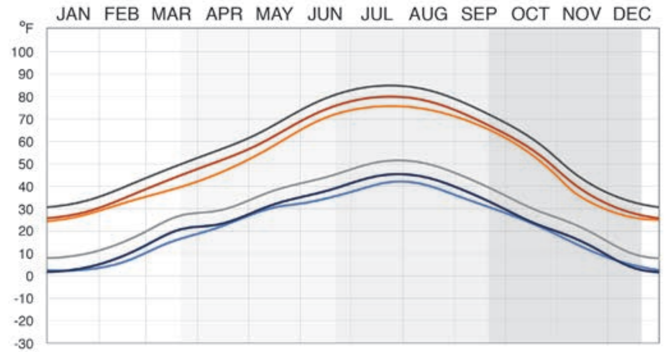
3.3 – Ecological

The ecological impact of the I-70 AGS system was briefly discussed in Chapter 2. The system itself benefits the environment and wildlife population by minimizing its footprint with an elevated track that allows freedom of movement beneath. The guideway is susceptible to environmental dangers, though, with landslides, rockslides, and avalanches being notable concerns (AGS Feasibility Study, 2014). For the most part the stations along the route are in less danger of these occurring.

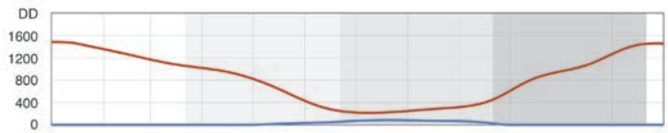
The stations will, however, be exposed to severe weather throughout the year (Fig. 21). This includes heavy snow, hail, rain, lightning, and high winds. Using Avon as an example, the average yearly temperature is 39.3 F with summer highs near 80 F and winter lows around 25 F. Buildings rarely require cooling, but are high-energy consumers for heat. Snowfall in Avon averages 74.79 inches, but precipitation is heaviest in summer. The total yearly precipitation of 15.64 inches is well less than the 38.67-inch national average. Winds average 22.39 mph with highs near 40mph in summer and fall (USA.com, 2014). The other towns throughout the corridor experience similar weather to Avon with some expected variation based on altitude and localized weather patterns.

Within this environmental context is highlighted the importance of addressing heating requirements to reduce energy

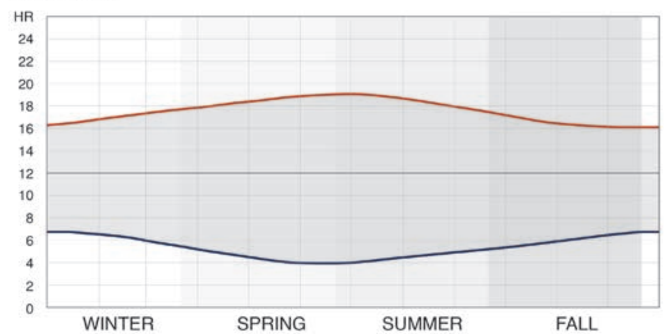
HIGH LOW TEMPERATURE



DEGREE DAYS - BASE 65*



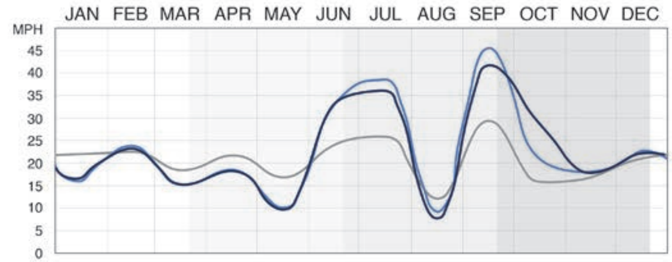
DAYLIGHT**



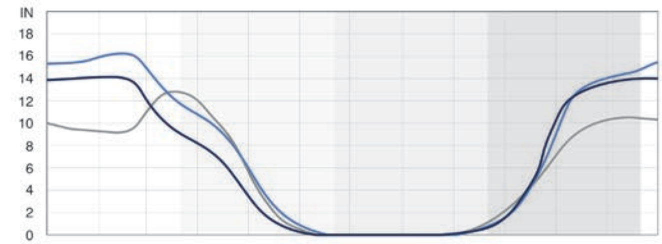
ANNUAL AVERAGES

	AVON	VAIL	STATE	NATION
TEMP - F	39.3	38.9	46.3	54.5
PRECIP - IN	15.64	15.24	15.98	38.67
SNOW - IN	74.79	69.16	67.30	23.27
WIND - MPH	22.39	22.22	20.16	16.93

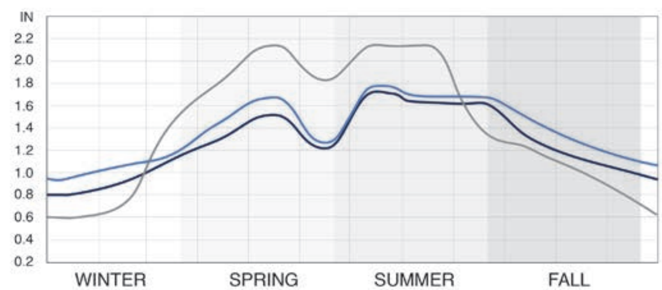
AVERAGE WIND SPEED



AVERAGE MONTHLY SNOWFALL



AVERAGE MONTHLY PRECIPITATION



AVON
VAIL
COLORADO

DATA SUPPLIED BY USA.COM
* DATA SUPPLIED BY DEGREEDAYS.NET
** DATA SUPPLIED BY CLIMATE-CHARTS.COM

FIGURE 21 - CLIMATE

consumption, improve sustainability, and improve passenger comfort. An interview with local engineer Brandon Chalk, revealed that the common passive energy methods in the mountain towns include solar energy, solar hot water, and geothermal heating and cooling (Chalk, 2014). However, snow and hail affect the longevity of solar systems, which require more maintenance than systems in less hostile climates. Geothermal, although a potentially excellent source of energy in the mountainous geology, is prohibitively expensive vertically due to drilling through mountain rock, but can be effective horizontally if a river or lake is within roughly 150 feet (Chalk, 2014). Regardless of the passive methods used, though, forced air and radiant heating are always required to augment passive systems.

Heating concerns are another motivator for placing trains on the outside of enclosed station platforms. The reduced volume has a smaller heating requirement. Additionally, the platform space does not have to be open at the ends to accommodate the guideway. Instead, doors from the platform to the train are opened only when required, and heat loss is minimized by air curtains or mechanized gaskets.

Other ecological considerations are aesthetic in nature. Cross-valley views of the mountains are cherished by residents and influence property values. For the AGS and stations to be welcomed by the mountain population an effort must be made to respect them. To accommodate this concern the state encourages low profiles, natural materials, and architectural language appropriate for the location (Final PEIS, 2011). Local zoning requirements also dictate density and buildable area limitations to ensure environmental permeability. However, mountain town growth predictions may see density and space restrictions relax in order to limit valley sprawl.

3.4 – Socioeconomic

The mountain corridor socioeconomic status is considerably different from the rest of Colorado and elsewhere in the United States. To demonstrate this, the towns of Vail and Avon are analyzed using data provided by usa.com (Fig. 22).

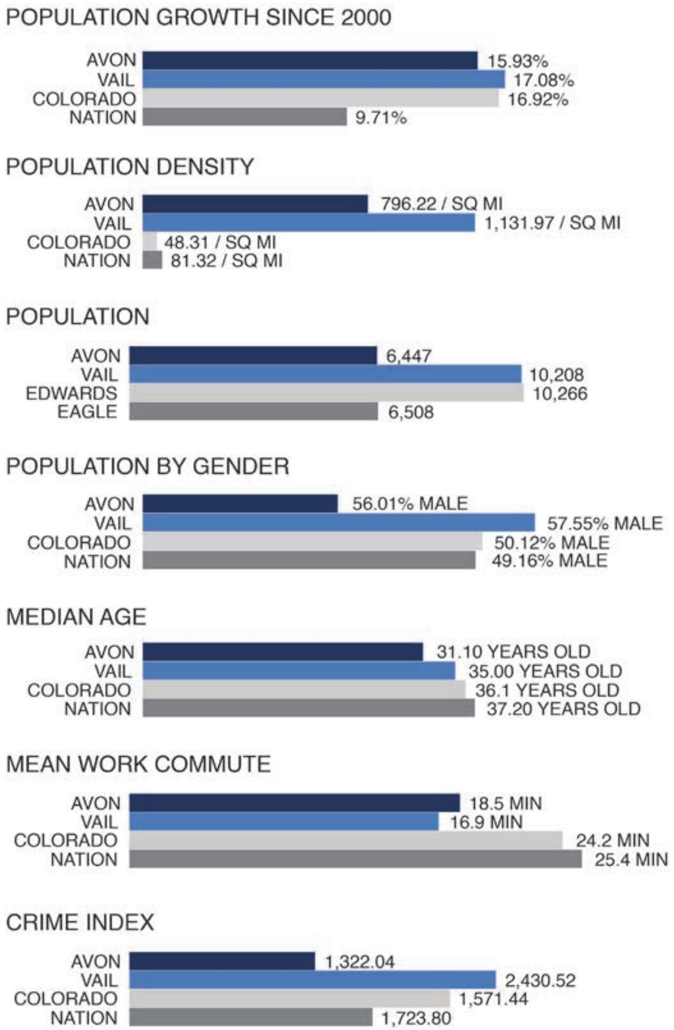
3.4.1 - Demographics

The corridor towns have very small populations, a result of their rural locations and limited land. Vail and nearby Edwards are the two largest towns with populations just over 10,000. Vail's density is the highest at 1,132 people per square mile, which places it at a staggeringly low 1.7 people per acre and well short of what TOD precedent's suggest is required (usa.com, 2014). As was discussed in Chapter 2, though, the existing town sizes and densities can support the AGS ridership demands through tourism and commuters from Denver. Encouraging TOD at station sites helps increase this number, but expecting urban density development is unreasonable.

Populations are in the range of 56% male, 7% higher than the national average, and are predominantly Caucasian (95%) with Hispanic comprising much of the remainder. The average age is also younger than the national average by two to six years. This is largely attributable to the attraction of the outdoors to young people. Population growth is well above the national average, but in line with the state. Since 2000, Vail and Avon have grown 17% and 16% compared to the national average of 9.7%. Housing prices continue to grow, but at a slower rate than the national average, which is due to pre-existing high home values. Average values in Avon and Vail are $476,400 and $670,800 respectively compared to the Colorado average of $236,800 and the national average of $181,400. Worker incomes are also higher, but not enough to gain ground on rising housing prices. Avon and Vail workers average $35,208 and $36,978 respectively compared to Colorado and the nation at $31,728 and $30,376 respectively (usa.com, 2014). With continued growth expected, the demand for new and more affordable housing increases, as does the ability to commute to towns with lower home values.

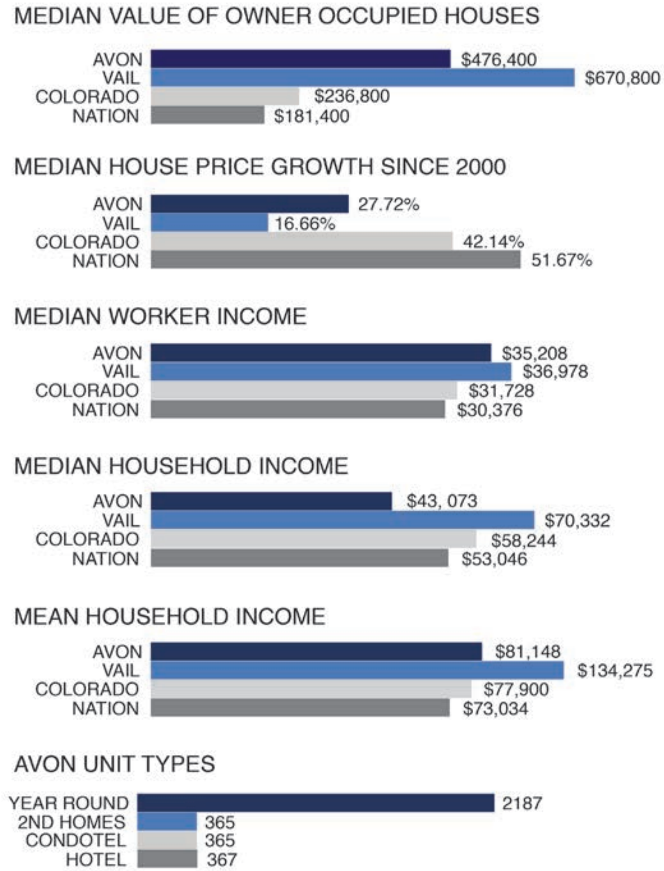
3.4.2 – Commuting and Transit use

The corridor towns are already open to mass transit, which is a byproduct of the small town sizes and shorter overall commuting times. Avon and Vail residents commute 18.5 minutes and 16.9 minutes respectively on average compared to 24.2 minutes for all of



TOWN OF AVON INCORPORATED FEBRUARY 24, 1978

DATA SUPPLIED BY USA.COM



COMMUTING METHOD

	AVON	VAIL	STATE	NATION
DRIVE	69.8	53.3	74.6	76.1
CARPOOL	9.6	9.9	10.2	10.0
TRANSIT	7.5	14.4	3.3	5.0
WALK	4.6	8.5	3.1	2.8
BIKE / OTHER	0.0	5.6	2.5	1.8
WORK AT HOME	8.4	8.3	6.5	4.3

FIGURE 22 - DEMOGRAPHICS

Colorado and 25.4 minutes for the nation. The commuting methods differ significantly from the national average as well, most notably in the rate of transit and pedestrian usage. 7.5% of Avon and 14.4% of Vail residents commute via transit compared to 5.0% nationally. Likewise, 4.6% of Avon and 8.5% of Vail residents commute on foot compared to 2.8% nationally. These figures can be attributed to the small town sizes, limited parking, extensive bus networks, and a generally more active lifestyle. Yet these figures could still be higher. For example, 15% of Breckenridge residents commute via transit and 27.5% commute on foot (usa.com, 2014). In general these numbers support the likelihood of AGS and TOD success throughout the mountains, and the importance for stations to be pedestrian and transit friendly.

3.4.3 – Revisiting a Denver Winter Olympics

Denver has expressed interest in hosting the Winter Olympics around 2034. These Olympics occur around the time that an AGS could be completed, and may serve as a global unveiling for a state of the art MAGLEV system and a reason to implement iconic station designs throughout the corridor. Denver was awarded the hosting honors for the 1976 Winter Olympics, but became the only host city in history to decline the responsibility when the populace passed a referendum that turned the Olympics away (Fig. 23). The reasons behind the decision were largely political, but at the forefront were fears the Olympics would spark a massive influx of permanent residents, as well as concerns that I-70 could not handle the number of visitors travelling to the mountains for alpine events. Colorado was a hard secret to keep, though, and the population grew rapidly anyway (Sanko, 1999). Now, with those fears behind them, and a new MAGLEV AGS on the horizon, the Olympics are reentering the discussion. Adding to the case is the Beaver Creek Ski Area near Avon. Beaver Creek owns two of the best alpine racecourses in the world, Birds of Prey and Raptor, and will host the 2015 World Alpine Ski Championships (Meyer, 2013).

This data suggests higher density affordable housing in close proximity to station centers will help alleviate housing problems for young people moving to the area at a high rate. Economic concerns for iconic station designs can also be offset by the argument for a possible Olympics, which will further improve tourism to the area long after the Olympics have left. This also suggests the inclusion of hotels within the TOD area may be of benefit since Avon currently has fewer than 750 hotel rooms (usa.com, 2014).

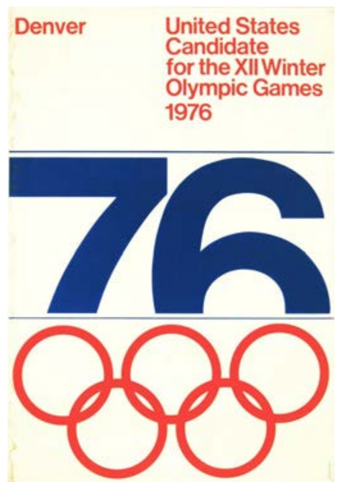


FIGURE 23 - 1976 DENVER WINTER OLYMPICS POSTER

3.5 - Case Studies

3.5.1 - Del Mar Station Transit Village

Location: Pasadena, California
Transit type: Lite Rail (Los Angeles' Gold Line)
Architect: Moule and Polyzoides – Pasadena, California
Year Completed: 2007
Residential Units: 347
Affordable Housing Units: 15%
Residential Density: 100 units / acre
Commercial Space: 20,000+ square feet
Parking: 1200 subterranean (600 dedicated to transit)
Site: 3.4 acres

Description:

The Del Mar Station Transit Village is a Post Modern New Urbanist redevelopment of a station on Los Angeles' Gold Line in Pasadena (Fig. 24-25). The village is comprised of 4 stylistically and compositionally unique buildings interconnected by open plazas and walkways, which bridge and flank the rail station. The project incorporated an adaptive reuse of the historic Santa Fe Station into a popular restaurant. Central to the design is the rail line itself, which passes through the middle of the project rather than beneath or beside it. A successful TOD, the Del Mar Station bolstered the local economy, which saw an increase of 1800 new residential units and 170,000 square feet of commercial space constructed in the immediate vicinity of the Del Mar station since its completion (US High Speed Rail Assc, 2013). As one of eight completed TOD stations throughout Los Angeles' light rail network, it contributes to the $14-15 million dollars in additional earnings that the transit agency now receives annually (Lubell, 2011).

FIGURE 24 - DEL MAR STATION TRANSIT VILLAGE - AERIAL

FIGURE 25 - DEL MAR STATION TRANSIT VILLAGE - INTERIOR

Analysis:

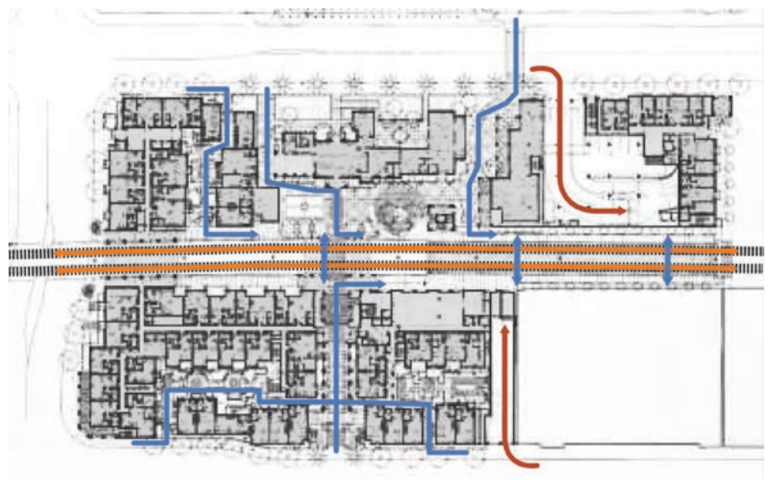
The value of this case study is found in its financial and programmatic success. As such, it is representative of the intended programmatic direction for this thesis project (Fig. 26). Through its incorporation of high density residential with readily accessible commercial, the Del Mar Station Transit Village has successfully demonstrated how Transit Oriented Development can increase profitability for public transportation. This combination is becoming prolific throughout the Los Angeles light rail system as well as other rail stations throughout the United States that are directly confronting the challenge of overcoming the American love affair with the car.

Although the post-modern design and New Urbanist plan are not representative of the aesthetic direction of this thesis, the placement of the buildings around the track is important. Passengers are brought to the heart of the complex, and are forced to find their way to one of the six pedestrian exit points (Fig. 27). This increases the pedestrian interaction with commercial spaces thereby benefiting the commercial lessees and building owners. This also increases the densification of the site. By building on top of and around the tracks, more program can fit within a smaller area. This solution is influential on the Colorado stations, which must be situated on smaller sites due to land value and availability.

Even though this project is incorporated into an urban lite rail system, which is smaller than the magnetic levitation (MAGLEV) system proposed for Colorado, its scale and placement within the community is similar to the small towns along Colorado's I-70 corridor. In the context of this thesis, the proven financial benefits of a rail centric transit oriented design will minimize the government subsidies required to maintain and operate the high speed rail line along Colorado's I-70 corridor while simultaneously increasing ridership and contributing to the community.

COMMERCIAL RESIDENTIAL PEDESTRIAN AREA

FIGURE 26 - DEL MAR STATION TRANSIT VILLAGE - SITE PLAN



VEHICLE ACCESS LIGHT RAIL PEDESTRIAN ACCESS

FIGURE 27 - DEL MAR STATION TRANSIT VILLAGE - CIRCULATION

3.5.2 - Shin-Minamata Station
Location: Minamata, Japan
Transit type: Heavy and High Speed Rail
Architect: Makoto Sei Watanabe
Year Completed: 2004
Floor Area: 52,400 sf
Platforms: 3

Description:

The Shin-Minamata Station brings a high-speed rail connection to the small fishing town of Minamata. Somewhat similar to the Colorado mountain towns, Minamata is small with a population of only 27,856 and a diffuse density of .68 people per acre (less than half that of Vail) (Minamata, 2014).

The station is a two level structure containing three boarding platforms above a terminal area with a transit plaza in front serving taxis and buses. The platform envelope is comprised of long rectangular panels floating in relation to one another, which communicate a frozen moment of motion (Fig. 28). The envelope is semi-open, which allows for a lower roof height and ventilation for heavy rail diesel vehicles (Fig. 29) (Jones, 2006).

Aside from the elaborate envelope design, the station's functional elements are reduced to their most essential components and optimized to make the best use of the available space within the platform footprint (Fig. 30-31). For safety, glass barriers border platform edges (Uffelen, 2010).

Analysis:

Minamata serves as the most ideal model for Colorado mountain stations. The floor area is equal to what is recommended for Colorado, and the circulation is similar to two of Watanabe's other stations, which enhances passenger familiarity within the system as a whole. The transit plaza is appropriately scaled for the bus and taxi requirement for a small town. The design also illustrates how iconic design can be brought out of urban areas and succeed in a rural context.

The station is less successful as a TOD, though. Surrounding program does not enrich community development, and residential areas have limited planned access to the station. These problems, however, are less a result of the station design, and more a failure to implement redevelopment plans for the surrounding area (Fig. 32-33).

FIGURE 28 - SHIN-MINAMATA - EXTERIOR

FIGURE 29 - SHIN-MINAMATA - PLATFORM

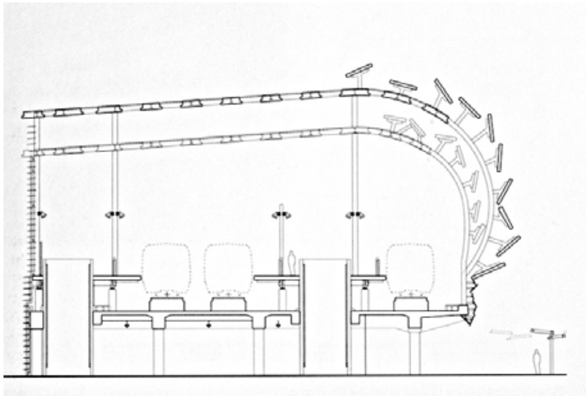


FIGURE 30 - SHIN-MINAMATA - SECTION

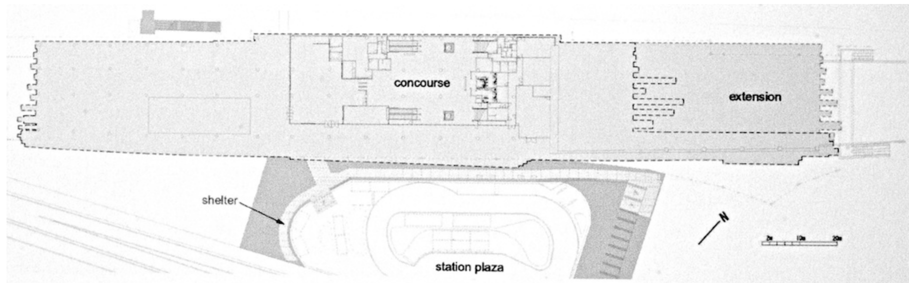
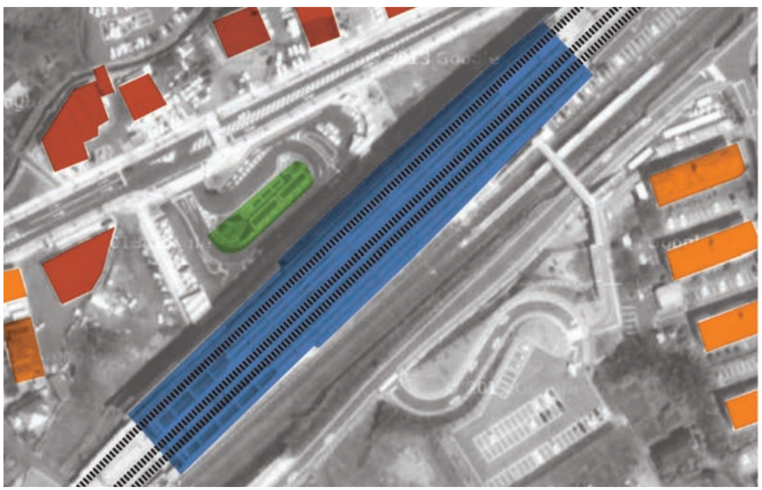
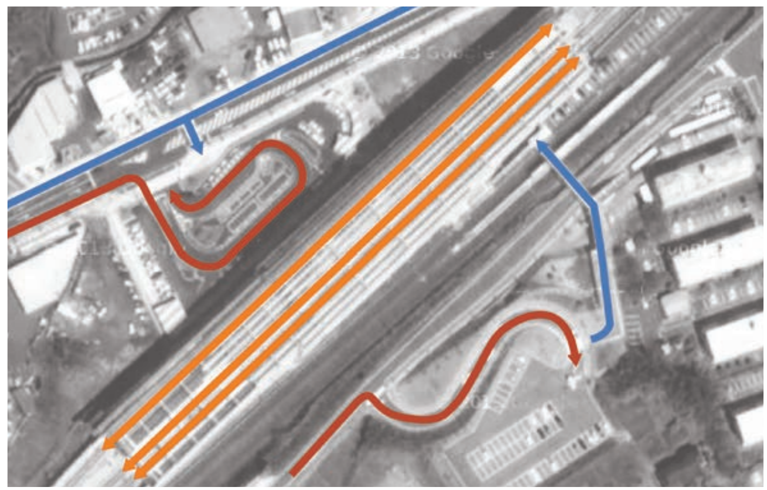


FIGURE 31 - SHIN-MINAMATA - PLAN



COMMERCIAL RESIDENTIAL PEDESTRIAN AREA STATION

FIGURE 32 - SHIN-MINAMATA - SITE PLAN



VEHICLE ACCESS PLATFORM PEDESTRIAN ACCESS

FIGURE 33 - SHIN-MINAMATA - CIRCULATION

3.5.3 - King's Cross Station
Location: London, UK
Transit type: Intermodal (rail, underground, taxi, and bus)
Architect: John McAslan + Partners
Year Completed: 2012
Residential Units Added Nearby: 2,000

Description:

The King's Cross station was remodeled starting in 1998. The double barrel train shed was restored, and the original 1852 façade was revealed with the removal of a 1970's structure that stood in front of it. John McAslan's design for the new Southern Concourse is the centerpiece of the station. Intended as a gathering place for King's Cross and neighboring St. Pancras station, it serves 50 million people per year. The steal diagrid structure is Europe's largest single span structure and highlights the original brick façade of the original ticket office (Fig. 34). It contains small restaurants and cafes in addition to small business services and news stands. Platform access from the Southern Concourse occurs at mid length of the train shed (Fig. 35-37). The concourse also serves as an intermodal connection point for buses, taxis, and the London underground (Jones, 2006). St. Pancras Station and the gothic style Great Northern Hotel lie across the street, making the area one of the largest transit centers in the world. The station remodel sparked redevelopment of the surrounding area, including 2,000 new housing units, and served as the rail gateway for the London Summer Olympics. The station is a popular tourist destination for its use in the Harry Potter series of books and films (London, 2014).

Analysis:

The Southern Concourse of King's Cross Station is a magnificent space. To the unsuspecting visitor it is an awe-inspiring surprise. It honors the history of the original station by incorporating the original ticket office and presenting it as the focal point for the entire design. Its role as a gathering place mandates the space remain open, which gives an impression that the architecture exists for its own sake. Multiple entry points and a division of modal types help

FIGURE 34 - KING'S CROSS STATION - SOUTHERN CONCOURSE

FIGURE 35 - KING'S CROSS STATION - PLATFORM

distribute visitors throughout the space and makes for a pedestrian friendly station area (Fig. 38-39). Allowing passengers to enter the train shed at mid length allows for better passenger distribution along the platform length and relieves congestion from the larger entrance at the end of the train shed. The station location near the Great Northern Hotel makes the area a good center point for tourists to stay and travel. This project also demonstrates how sizeable transit facilities can function well without major commercial programs within the station itself. The lack of these may even be responsible for an influx of commercial space in the surrounding area. Joined with the addition of more housing and an upswing in the neighborhood, the station serves as a successful iconic centerpiece at the center of a transit-oriented development.

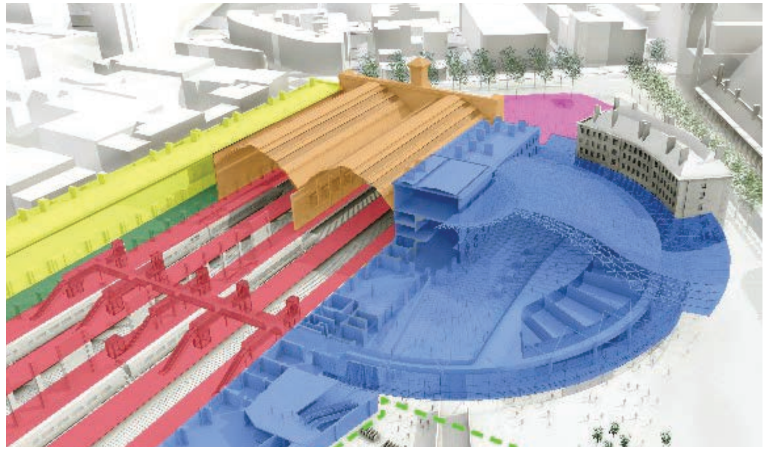


FIGURE 36 - KING'S CROSS STATION - PERSPECTIVE SECTION

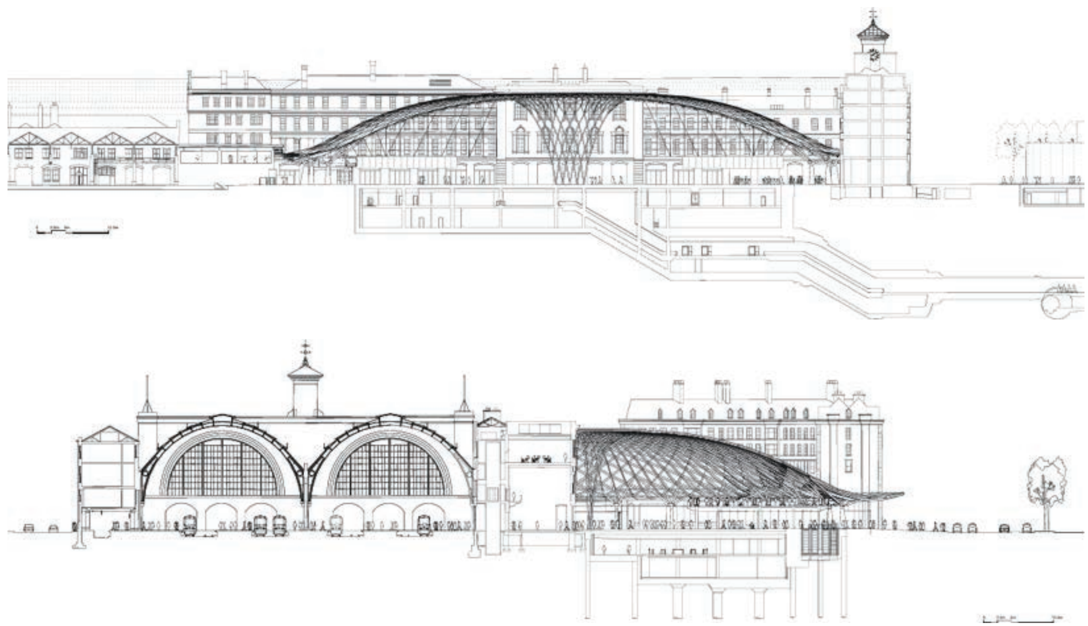


FIGURE 37 - KING'S CROSS STATION - SECTIONS

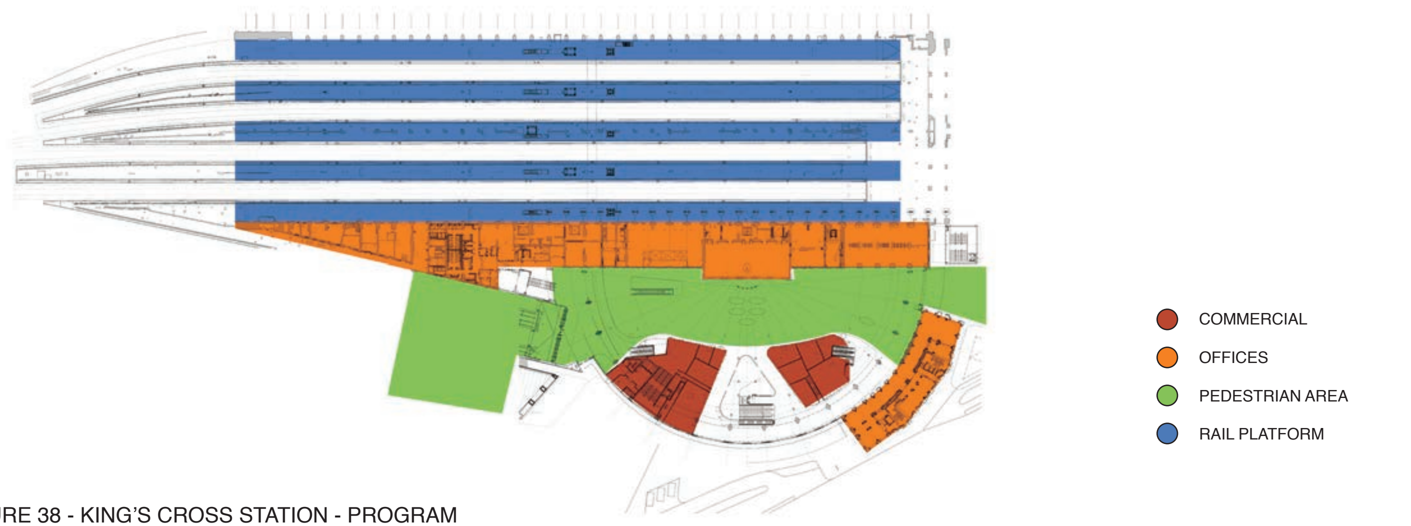


FIGURE 38 - KING'S CROSS STATION - PROGRAM

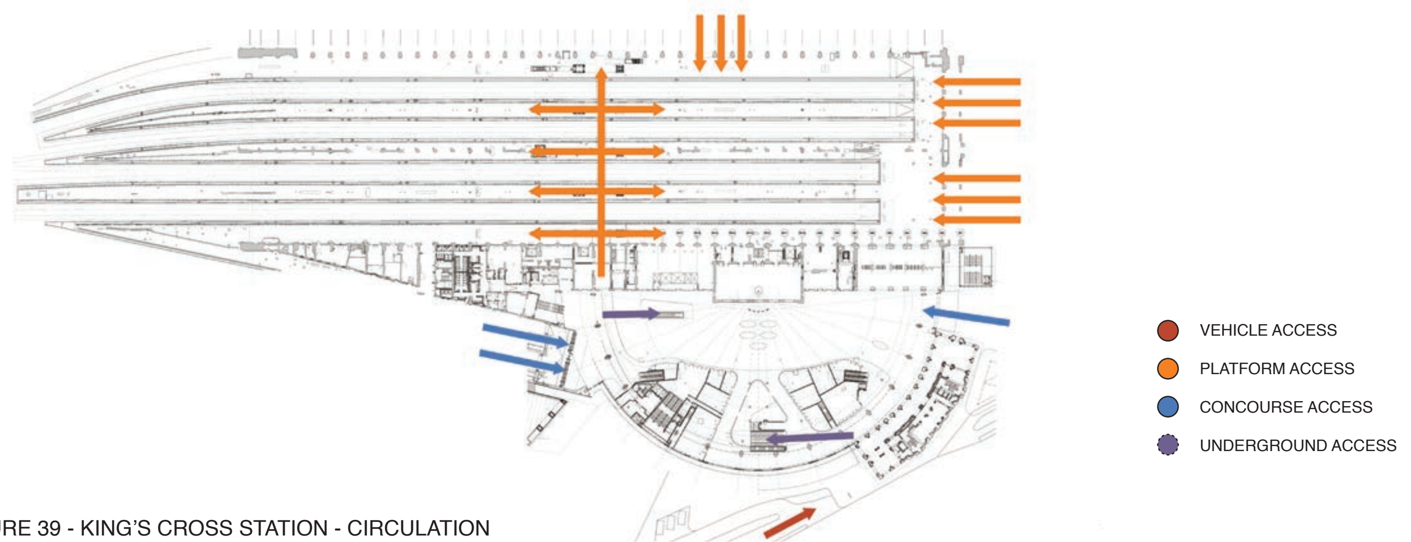


FIGURE 39 - KING'S CROSS STATION - CIRCULATION

3.5.4 - Denver Union Station Redevelopment
Location: Denver, Colorado
Transit type: Multimodal
Architect: Skidmore, Owings, and Merrill
Year Completed: 2014
Retail Space: 22,000 sf
Site: 19.5 acres

Description:

The Original Union Station opened in 1894 in the lower downtown area of Denver. At its height it served 80 trains a day, but that figure plummeted to one train a day with Amtrak's California Zephyr line plus the Rio Grande Western Railroad's Ski Train serving the Winter Park Ski Area. The historic icon of LoDo began renovation in 2012 to transform the unused station into a revived intermodal hub. The completed station will have three light rail tracks at one end, eight heavy-rail tracks at the other, and a below grade 20 gate bus hub oriented perpendicularly between the two (Fig. 40). The signature addition is SOM's layered fabric canopy over the heavy rail platforms (Fig. 41). The ground level of the original station still accesses the platforms, but the upper levels are converted to the 112-room Crawford Hotel. The central 12,000 square foot Great Hall serves as a public common area opening onto a 40,000 square foot outdoor plaza. 22,000 square feet of ground level retail space is divided amongst ten independent retail stores and restaurants. The station serves light rail, commuter-rail, interstate passenger rail, and bus service, and will create a commuter rail connection between downtown and the Denver International Airport (Fig. 42-43). The surrounding area is redeveloped as a dense urban transit oriented development, which sets a high standard for other US cities to meet ("A whole new way to ride", 2014).

Analysis:

The decline of Union Station left a sad hole in lower downtown. Surrounded by the redeveloped LoDo and adjacent to both Coors Field and the Pepsi Center, Union Station remained rarely used for decades. The change brought to the area with this project completes the LoDo redevelopment begun over twenty years ago.

FIGURE 40 - DENVER UNION STATION - AERIAL

FIGURE 41 - DENVER UNION STATION - SOM ADDITION

Similar to King's Cross, the contemporary addition to the historic station stands in stark contrast to the original building. The white canopy creates visual continuity with the Airport's main terminal, and allows organic shapes to be achieved at a lower cost. The design originally called for the heavy-rail line platforms to be below grade, but due to budget restraints only the bus terminal is below grade (Krutsinger, 2014). The corridor above the bus terminal creates a pedestrian thoroughfare cutting through the transit-oriented development, which encourages walkability.

Aside from the program within the original station building, the majority is spread amongst the surrounding buildings and a variety of contemporary architectural languages. This helps differentiate between the station and the TOD, and aligns with research stated earlier warning against establishing aesthetic ties between stations and surrounding buildings.

The Great Hall and outdoor plaza create much needed gathering areas downtown. Before this addition the only gathering area nearby was Civic Center Park located between the State Capitol and the City and County Building. It also acts as an active junction at the intersection of the 16th Street Pedestrian Mall and Wynkoop Street, which connects Coors Field and the Pepsi Center (Fig. 44-46).

One of the planning shortfalls of the redevelopment is the inability of the station to accommodate AGS service (Fig. 47). Due to land availability between the base of the Rocky Mountains and downtown, and trains' large turning radii, it is near impossible to connect to Union Station on the way to the airport (Krutsinger, 2014). This unfortunate inability will prevent the AGS from realizing its full capacity potential.

FIGURE 42 - DENVER UNION STATION - BUS DEPOT

FIGURE 43 - DENVER UNION STATION - HEAVY RAIL PLATFORM

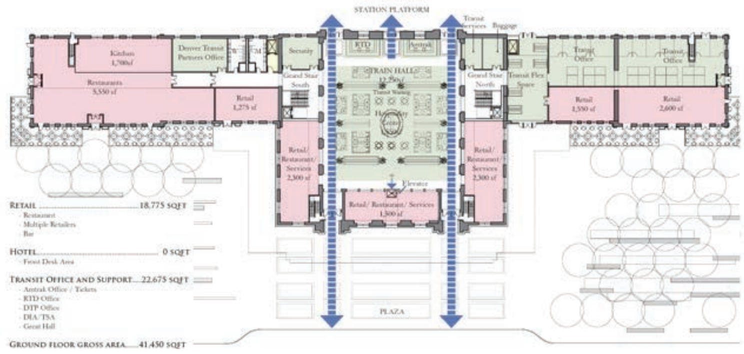


FIGURE 44 - DENVER UNION STATION - GROUND FLOOR PLAN

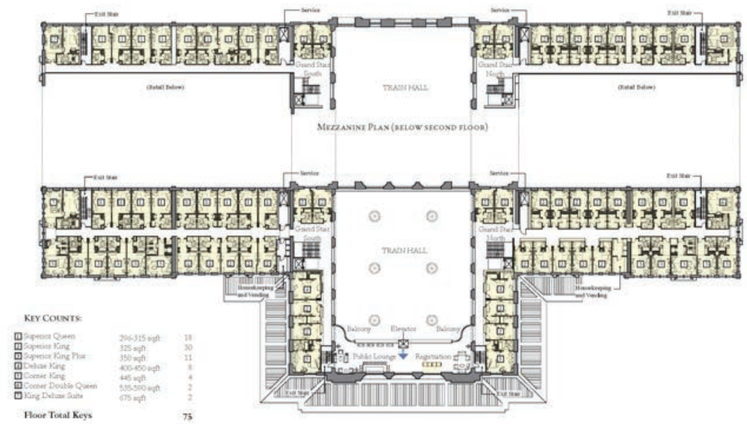
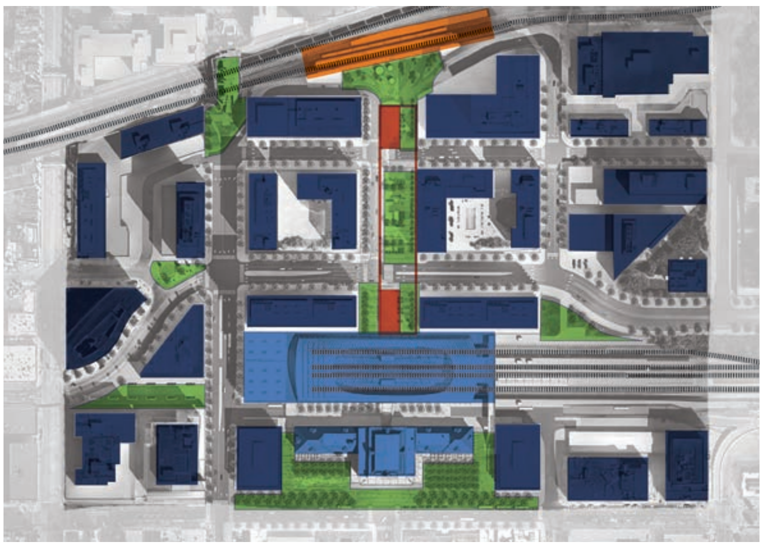
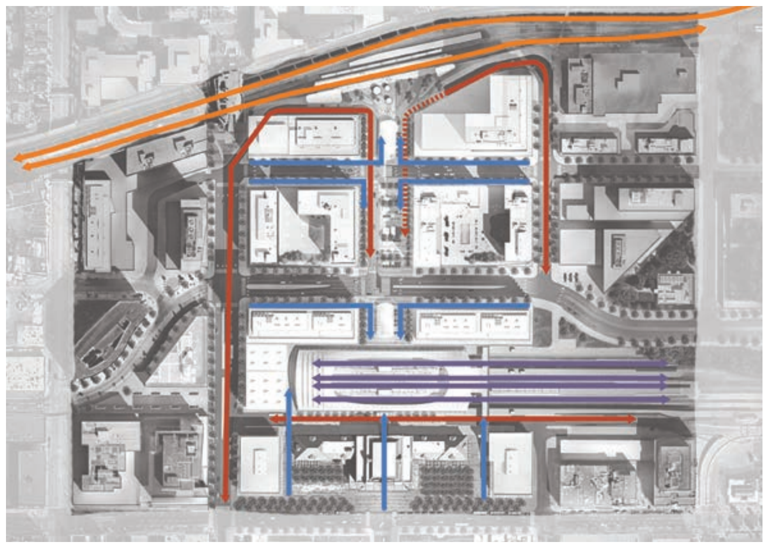


FIGURE 45 - DENVER UNION STATION - HOTEL FLOOR PLANS



BUS DEPOT LIGHT RAIL PEDESTRIAN AREA STATION MIXED USE

FIGURE 46 - DENVER UNION STATION - SITE PLAN



VEHICLE ACCESS LIGHT RAIL PEDESTRIAN ACCESS HEAVY RAIL

FIGURE 47 - DENVER UNION STATION - SITE CIRCULATION

3.5.5 - Brentwood Skytrain Station
Location: Vancouver, Canada
Transit type: Light rail
Architect: Busby Perkins + Will Architects
Year Completed: 2002

Description:

One of 13 stations on Vancouver's Millennium light rail transit line, the Brentwood Skytrain Station is built in the median of the Lougheed Highway (Fig. 48). The concept was intended to raise passengers above the pollution of the road below and provide access to light and views of the mountains. Two circulation wings on either side of the highway bring passengers up to a mezzanine bridge across the highway from which they ascend to the platform (Fig. 49). Mirrored platforms flank the central rail lines, and flare in the middle to accommodate vertical circulation elements. The exterior is glass, steel and concrete, which contrast the interior of curved glulam ribs and wood roof decking. The station is open at the ends, but provides some protection from the elements with glazing along the sides. (Slavid, 2005)

Analysis:

Although the Brentwood station accommodates significantly smaller trains than would a Colorado AGS station, many of the features it employs are useful solutions to similar problems. The station provides another solution to the small footprint challenge by elevating the platform and distributing most of the circulation and ancillary program elements to the sides of the highway. This creates a longer walk for passengers, but the allure of the wood interior is powerful enough to draw passengers in (Fig. 50). Another drawback is the 30 foot of height required to allow the bridge to pass beneath the platforms and above vehicular traffic. However, this height is appropriately scaled for the width of the station, and prevents the structure from feeling heavy.

The contrast between interior and exterior materiality has interesting psychological effects for attracting ridership (Fig. 51). The exterior form is different enough to attract interest, but the station must be viewed from the inside to gain the full of experience. This is the same effect produced by cathedrals, which are powerful from the outside but designed to be experienced from the inside. This encourages people to interact with the structure. Rather than viewing from afar and never

FIGURE 48 - BRENTWOOD SKYTRAIN STATION - AERIAL

FIGURE 49 - BRENTWOOD SKYTRAIN STATION - EXTERIOR

needing to go inside, the warm wood tones and curved roof become a reason to go into and ultimately use the station. This is in contrast to the Shin-Minamata station, which, short of light patterning through the envelope, is purely functional on the interior and can be largely appreciated for its architectural contributions from a distance. In the author's opinion this case study gives supporting evidence for creating an interior space that is more powerful than the exterior form.

FIGURE 51 - BRENTWOOD SKYTRAIN STATION - PLATFORM

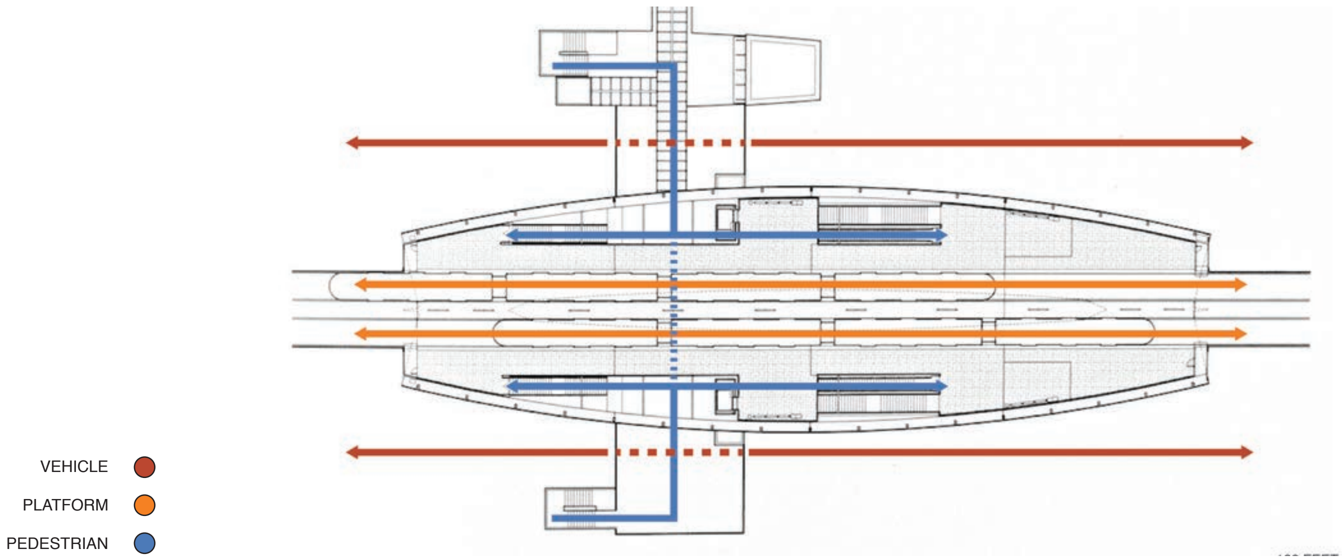


FIGURE 50 - BRENTWOOD SKYTRAIN STATION - FLOOR PLAN & CIRCULATION

3.6 Interviews

Three interviews were conducted in regards to this thesis to clarify specifics of the I-70 AGS and to better understand community feedback and heating requirements .

The first interview occurred on 29 January, 2014 with David Krutsinger from the Colorado Department of Transportation. Krutsinger is the Project Manager for the AGS feasibility studies along I-70 and I-25. The 45-minute discussion included clarification of the AGS project and expected outcomes from the final AGS Feasibility Study, which further refines the alignments and technologies proposed in earlier studies. The conversation also included the potential for well-designed architecture to contribute to the functionality and popularity of the system. To assist in this endeavor, he provided many practical parameters that the system will face in real life such as how stations will connect to towns while accommodating alignment and technology limitations, and the expected space requirements needed to serve AGS vehicles. The aesthetic expectations for stations were also discussed. Two approaches are possible. The first is to establish a common architectural language to be used at all stations similar to the existing light rail stations throughout Denver. The second is to allow aesthetics to reflect the desires of individual communities. The conclusion was to allow each town to influence the design for their respective station to best fit the context, history, and existing architectural styles of each site.

The second interview occurred on 3 February, 2014 with Jim Jose, Principal at Path 21 Architecture in Denver. Mr. Jose was the past Western Colorado AIA chapter President and volunteered his firm's time to develop three station concept designs for the Golden/Jefferson County, Idaho Springs, and Breckenridge sites. The 30-minute discussion confirmed much that was discussed in the Krutsinger interview. On the subject of station programming Mr. Jose identified a significant challenge. In his discussions with the mountain communities, specific program proved to be highly controversial with little consensus amongst residents. He recommended this thesis focusing on form and station functionality while leaving generic program placeholders in the master plan to be specified at a later time.

The third interview occurred on 15 February, 2014 with Professional Engineer Brandon Chalk of Beaudin Ganze Consulting Engineers in Avon, Colorado. As a local engineer, Mr. Chalk is familiar with the passive and active heating and cooling requirements in the mountain climate. His input was included in section 3.1.3 on ecological research.

3.7 – Questionnaires

Questionnaires were submitted to town planning and transit officials for the town of Avon and to RMT architects, master plan designers for the Village at Avon, which must be modified to accommodate an AGS station. None of the individuals contacted returned their questionnaires. The Questionnaires asked the following:

Questionnaire 1 – Submitted to Matt Pielsticker, Avon Town Planner, Jaime Walker, Avon Community Relations, and Jane Burden, Avon Transit Division Manager. No questionnaires were returned.

1. What are the top three pro's and con's of a High Speed Rail Station from Avon's perspective?

2. To what degree is the Town of Avon able to order a change to the Village of Avon master plan in order to accommodate a HSR station?

3. What is the public opinion of a HSR station and the rail system as a whole (is it viewed positively or negatively and why)?

4. What program elements would the town envision being collocated with the station (i.e.: car rental, transit hub, hotel, ski and bike rental, conference center, outdoor music venue, plaza, gondola to town/beaver creek etc)

5. From a town planning perspective, what are the top three challenges to bringing a station to Avon?

Questionnaire 2 – Submitted to Harvey Robertson of RMT Architects in Avon. RMT developed the master plan for the Village at Avon development. The questionnaire was not returned.

1. Do you have downloadable plans for the development available?

2. Were concessions made in the master plan for a rail station?

3. What design priorities guided the design?

4. Was affordable / employee housing included in the plan?

5. Was mixed use incorporated horizontally or vertically (i.e. complete separation of typologies vs a residential over commercial arrangement)?

3.8 – Legal Issues

Legal restrictions are set forth in the Town of Avon's Development Code, the 2012 International Building Code, and the Americans with Disabilities Act. However, as this typology is infrequently used, some code and zoning requirements are predicted based upon related zoning typologies such as 'community facilities' and 'mixed-use commercial'. Code analysis uses the 2012 International Building Code.

3.8.1 - Zoning

The site was determined by the Colorado Department of Transportation to be located within the future Village at Avon development. The Village at Avon is zoned as a PUD (Planned Unit Development). The Town of Avon Development Code uses the PUD zone in areas that require flexibility otherwise unachievable in the existing development code (Fig. 52-53). When the area was zoned as a PUD, the developer was required to create its own PUD zoning guide to augment

FIGURE 52 - AVON ZONING OVERLAY

the town's development code. The current guide was approved by the town of Avon on November 7, 2012. If development does not begin within 3 years, the PUD Guide must be reapproved.

The proposed train station or any area zoned for use as a train facility was not included in the developer's PUD guide or the town's development code. Therefore, the zoning within the PUD itself will have to be redrawn or amended for the typology. The Department of Transportation acknowledges that all of the towns along the route alignment will have to make similar adjustments to their town zoning ordinances.

The current site sits on the northern border of Planning Area A and C. Area A is listed as Village Center Mixed Use and Area C is listed as a Village Residential Mixed Use. However, nearby Planning Area B is listed as a Community Facility, which is a more appropriate category for a train station. However, the PUD tailors the Community Facility zone for a water tower or other infrastructure element, and its coverage area limits are too restrictive for a train station. At this stage the PUD would have to be amended using a combination of requirement from Areas A,B, & C or incorporate the town's requirement for Public Facilities. The following will list requirement for all four areas and a recommendation for amendment to the PUD. The requirements for Public Facilities are not adopted outright since they would not be in keeping with the purpose of zoning the area as a PUD, which is more flexible than the town code. (Avon Development Code, 2013)

Front yard setback:
Village Center Mixed Use (A): none listed for the proposed train site.
Community Facility (B): 20 feet from road ROW, 0 along Main Street.
Residential Mixed Use (C): 25 feet
Public Facilities (PF): 20 feet (Avon Development Code, 2013)
Recommendation: no front yard setback along the street serving the station, which is in keeping with a Community Facility accessible from Main Street.

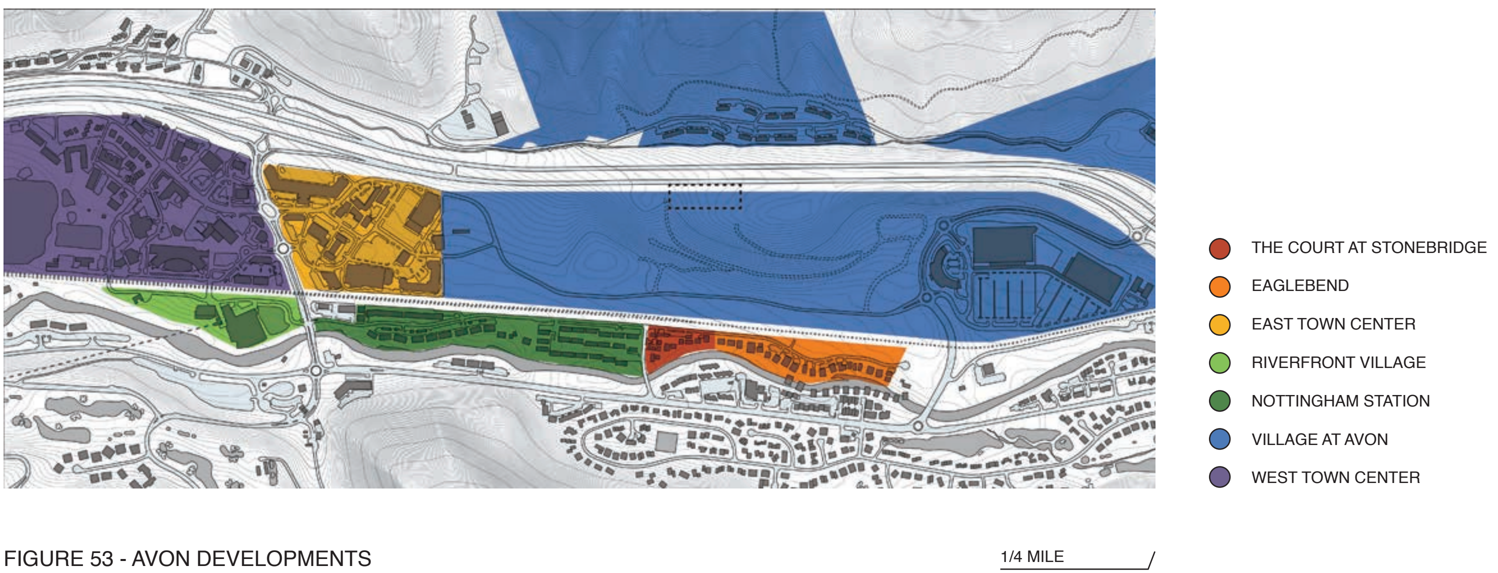


FIGURE 53 - AVON DEVELOPMENTS

Side yard setback:
Village Center Mixed Use (A): none
Community Facility (B): none
Residential Mixed Use (C): none
Public Facilities (PF): 20 feet (Avon Development Code, 2013)
Recommendation: no side yard setback (Community Facility)

Rear yard setback:
Village Center Mixed Use (A): none
Community Facility (B): none
Residential Mixed Use (C): 10 feet
Public Facilities (PF): 20 feet (Avon Development Code, 2013)
Recommendation: no rear yard setback (Community Facility)

Height Limit:
Village Center Mixed Use (A): none listed for the proposed train site.
Community Facility (B): 60 feet
Residential Mixed Use (C): 48 feet
Public Facilities (PF): 40 feet (Avon Development Code, 2013)
Recommendation: 60 feet (Community Facility)

Allowable Coverage:
Village Center Mixed Use (A): no limit
Community Facility (B): 20%
Residential Mixed Use (C): 20% minimum landscaped area requirement
Public Facilities (PF): 60% (Avon Development Code, 2013)
Recommendation: 60% (Public Facilities)

FAR:

FAR limits are not included in the Town of Avon Development Code or the Village at Avon PUD Guide.

3.8.2 - Accessibility

In addition to the number of accessible parking spaces delineated earlier, handicap parking must be located so as to create the shortest possible path to the building entrance. Spaces must be 8 feet wide at a minimum, and van accessible spaces must have an adjacent 8-foot access aisle.

Other accessibility requirements mandate elevators to meet accessibility requirements in the event of a fire. Platform edges must be of a different material and texture than the rest of the platform to aid visually impaired passengers in identifying the edge. Also, at least one wheel chair accessible toilet and one ambulatory toilet are required in each restroom. (ADA, 2014)

3.9 – Financial Issues

The financial burden of the I-70 AGS is the main obstacle preventing construction of the project. Four cost estimates for the four technologies and alignments were made as part of the AGS Feasibility Study. The author determined the Hybrid MAGLEV alignment and technology to be the most likely candidate of the four. The cost for the entire system is estimated at $13.3 billion with only $140 million dedicated to station construction.

Minor stations, those located between the Major end stations at Golden/Jefferson County and the Eagle County Airport, are estimated at $15 million each. That dollar amount is expected to pay for a 10,000 square foot terminal and 600 foot platform, a 600 space 4-story parking garage, road and site improvements, and furnishings and infrastructure (AGS Feasibility Study, 2014). The breakdown is as follows:

Terminal:	$2.5 million
Parking Garage:	$9 million ($15,000 / space)
Road and Site Improvements:	$1.5 million
Furnishings and Utility Infrastructure:	$2.0 million

These estimates provide costs for the minimum facilities required for the system to function, but do not accommodate the more aggressive designs within this thesis. Therefore, only the space requirements influence this project, with the assumption that private investors such as Vail Resorts & Coors will recognize the value of high design architecture to their businesses' and communities' development.

3.10 – Preliminary Building Systems

A review of the 2012 International Building Code was used to collect the following information for the Avon Station. This information includes Occupancy Groups, Construction Types, Building Envelopes, and Fire Protection Requirements and is used to inform design parameters.

Occupancy Groups:

Platform: A-3 (waiting areas in transportation terminals per IBC 303.4)
Terminal: A-3 (waiting areas in transportation terminals per IBC 303.4)
Café: A-2 (located in the terminal and will use terminal construction type)
Office: B

Allowable Construction Type:

Platform and spaces below (23,250 sf building area): Type IB
Terminal (9,000 sf building area): Type IIB
Preliminary Building Material: Steel and Concrete

Maximum Building Area:

A-3 Type IB: unlimited
A-3 Type IIB: 9,500 square feet

Maximum Number of Stories:

A-3 Type IB: 11 stories
A-3 Type IIB: 2 stories

Maximum Height:

A-3 Type IB: 160 feet
A-3 Type IIB: 55 feet

Sprinklers: Automatic sprinklers are required throughout the station due to occupant loads greater than 300.

Fire Ratings:

All Type IB construction must achieve the following fire ratings:

Primary Structural Frame:	2 hours (1 if only a roof above)
Exterior Bearing Walls:	2 hours
Interior Bearing Walls:	2 hours (1 if only a roof above)
Non Bearing Walls:	0 hours
Floors:	2 hours
Roof:	1 hour (heavy timber ok)

All Type IIB construction must achieve the following fire ratings:

Primary Structural Frame:	0 hours
Exterior Bearing Walls:	0 hours
Interior Bearing Walls:	0 hours
Interior Non Bearing:	0 hours
Floors:	0 hours
Roof:	0 hours (heavy timber ok)

Exterior Baring walls for Type IB / IIB must achieve the following fire resistance ratings for each fire separation distance in feet:

Less than 5:	1 hour / 1 hour
5 to 9.99:	1 hour / 1 hour
10 to 29.99:	1 hour / 0 hours
30 or more:	0 hours

Smoke Barriers:

Assembly occupancy groups are considered Smoke Protected when ceiling heights are 15 feet or greater. In other occupancy areas, such as the café and offices, smoke barriers are required to have a 1 hour fire rating and extend from outside wall to outside wall and from the beneath the floor up to the floor or surface above. All penetrations must be protected.

Wall section construction required to achieve conformance:

Type I and II construction require walls to be constructed of non-combustible materials. Where fire rated glazing is not used, walls will be constructed of 24 gage metal studs with 2 layers of ½” gypsum on each side. This wall section meets a 2-hour rating.

Area separations:

As this design calls for a large amount of glazing, building position determines permissible glazing percentages. For unlimited glazing area, the building must have a fire separation distance of at least 20 feet.

Doors:

Doors throughout the station must be a minimum of 32 inches wide and a maximum of 48 inches wide. Doors from all assembly areas must open in the direction of egress travel. In the current floor plan arrangement doors are not required to be recessed, and all doors opening inward serve spaces less than 50 occupants. Panic hardware must be installed on all exit doors throughout the station.

3.11 – Specialized Building Performance Criteria

When the train station typology is broken down to its core purpose we see that the entire station is simply a circulation system that delivers people from the street to the train. With the purpose of this thesis in mind, the code was carefully exploited to make the most efficient use of space through the station's exiting components so that the station could fit within a 40' right of way.

Platform Occupant Load:

The closest category for calculating occupant load is an Airport Terminal Waiting Area, with an occupant load factor of 15 square feet of gross floor area. The platform width was designed using this figure with the assumption that the worst-case scenario would require the complete simultaneous evacuation of two trains. The train manufacturer claims a capacity of 960 passengers, but the train length for this load cannot fit within the Department of Transportation's 600-foot platform length. Train length was thus reduced by two cars to fit within the platform with a resultant passenger load of 775 passengers per train.

23,250 sq ft / 15 sq ft per occupant = 1550 Occupants
(two trains of 775)

Terminal Occupant Load:

The terminal is comprised of the enclosed bridge, main hall, and café. The closest category for calculating occupant load is an Airport Concourse with an occupant load factor of 100 square feet of gross floor area. The café is divided into kitchen space, standing space, and concentrated movable seating with respective occupant load factors of 200 square feet gross, 5 square feet net, and 7 square feet net. The terminal occupant load is calculated as:

Bridge: 9790 sq ft / 100 sq ft per occupant = 98 Occupants
Main Hall: 16,800 sq ft / 100 sq ft per occ. = 168 Occupants
Café Kitchen: 930 sq ft / 200 sq ft per occupant = 5 Occupants
Café Standing: 440 sq ft / 5 sq ft per occupant = 88 Occupants
Café Seating: 520 sq ft / 7 sq ft per occupant = 74 Occupants
Total Terminal Occupant Load = 433 Occupants

Office Occupant Load:

Office space occupant load factor is 100 square feet Gross Floor Area. The office occupant load is calculated as:

5670 sq ft / 100 sq ft per occupant = 57 occupants

Exit Number Requirements:

Platform occupancy of 1550 requires 4 exits
Terminal occupancy of 433 requires 2 exits
Bridge occupancy of 98 requires 2 exits
Office occupancy of 57 requires 2 exits

Exit Access Requirements:

Terminal and Office area exits must be placed a distance apart equal to not less than one-half of the length of the diagonal dimension of the area. In the case of the platform, at least two of the exits must abide by this requirement (Fig. 54-56). The resultant distances between exits are:

Terminal: 187 foot diagonal length / 2 = 118 feet
Office: 115 foot diagonal length / 2 = 57.5 feet
Bridge: 147 foot diagonal length / 2 = 73.5 feet

Platform: 603 foot diagonal length / 2 = 301.5 feet

Exit access length for A-2 and A-3 areas is 200 feet, with an extension to 250 feet because the entire station must be fitted with automatic sprinklers. Likewise B occupancy access length is 200 feet with an extension to 300. Automatic sprinklers also permit stairways used as part of the exit access route to be unenclosed.

In the case of the platform the two main stairwells are included in the exit access path, and feed four evenly distributed enclosed exit stairwells on the bridge level.

Exit Stair Requirements:

Specific exit requirements for assembly areas apply to the station. Main exits are required to handle no less than one half of the occupant load. If no main exit exists, the exits may be distributed around the perimeter of the building so long as their total width is not less than 100 percent of the required width.

Due to the narrow width of the platform, the even distribution of people boarding / alighting the train, and the even distribution of exits along the length of the platform the total exit width method is used under the assumption that occupants at one end will not need to travel 600 feet to the furthest exit when three other exits are available along the way. The resultant minimum exit stair widths leaving the platform are calculated as follows:

Platform: 1550 occupants X .3 inches per occupant = 465 inches / 4 exits = 116.25 inches or 9 feet 8.25 inches per exit

If the uniform distribution method is not acceptable and a main exit is identified, then two catchments can be designated along the platform. These catchments, to meet occupancy requirements, must each contain three exits. The resultant calculations for this method are as follows (Fig. 55):

Catchment area containing 3 exits = 14,880 sq ft
14 ,880 sq ft / 15 sq ft per occ. = 992 occ. per catchment
992 occ. X 0.3 inches per occ. = 24.8 feet for exit stair width
24.8 feet / 2 = 12.4 feet main exit width and 6.2 feet other exits

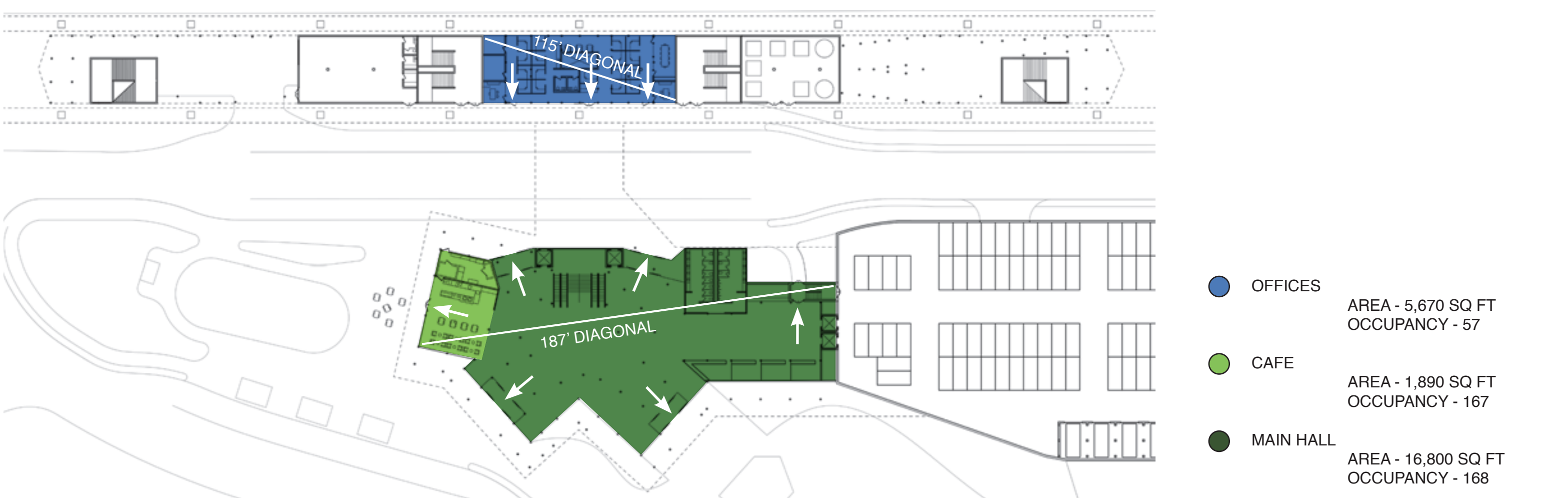
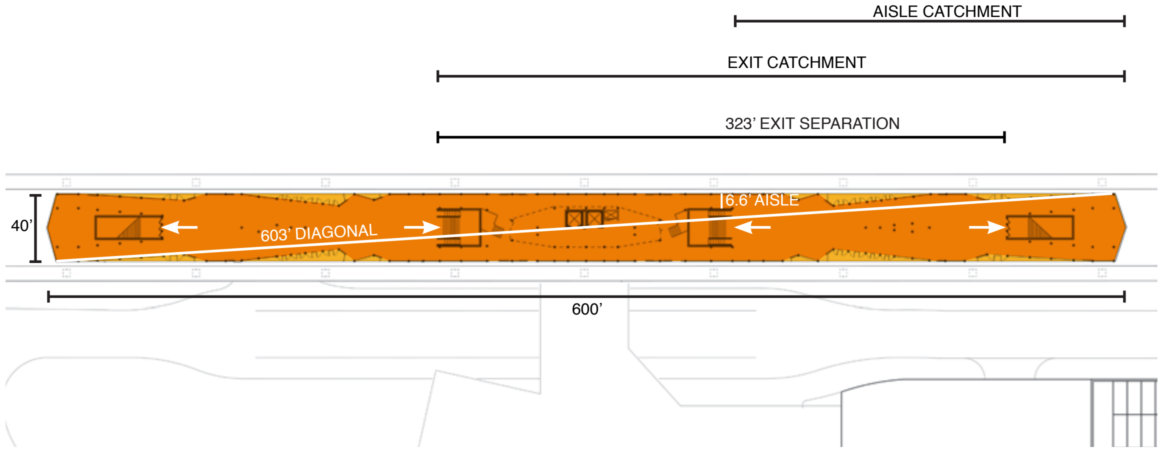


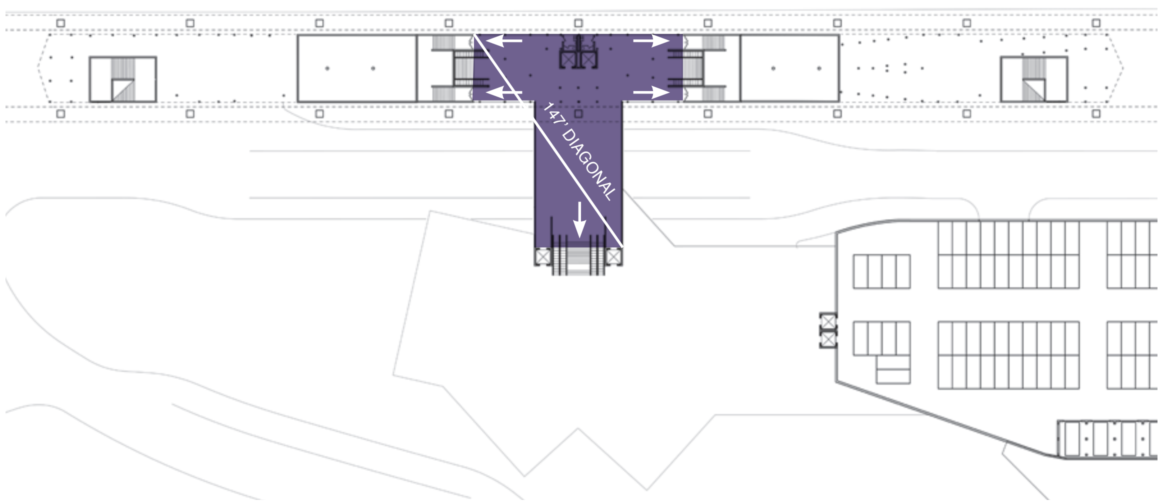
FIGURE 54 - GROUND LEVEL OCCUPANCY AND EGRESS



PLATFORM
AREA - 23,250 SQ FT
OCCUPANCY -1550

TRAIN (EACH)
OCCUPANCY - 775

FIGURE 55 - PLATFORM LEVEL OCCUPANCY AND EGRESS



BRIDGE
AREA - 9,790 SQ FT
OCCUPANCY - 98

FIGURE 56 - BRIDGE LEVEL OCCUPANCY AND EGRESS

In addition to these exit requirements, areas of refuge are not required at the stairways due to the exception for automatic sprinklers.

Dead End Corridors:

Dead end corridors are limited to a maximum of 20 feet.

Aisle Width:

Due to the progressive widening required along egress routes, aisles will grow in width when exit access routes convene. Aisles, as components of the exit access route are calculated as follows:

Platform: 992 occ. per catch X 0.2 inches per occ. = 198.4 in
= 16.5 feet

This aisle width can be further divided on the assumption that occupants will utilize the aisle closest to the train they are alighting. This reduces aisle width to 8.25 feet in areas leading into exits.

The aisle directly adjacent to the main stairwell utilizes a different catchment figure since only 56% of occupants will have to proceed through the aisle if use of the furthest exit within the exit catchment is required. The resultant width for the aisle is:

Platform: 992 occ. X 56% = 556 occ. through the aisle
556 occ. X 0.2 inches per occ. = 111 inches
= 9.2 feet

Dividing this figure in half for occupants using the aisle closest to the train they are alighting results in stairwell adjacent aisle widths of 4.6 feet. This figure is increased an additional 2 feet for platform edge safety with a final width of 6.6 feet.

This code analysis informed preliminary structural and environmental systems compatible with the design concept. The design uses a highly populated column grid to emulate a forest. As a result, long span issues are not a problem. Only a pedestrian bridge connecting the terminal to the platform has a span greater than 30'. Column material is steel. The forest concept encourages these structural members to be exposed and to intersect. Lateral stability, therefore will be provided by moment frame connections. Fire ratings for steel will require additional fire proofing.

Those areas where wood will be used will use local Colorado Beetle Kill Pine. The Pine Beetle has decimated over 1.5 million acres of forest in Colorado, which has created a high fire hazard from swaths of dead trees. A side effect of the Pine Beetle is a change in the wood's color. The normally yellow tinted pine is tinted blue by the beetle. Use of this material will enhance sustainability, and support the local economy.

Preliminary MEP Considerations were spoken of in an interview with Professional Engineer Brandon Chalk, as was mentioned in 3.3. The interview concluded that solar energy and solar heating are frequently used, but must be augmented with radiant heating boiler system. Plumbing and ducting for these systems is accommodated by a four-foot high space beneath the station platform. However, emerging and unforeseen technologies will inevitably come to market in the eight to ten years before construction could start, which will enable new possibilities. Therefore solar energy generating methods are proposed that do not yet exist.

3.12 – Parking

The Village at Avon PUD guide defers back to the Avon Development Code for parking requirements. These requirements dictate the minimum, but the Colorado Department of Transportation recommends each train station include a four story parking garage with 600 spaces (AGS Feasibility Study, 2014).

The Avon Development Code requires parking be located within 500' of the structure served with space count based upon the programmatic elements of the train station, which include the station, a café, and office space:

Community Services: 4 spaces per 1000 square feet of GFA
Food and Beverage Services: 1 space per 60 square feet of GFA
Office: 3 spaces per 1000 square feet of GFA
Handicap: per ADA (Avon Development Code, 2013)

Using program areas and the rates listed above the minimum parking requirements per the code area broken down as follows:

Station (51,700 square feet) = 208 parking spaces
Café (1,890 square feet) = 32 parking spaces
Office (5,670 square feet) = 17 parking spaces
Total required = 257 parking spaces
Handicap spaces per ADA = 7 parking spaces, 2 for vans
Loading Birth = 1 required
Bicycle Parking = 21 spaces

However, the 600-space garage recommendation by the Department of Transportation would require the following break down for handicap and bicycle parking requirements

Handicap (2% of total) = 12 parking spaces, 2 van accessible
Bicycle Parking = 60 spaces

Additionally, 20% of surface parking must be reserved for snow storage. The storage area must be at least 5' wide and directly adjacent to the area from where the snow will be removed. Also, transportation facilities are required to have an off street loading birth with dimensions of 12 feet wide, 35 feet long, and 15 feet high, with a second birth required for facilities over 40,000 square feet. Finally, Secure bicycle parking is required within 150' of the primary entrance at the rate of one spot for every 10 vehicle spots. (Avon Development Code, 2013)

3.13 – Pre-Design and Field Analysis

A site visit was conducted between January 28th and February 2nd, 2014 during the largest snowstorm in over ten years, which saw over 30 inches of snow in three days. The town of Avon is small and well within reasonable walking ranges. It is not a walkable town though. Street organization and density suggests no formal planning or forethought. This is reflected in the approve master plans that will see East Avon completely redeveloped and West Avon transformed into a

FIGURE 57 - AVON SATELLITE IMAGE

1/4 MILE

Pedestrian area. The village at Avon will be the largest expansion in the town's history and will more than double the built area within the city limits.

The site itself sits just east of the crest of 100-foot hill. It is highly visible from both sides of the freeway and from the river at the bottom of the valley. The elevation change is steep in places, and is the largest influence on street planning. Streets must descend hills gradually by travelling in an East / West direction. The view to the south is a mountainside panorama blanketed in pine trees (Fig. 58-65).

3.14 – Programming

In regards to station programming there are two schools of thought. The first school emerged from European airport design, and joins the station with a shopping mall type of retail experience. The second school incorporates essential program for passenger comfort, and spreads commercial and residential elements to the station area. Some German stations have followed the first school, and have observed tremendous cost overruns, which come at the expense of stations in less populated areas. The second school is more in keeping with the concept of a transit oriented development. The purpose of TOD's is to activate the area around the station in order to increase activity and ultimately ridership. Therefore, the program within the station is limited, and focus is given to developing the station as an icon. The platform and terminal are then able to remain open and airy with 35 foot ceilings in places, which is reminiscent of grand station terminals before the collapse of rail travel in the United States.

The Avon station and surrounding area is divided into the following programmatic elements and areas in square feet:

Station site: 4.35 acres total
- Terminal and Parking site: 1.52 acres
- Platform site: 0.54 acres

Terminal: 18,590 total
- Main Hall: 15,420
- Restrooms: 1,280

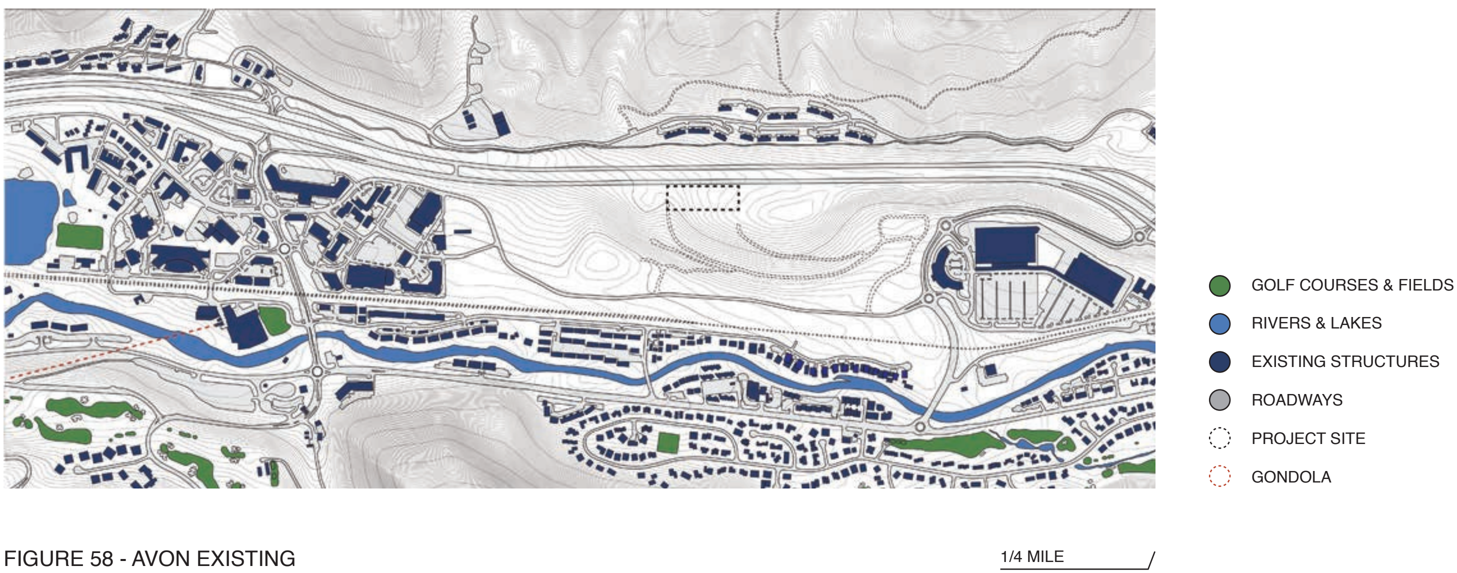


FIGURE 58 - AVON EXISTING

Café: 1,890
Bridge: 9,790
Circulation: 960
Restrooms: 180
Platform: 23,251
Parking Garage: 185,250 (580 spaces)
Bus Hub: 3,000
Mixed-Use Commercial: 75,000
Hotel: 100,000 (approximately 100 rooms)
Ice Rink: 3,600
Landscaping and Promenade: 1.8 acres

In light of the purpose of this thesis, which is to create a station design that enable transit oriented development, the specific programming beyond the station facilities falls more into the realm of Urban Planning and is merely a suggestion rather than a solution. Facilities for the handling of freight are to be concentrated at the Eagle County Airport and Breckenridge Stations, which limits freight impact upon TOD functionality while allowing freight to be delivered to central points on each side of the major high mountain passes.

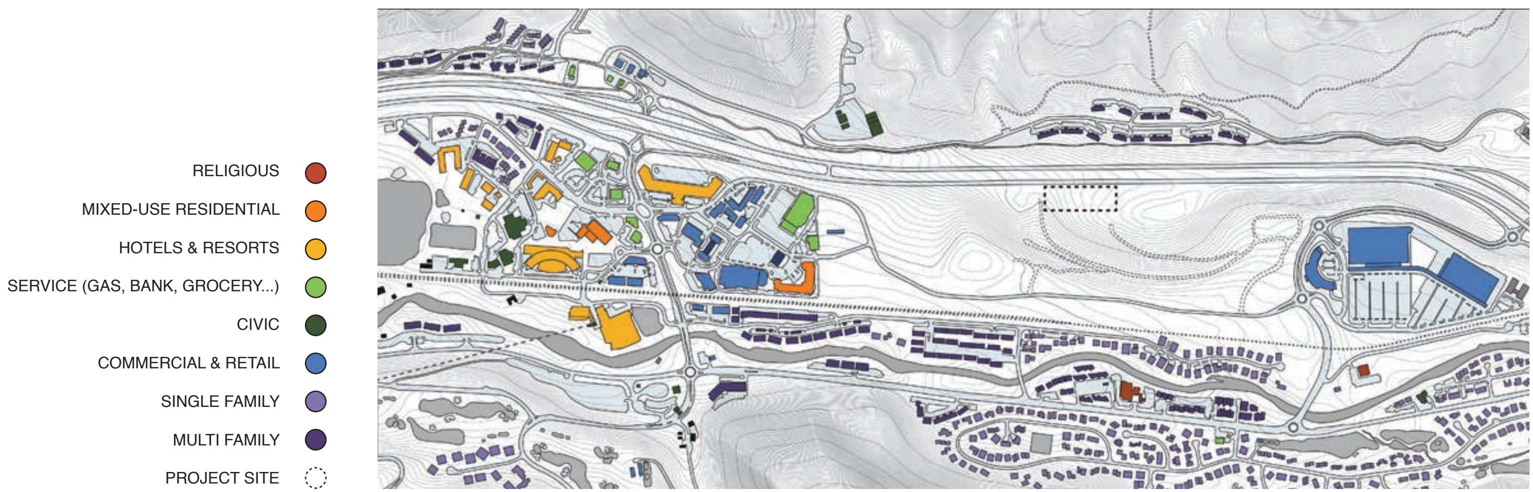
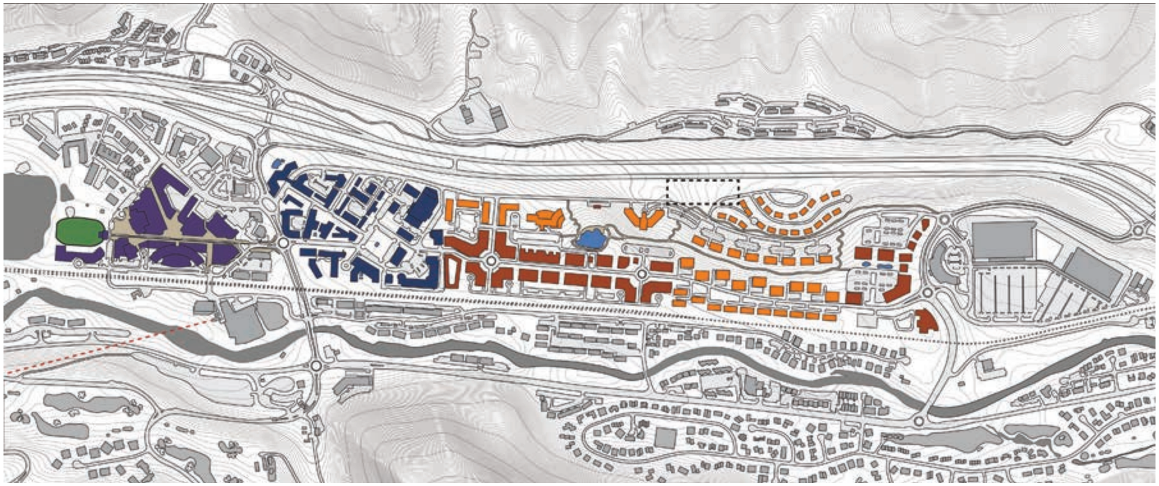


FIGURE 59 - AVON TYPOLOGIES

1/4 MILE



VILLAGE AT AVON COMMERCIAL
VILLAGE AT AVON RESIDENTIAL
PARK
LAKES & POOLS
AVON EAST
AVON WEST
WALKING PATHS & PEDESTRIAN AREAS
PROJECT SITE

FIGURE 60 - AVON APPROVED MASTER PLANS

1/4 MILE

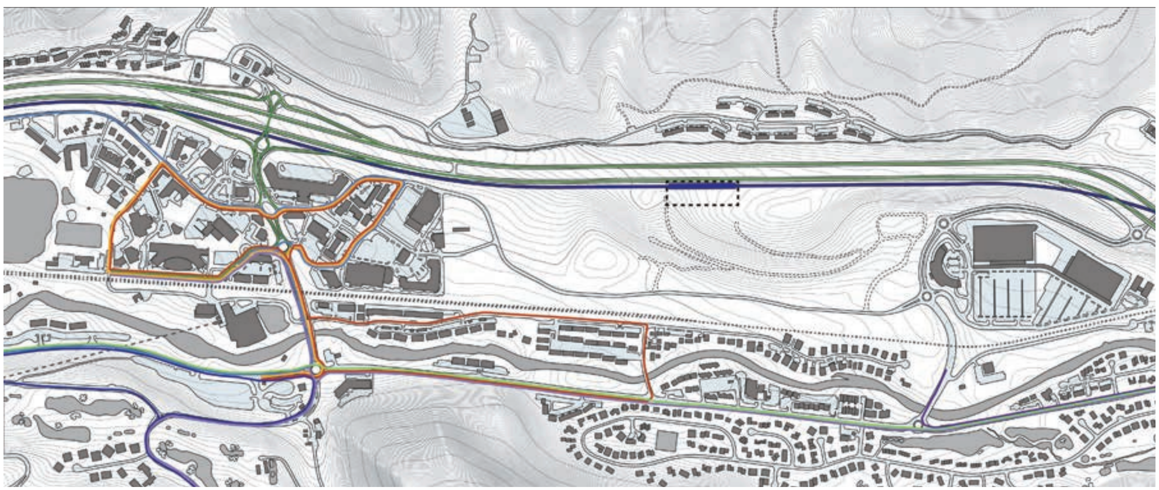


FIGURE 61 - AVON AND REGIONAL TRANSIT ROUTES

1/4 MILE

1/2 MILE RADIUS / 10 MINUTE WALK

1/4 MILE RADIUS / 5 MINUTE WALK

750 FOOT RADIUS / 2.5 MINUTE WALK

PROJECT SITE

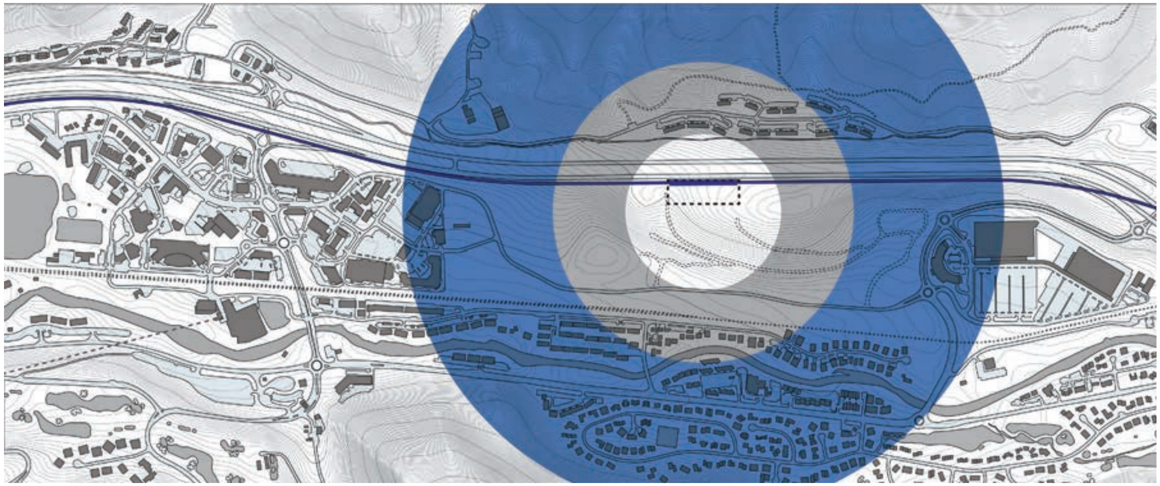


FIGURE 62 - AVON STATION SITE WALKING RADII

1/4 MILE

FIGURE 63 - SOUTH VIEW FROM AVON STATION SITE

1 - THE SEASONS AT AVON HOTEL

2 - CHAPEL SQUARE

3 - THE WESTIN RIVERFRONT RESORT

4 - NORTH VIEW FROM AVON STATION SITE

5 - SOUTHERN VIEW DOWN AVON ROAD

6 - WEST VIEW FROM AVON STATION SITE

7 - AVON CITY HALL

8 - VIEW OF SITE FROM NORTH SIDE OF INTERSTATE 70

AVON OVERVIEW

FOUNDED - 1889 (AS A RAIL STATION)

INCORPORATED - 1978

POPULATION - 6,447

POP GROWTH - 15.93% SINCE 2000

POP DENSITY - 796.22 / SQ MILE

RACE PROFILE - WHITE / HISPANIC

LAND AREA - 8.03 SQ MILES

(USA.COM, 2014)

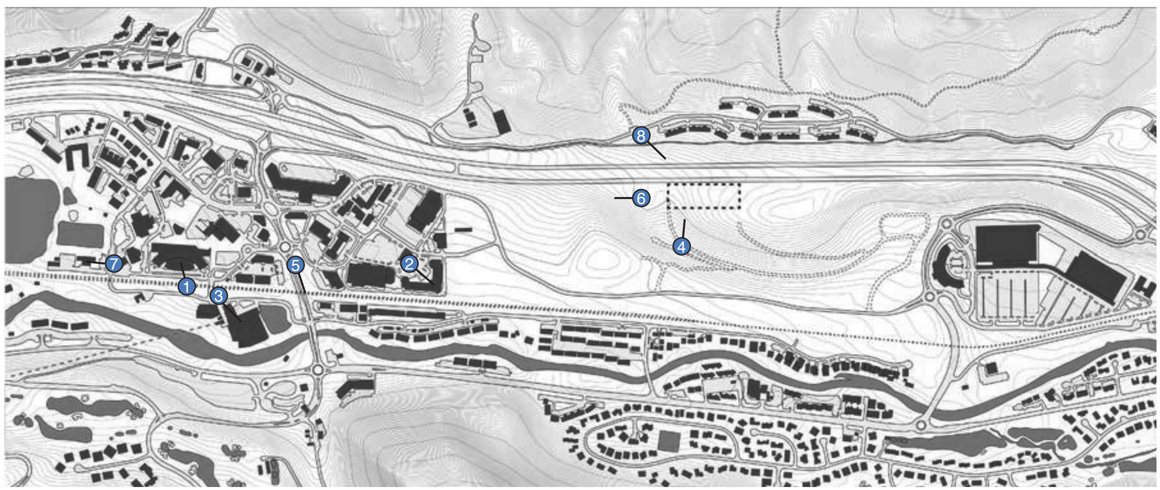
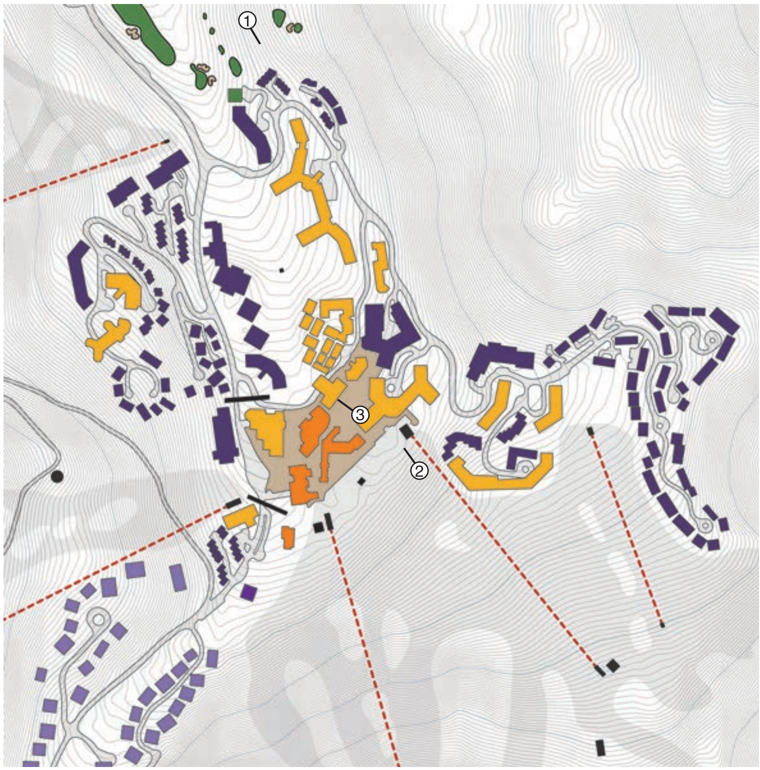


FIGURE 64 - AVON IMAGERY

1/4 MILE

1 - BEAVER CREEK RESORT AREA

2 - PARK HYATT BEAVER CREEK RESORT



3 - VILAR PERFORMING ARTS CENTER AND ICE RINK

- MIXED USE RESIDENTIAL
- HOTELS AND RESORTS
- GOLF COURSE
- SINGLE FAMILY
- MULTI FAMILY
- BRIDGES & SERVICE BUILDINGS
- PEDESTRIAN AREAS
- SKI LIFT

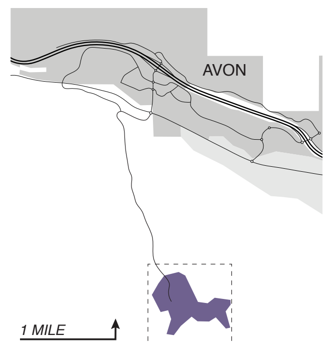
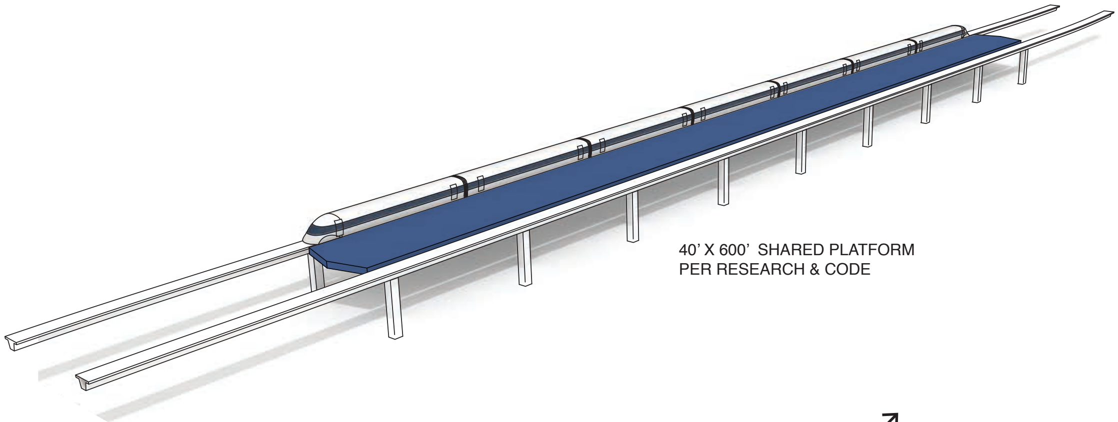


FIGURE 65 - BEAVER CREEK SKI AREA

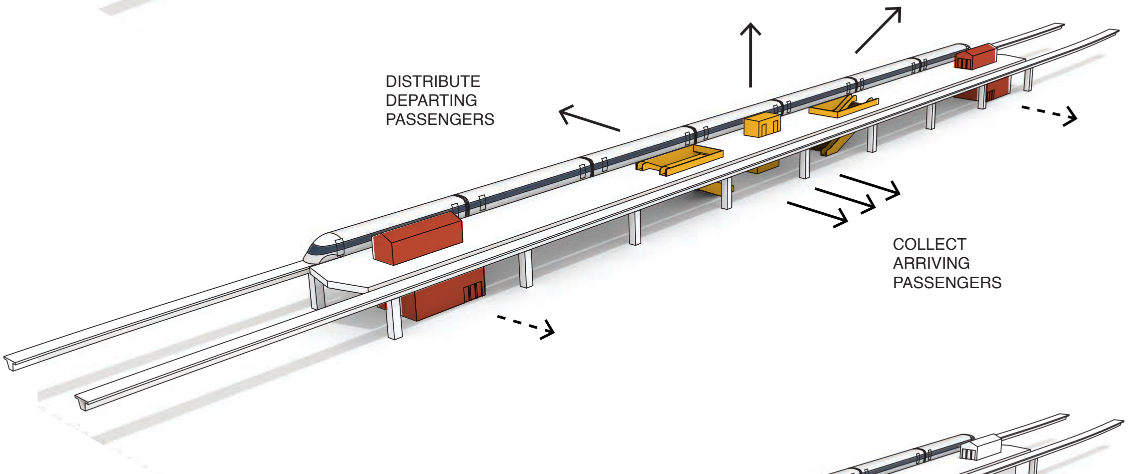
1/4 MILE



1. PLATFORM

FITS WITHIN 40' RIGHT-OF-WAY

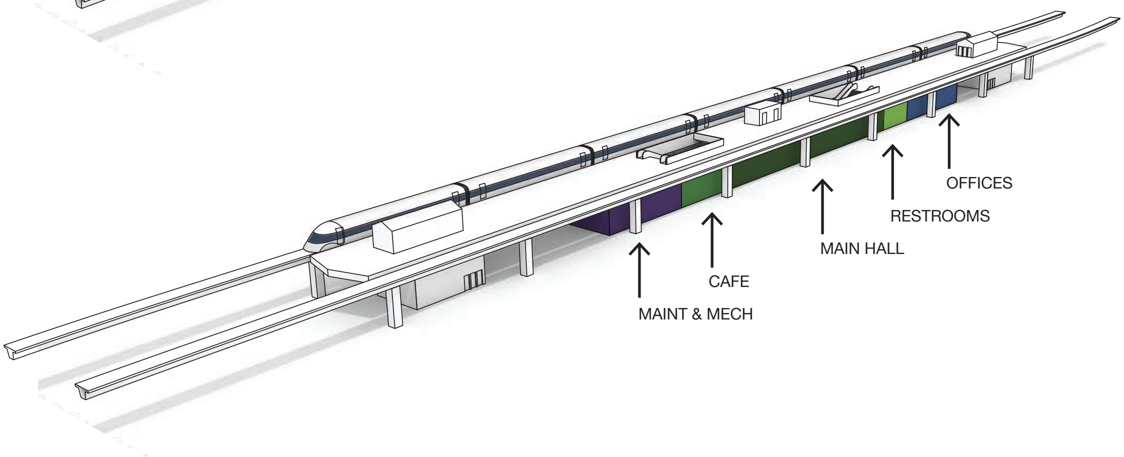
SMALLEST FOOTPRINT OPTION



2. CIRCULATION

EVENLY DISTRIBUTES DEPARTING PASSENGERS ALONG PLATFORM

DIRECTS ARRIVING PASSENGERS TO MAIN EXIT



3. PROGRAM

PUBLIC SPACE IN CENTER & PRIVATE SPACE ON ENDS

SKELETON PROGRAM ENCOURAGES GROWTH IN SURROUNDING MIXED-USE

4.1 – Design Concept

As previously stated in chapter 1.3, the concept for this thesis is based upon the quaking aspen native to Colorado. These trees serve as a functional model for the system of stations as well as an influence upon the architectural language for the station at Avon. Like the aspen, each station is derived from the same genetic template, which ensures each station functions identically, but also differs physically due to varying contextual influences such as topography, land availability, population densities to which it must adapt.

4.1.1 – Station Template

In the case of the station template, the driving principle is to create a circulation pattern that succeeds in evenly distributing departing passengers along the length of the platform while clearly directing arriving passengers to the station exits. In this case the result is a 40-foot wide by 600-foot long platform with emergency exits at either end, an accessible elevator core in the middle and main escalators and stairs mirrored to either side. The escalators and stairs distribute passengers to the end vehicles while the elevators serve those in the center. Working in reverse, passengers are directed to a central main exit. Programmatic elements are located beneath the platform and arranged so that public spaces are flanked on either side by operational spaces. Finally, the template directs vehicles to the back side of the station and pedestrians to the front side. This compact spatial arrangement is then adapted to the individual sites (Fig. 66).

4.1.2 – Adapting the Station Template to Avon

When applied to Avon, the spatial arrangement of the template is modified to accommodate the terrain. The CDOT hybrid MAGLEV alignment through Avon calls for the route to pass to the north side of I-70, but David Krutsinger with CDOT indicated that it may be possible to adjust the alignment to the south of I-70 (Krutsinger, 2014). The southern placement eliminates the need for a long pedestrian bridge across the highway, which should improve convenience for riders and ultimately ridership. However, the sloped site on the south side of I-70 requires the alignment to run directly adjacent to the freeway in order to accommodate the train's turning radii and to avoid unnecessary tunneling or bridging. Unfortunately, this freeway adjacency precludes placing the vehicle access road to the north of the station. Instead the road must

4. MODE SEPARATION

CREATES A PEDESTRIAN FRIENDLY STATION PLAZA FACING TOWN

ALLOWS CONVENIENT ACCESS TO ALL MODES

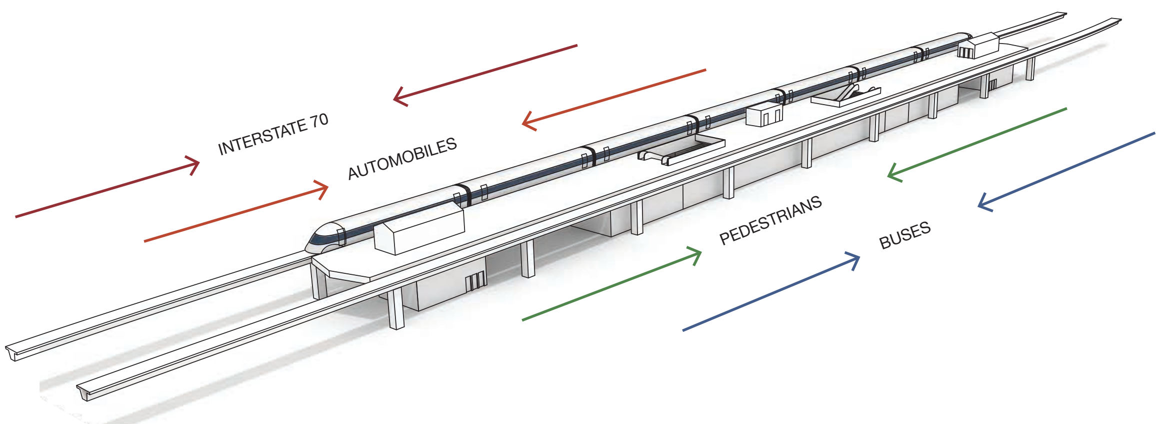
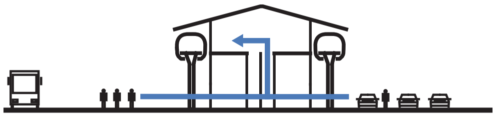
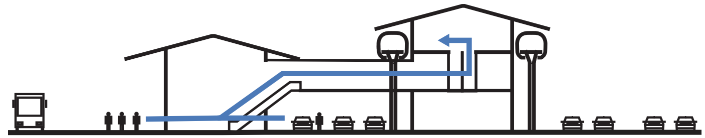


FIGURE 66 - STATION TEMPLATE GENERATION



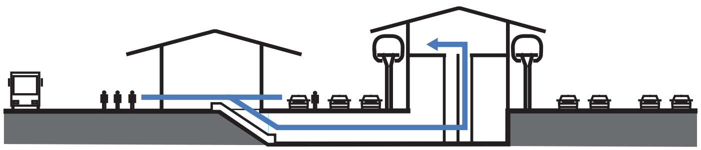
CENTER PLATFORM

PRO - SMALL FOOTPRINT, CLEAR DIVISION OF MODES
CON - CROWDED TERMINAL



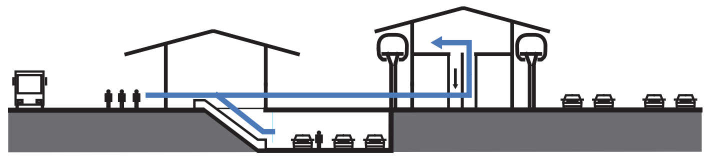
PEDESTRIAN BRIDGE

PRO - NO TUNNELING
CON - VEHICLE HEIGHT LIMITS



PEDESTRIAN TUNNEL

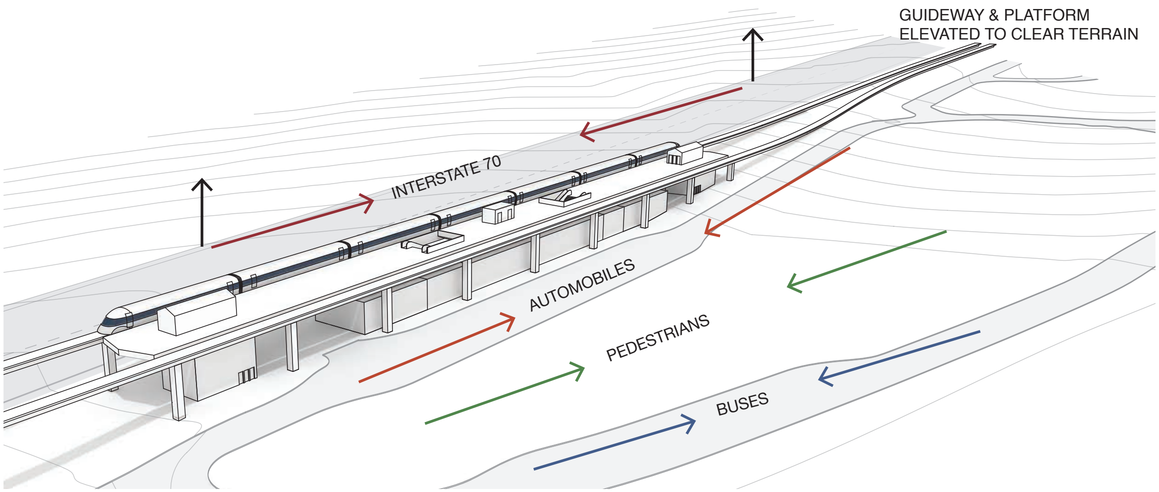
PRO - ALL ACCESS AT GRADE, NO VEHICLE HEIGHT LIMITS
CON - TALLEST ESCALATORS, GREATEST VERTICAL CHANGE



VEHICLE TUNNEL

PRO - PEDESTRIAN FRIENDLY, CREATES INNER COURTYARD
CON - TUNNEL AIR QUALITY

FIGURE 67 - STATION CONFIGURATION OPTIONS TO ACCOMMODATE TOPOGRAPHY AND CONTEXT



1. STATION AREA PLAN

STREET PLAN MAINTAINS A MAX 8% GRADE

CREATES PEDESTRIAN FRIENDLY PLAZA AND STREET

FASTEST ROUTE THROUGH AREA ON INTERSTATE SIDE

SPLICES INTO EXISTING VILLAGE AT AVON PLAN

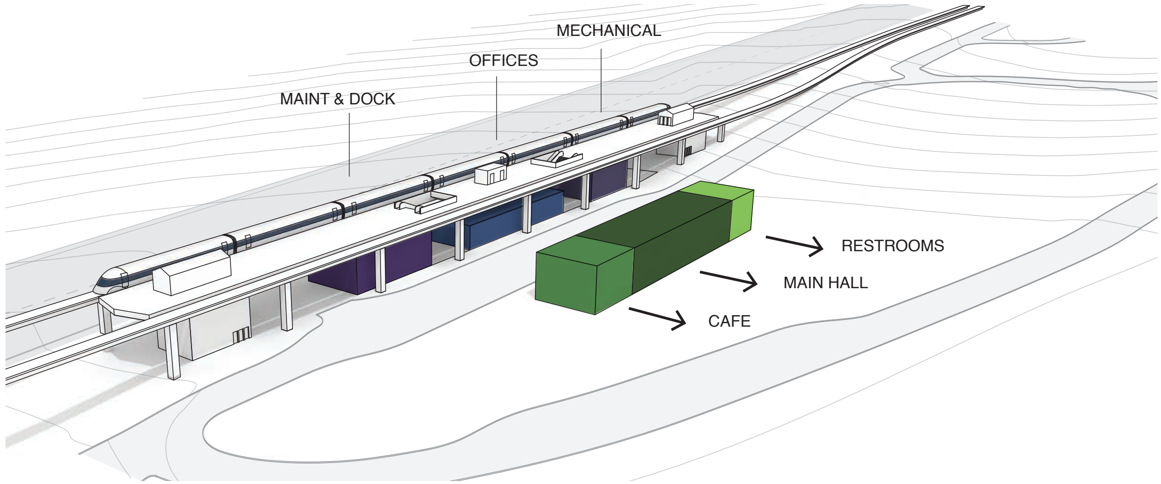
2. PUBLIC & PRIVATE

PUBLIC PROGRAM MOVED SOUTH OF AUTO ACCESS STREET

RESOLVES MODE SEPARATION ISSUES

CAFE LOCATED TO END WITH BEST DOWN VALLEY VIEW

PRIVATE & LIMITED ACCESS PROGRAM REMAINS BENEATH PLATFORM



3. CIRCULATION MOD

ADDS TWO EMERGENCY EXITS FOR EXIT ACCESS LENGTH REQS

INSTALL CONNECTING BRIDGE FROM TERMINAL TO PLATFORM

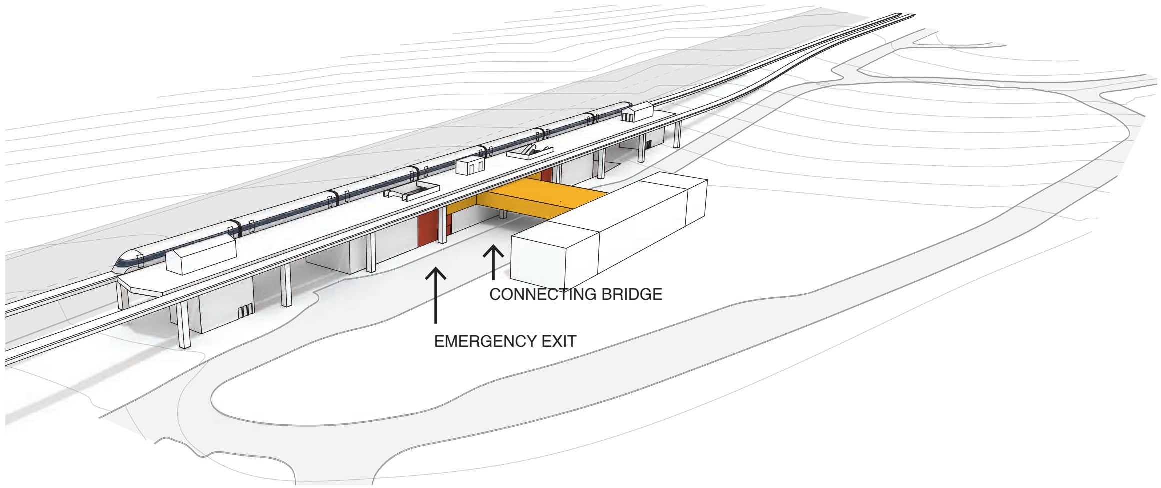


FIGURE 68 - STATION TEMPLATE ADAPTED TO AVON STATION SITE

run to the south and a short bridge used to bring passengers from the platform, over the road, and down into the main terminal, which faces a pedestrian plaza. Those spaces essential to station operation, such as offices, maintenance, and major mechanical remain beneath the platform, while public spaces are pulled across the street into the terminal building and closer to pedestrian access points. Despite the rearrangement of spaces into a tri-part platform, bridge, terminal sequence, the circulation routes, and thereby passenger familiarity with the entire network of stations, is maintained. This modified arrangement serves as the foundation for the aesthetic portion of the station design (Fig. 67-68).

4.1.3 – Architectural Language for Avon

In addition to establishing a baseline user familiarity, the purpose of the station template is to offer a blank canvas for different architectural languages to be expressed between stations. As mentioned earlier, community feedback identified contextual sensitivity and iconic design as priorities for station designs. Three concepts for the Avon station were proposed. The chosen concept is inspired by the local aspen groves and populates the station with a grid of abstracted aspen trees. The resulting space reveals a forest growing within the form of a vernacular gabled train shed. This concept was chosen for its ability to overcome the harsh aesthetic division between form and function in the train station typology, and to meet community expectations for the station within the fabric of the town. The tree language is intended to serve as a reminder to passengers that the AGS was built to provide access to nature rather than an opportunity to overpower it.

From a very early stage in the design process a number of important principles were identified. The first was the use of structural trees as a tribute to Colorado's aspen (Fig. 69). The second was the use of a barn or shed profile to honor the vernacular derived from the mining and farming tradition along I-70 (Fig. 70-71). The third was to use translucent materials in the roof to create commonality with the Denver International Airport (Hook, 2000) and SOM's new Denver Union Station, both of which employ translucent canopies (Fig. 72).

Lastly, this design process sought to challenge the traditional

FIGURE 69 - QUAKING ASPEN COLONY

FIGURE 70 - TYPICAL COLORADO BARN

understanding of an architectural icon. It is the author's assertion that too much importance is placed upon the exterior of a building today. This misplaced affection overshadows the success of a truly beautiful piece of architecture. These structures succeed in harmonizing the exterior and interior for a more complete experience. Too many of today's icons present magnificent facades disguising banal floor plates. We are quite literally judging the book by its cover. An awe-inspiring interior on the other hand is capable of sparking true intrigue. An interior is something people talk about because they can't just look down the street and point. It has to be described or it has to be experienced, and both of those turn a piece of architecture into a destination. The first inspires the thought, "I should go see for myself", and the other inspires the thought, "If I want to see it I have to go inside it." This is in no way an original concept, though. The design for the Pantheon deliberately hid the dome from view in order to heighten the surprise upon entering the temple. The Sistine Chapel is one of the most visited sites in all of Italy because it simply has to be experienced in person. In Gothic architecture, intimidating exteriors function as scaffolding for delicate luminous interiors that are alive with color. One could go so far as to argue that it is better to be inside of a Gothic building than outside of it. This is an effective strategy for a church seeking parishioners or even a train system attracting passengers. Much of this design process, therefore, focuses upon the interior experience as the primary architectural element.

FIGURE 71 - THE ARGO GOLD MINE & MILL, IDAHO SPRINGS

FIGURE 72 - DENVER INTERNATIONAL AIRPORT

4.2 – Design Iterations

4.2.1 – First Iteration

The first iteration of the station design is highly literal in its employment of the aspen concept, and is applied to an unmodified version of the station template. Trees of brushed steel sprout arbitrary branches that reach out to support a single span Teflon fabric canopy. Steel trees on the exterior wrap around the train guideway, thereby allowing the train to arrive amongst the trees while also providing points of tension to pull the fabric roof taut. The canopy's white outer surface and gold inner surface create a roof with a clean exterior and an interior glow reminiscent of the changing autumn leaves. This autumn glow is interrupted by beams of light through clerestories and skylights. From the exterior, only subtle ribbons of the roof's gold underside are visible, which pays tribute to the veins of gold mined deeper in the mountains. The quality of light and the airiness of the space are influential upon the final iteration, but the trees and canopy need considerable refinement (Fig. 73-78).

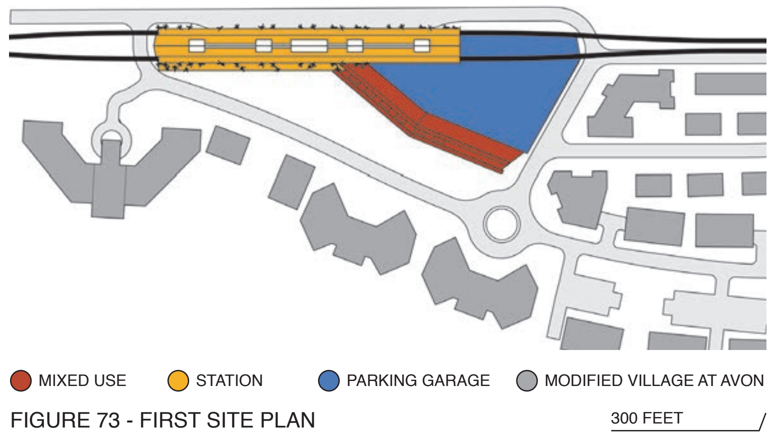


FIGURE 73 - FIRST SITE PLAN


FIGURE 74 - VIEW FROM EAST BOUND INTERSTATE 70

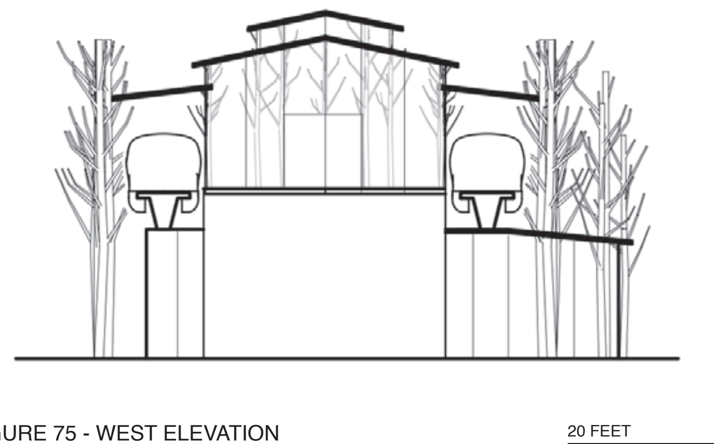
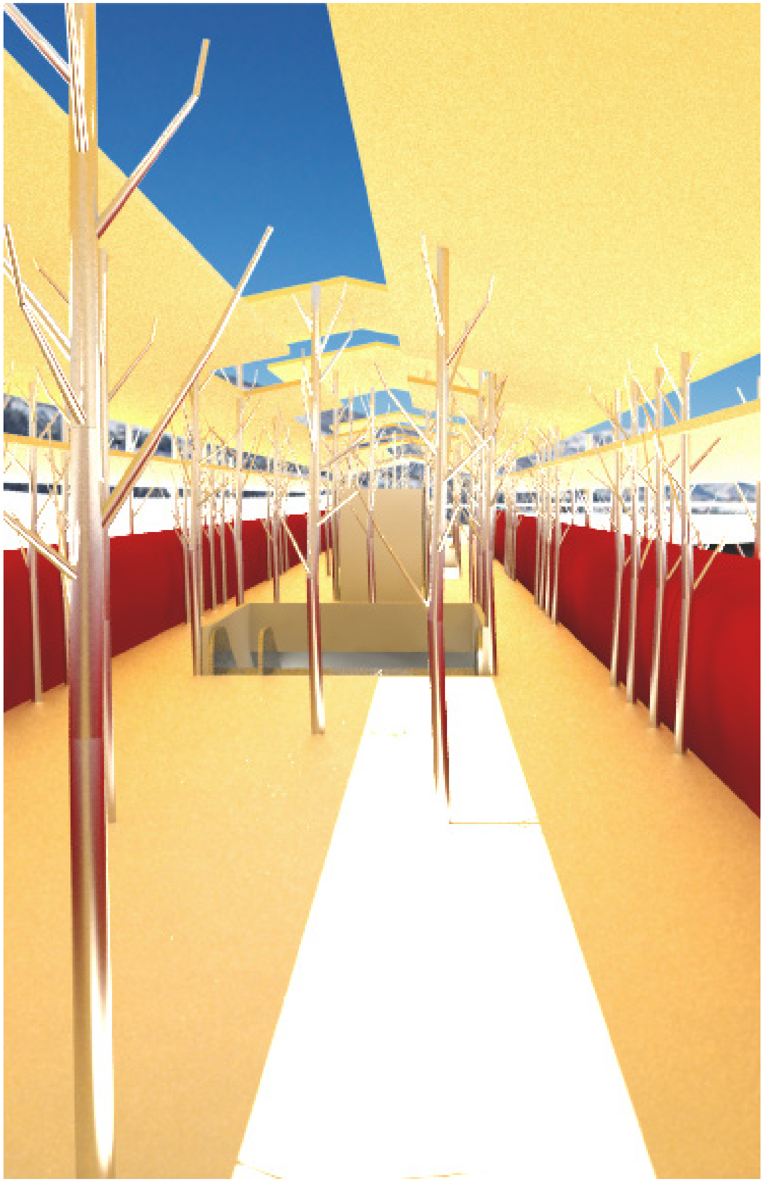


FIGURE 75 - WEST ELEVATION



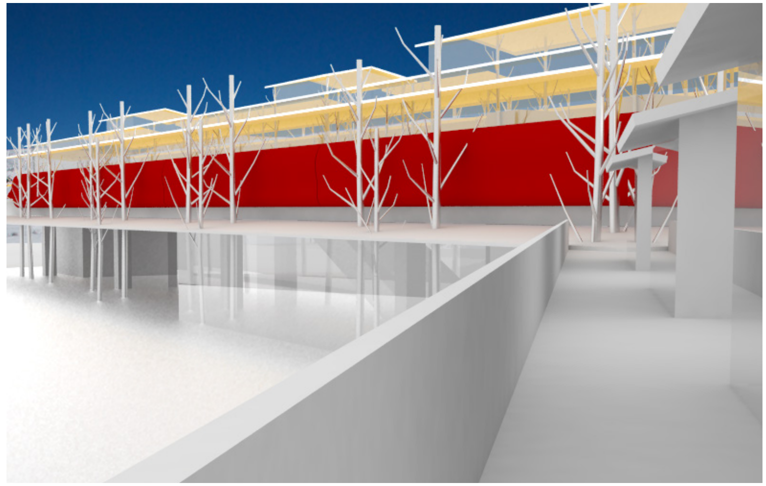


FIGURE 77 - VIEW FROM PEDESTRIAN PLAZA MIXED USE RESIDENTIAL

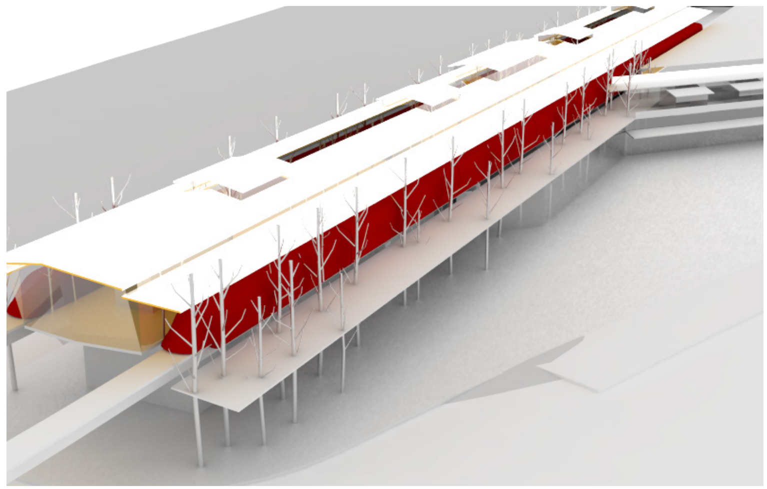


FIGURE 76 - PLATFORM INTERIOR WITH TRAINS

FIGURE 78 - FIRST ITERATION AERIAL

4.2.2 – Second Iteration

The literal adaptation of the trees in the first iteration leeds to a substantially more abstract interpretation in the second. This version springs four arching steel ribs from a single column and intersects them with the diagonal ribs running through a rigid rectangular canopy. The entire tree / canopy module is bent to fit the barn profile and then repeated down the length of the platform and throughout the main terminal. This version of the canopy uses wood panels around a central skylight. The resultant platform space is significantly darker than the first iteration, but is effective at framing the view of the hillside across the valley between the low hanging eave and the train guideway. The master plan for this iteration is the first to separate the automobile traffic from pedestrians by use of the tri-part arrangement, and focuses upon place making for the pedestrian plaza by incorporating an ice rink, pedestrian promenade, and a rooftop park above the parking garage.

This iteration is much more refined than the first, but fails in multiple areas. The tree canopy is too heavy for the slenderness of the supporting tree column, and mechanical connections to neighboring trees of varying heights are problematic. These problems initiated a search for a third structural solution in the following iteration. Aesthetically, the conspicuous repetition of the module is monotonous, visually tiring, and begs for a more creative column arrangement. The three rows of columns create a double nave running the length of the platform, which exaggerates its length. However the gothic undertones and framed views are highly influential upon the final design.

At the master plan level, the rectangular design for the main terminal fails to respond to the greater context of the town, and needs a more deliberate orientation. Although the street arrangement successfully divides transit modes, it also creates areas of steep grade. These grades create an unsafe condition for automobiles that must be fixed to ensure convenient access for all transportation modes. The parking garage is also problematic. Using a standard ramp style garage requires a large footprint, and comes at a high cost for excavation. The 600-vehicle capacity also makes the structure enormous relative to the smaller terminal, and pushes any attached mixed-use buildings closer to the street (Fig. 79-86).

FIGURE 79 - TERMINAL INTERIOR

FIGURE 80 - COLUMN TREE

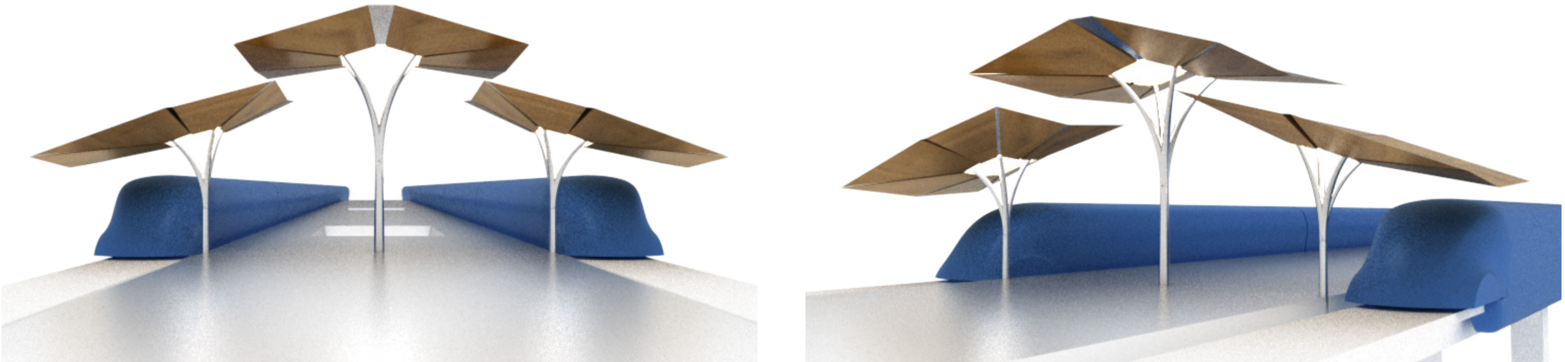


FIGURE 81 - COLUMN TREE PROFILES

FIGURE 82 - PLATFORM INTERIOR

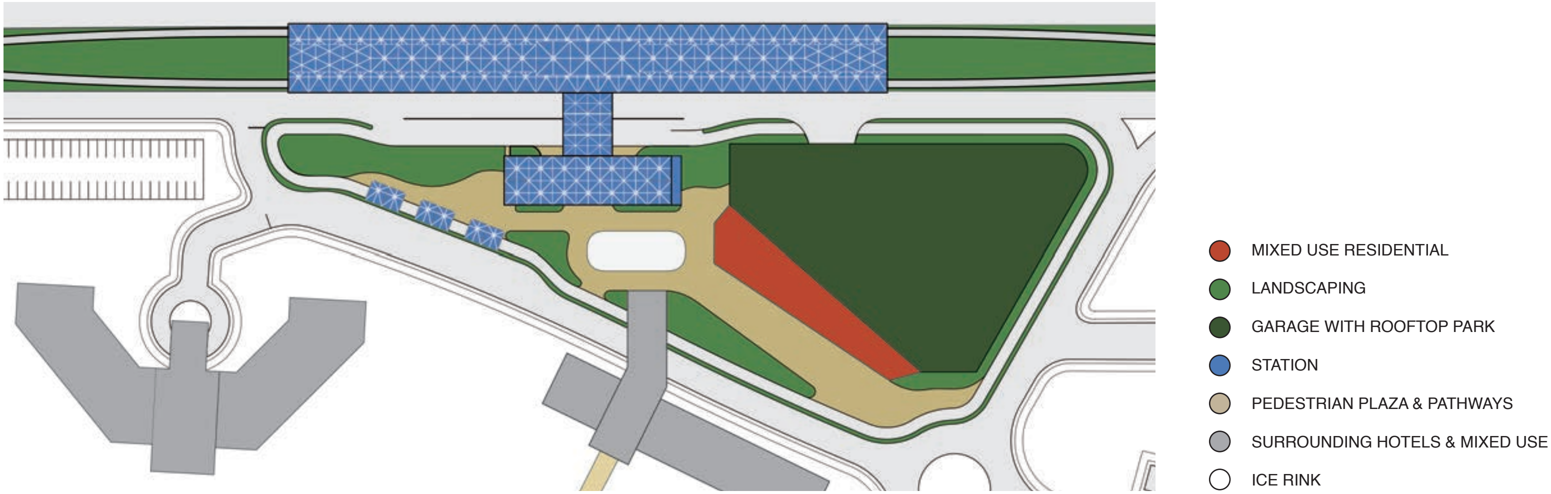


FIGURE 83 - SECOND SITE PLAN

150 FEET

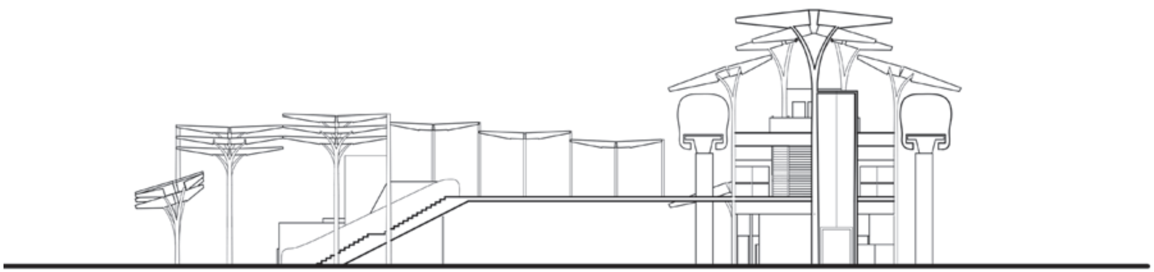


FIGURE 84 - TRANSVERSE SECTION

15 FEET

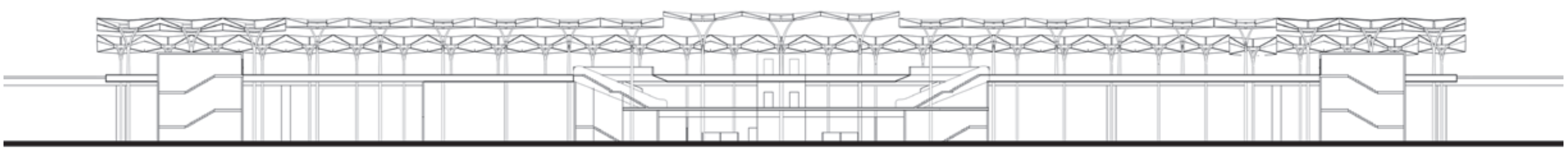
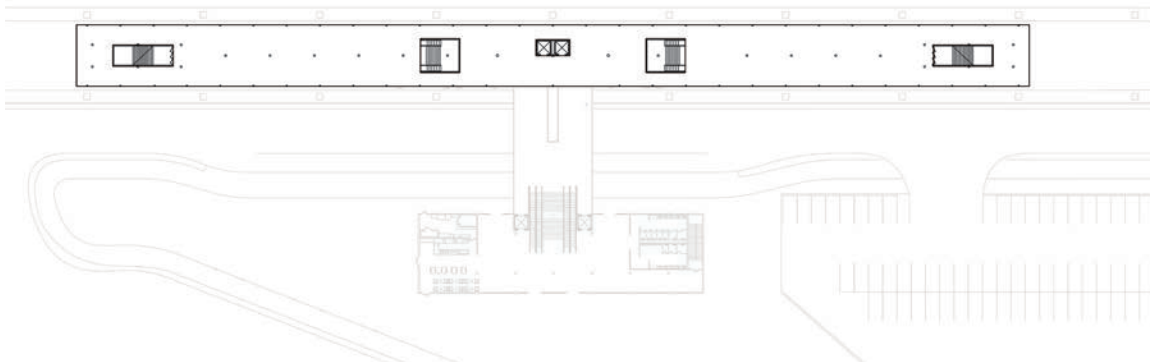


FIGURE 85 - LONGITUDINAL SECTION (PLATFORM)

50 FEET

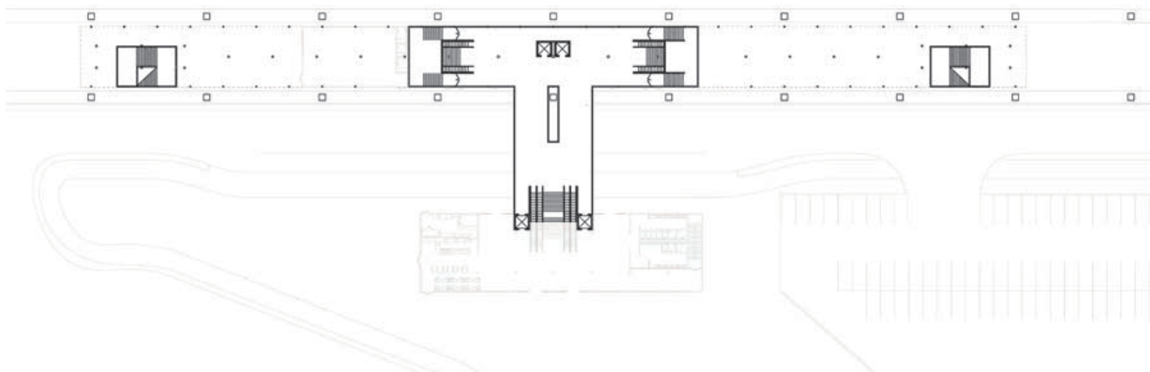
PLATFORM LEVEL

DOUBLE NAVE COLUMN GRID



BRIDGE LEVEL

CIRCULATION & EMERGENCY EXITS



GROUND LEVEL

PLATFORM, OFFICES & MECHANICAL

MAIN HALL, CAFE, & RESTROOMS

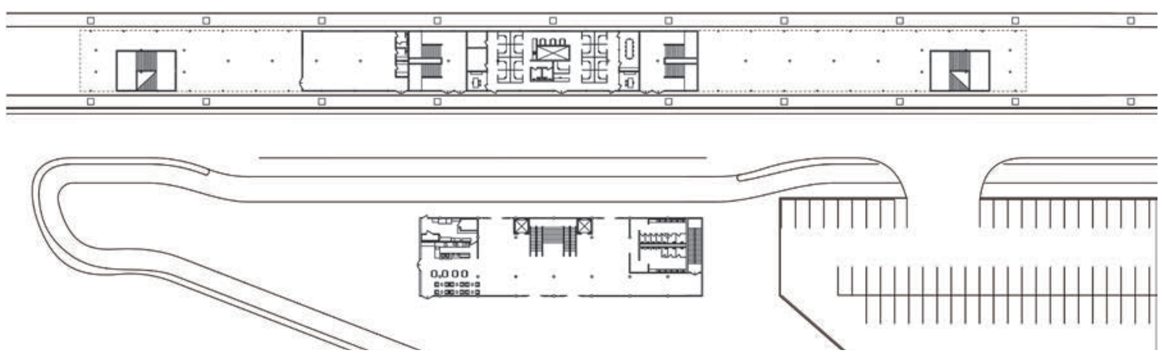


FIGURE 86 - FLOOR PLANS

100 FEET

4.2.3 – Third Iteration

The third iteration attempts to join the positive aesthetic elements of the first two iterations while also solving their problems. This version only focuses upon the visual language of the platform, and was abandoned as soon as the language for the final iteration became apparent. Three areas were addressed: the column arrangement, the tree form, and the quality of light.

In order to adjust the column grid without negatively impacting functionality, a diagram of the platform's most direct egress and circulation routes is used. This diagram draws upon the pedestrian self-organization principles discussed under 3.1.2, which argue that pedestrians will walk the most direct path available and will react to a column row as if it were a wall. With this in mind, pathways were drawn from each train vehicle door to the primary and emergency exits. The pathway widths increase as exits are approached in order to compensate for increased occupant densities as exit access routes progress. The result is a highly rationalized circulation plan that fully satisfies all egress requirements. This plan is then used to determine a column grid that reacts to platform function. Columns are placed along the edges of active circulation paths with attention given to their impact upon spaces below the platform as well. When viewed from the level of the occupant, the columns in this arrangement align so as to clearly direct occupants to the exits. The voids behind the columns are free for passengers to occupy, and the same column alignment effect provides reassurance that standing in these areas will place waiting passengers outside traffic paths.

The trees for this column grid take an entirely new approach from previous iterations. The challenge for this version is to design a column tree that communicates the verticality and flexibility of aspen, while simultaneously capturing the gothic undertones from the previous iteration. To do this a basic trumpet shaped form is adjusted to fit the profile of a gabled roof, and then propagated throughout the column grid. Since the grid varies in width and separation, the points of intersection for the tree forms also varies. The result is a series of imperfect pointed arches of varying heights. The implied ceiling they create is thereby lower in areas where columns are close together and higher where columns are further apart. Ultimately this creates open spaces with high ceilings in areas of highest traffic density, and more confined spaces in areas of lower traffic density. To create harmony between the trees and the roof they visually support, each column bay is tessellated and then projected vertically through the column trees and roof above. The resulting lines of projection delineate the paths for both the tree colonnettes and the tessellation of the roof.

The roof is comprised of two layers of transparent ETFE panels offset vertically by two feet, and subdivided into an array of colors per the tessellation. ETFE is a high tensile plastic with excellent thermal and UV resistance, which was made famous by its use in the bubble façade for the Beijing National Aquatics Center. This concept intends to use ETFE to capture the immersive quality of light found in the first iteration, as well as in the main terminal of the Denver International Airport. The multi colored tessellation is inspired by the naturally occurring variation of changing autumn leaves, and the offset roof layers allow for an active

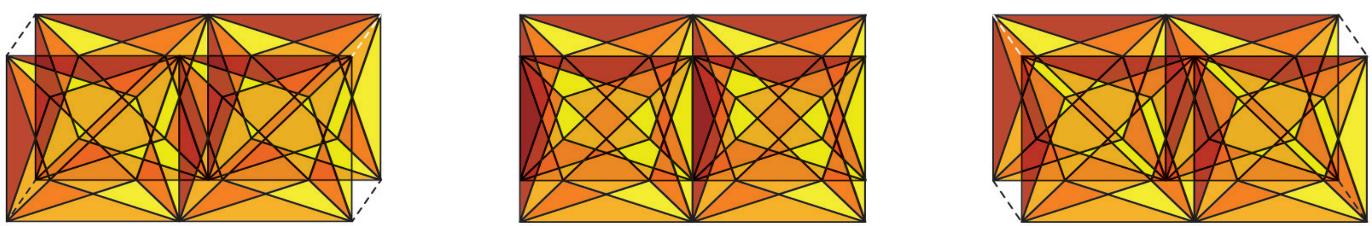


FIGURE 87 - ACTIVE COLOR MIXING OF OFFSET ETFE ROOF PANELS

mixing of color as passengers walk bellow. By using featherweight ETFE panels, tremendous weight savings are observed, which allows for a more delicate structure. However, this iteration uses one-inch diameter polished steel bars for all tree colonnettes, and relies upon a traditional steel skeleton hidden between the roof layers and column grid for structural support. This has the unfortunate effect of reducing the colonnettes to the level of an aesthetic treatment rather than an integrated part of the structure. As a whole, however, the visual effect of this iteration is a success, and is refined in the final iteration (Fig. 87-93).

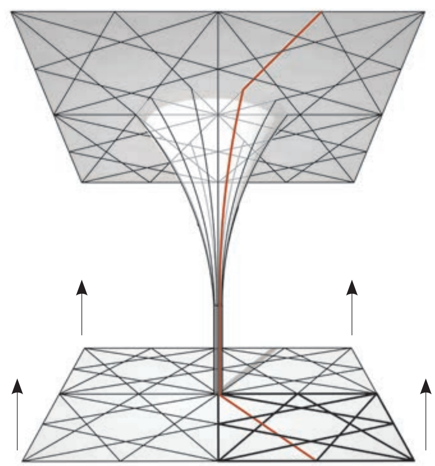


FIGURE 88 - PROJECTED TESSELATION TO DERIVE STRUCTURE

TESSELATION PATTERNS ATTEMPT TO CREATE A COLONNETTE AND ROOF PATTERN THAT BALANCES THE NUMBER OF ROOF PANELS WHILE CREATING A WEB THAT RADIATES FROM COLUMN BASE POINTS.

NUMBER 6 IS USED IN THE 3RD ITERATION

NUMBER 8 IS USED IN THE 4TH ITERATION

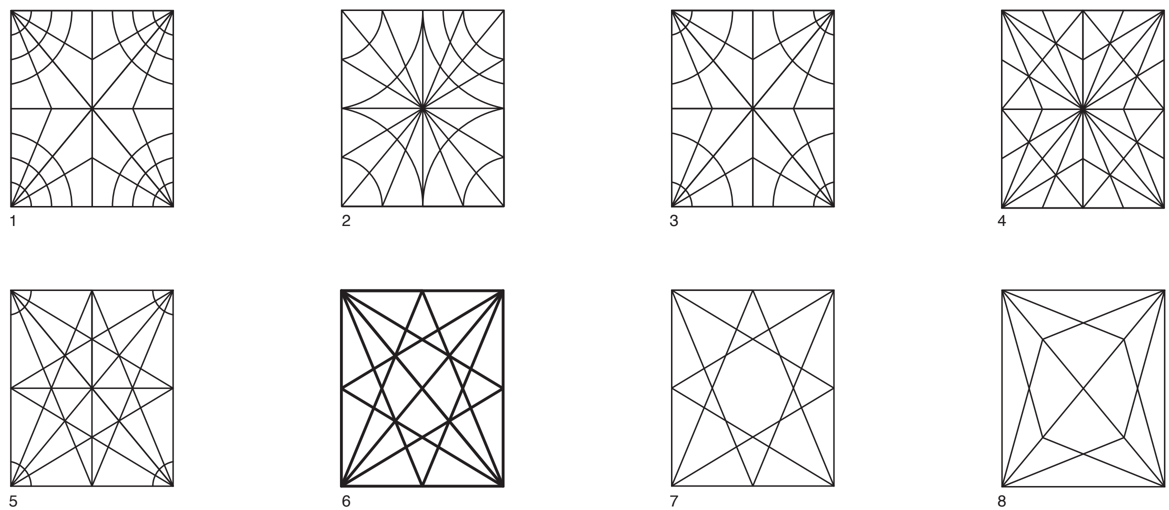
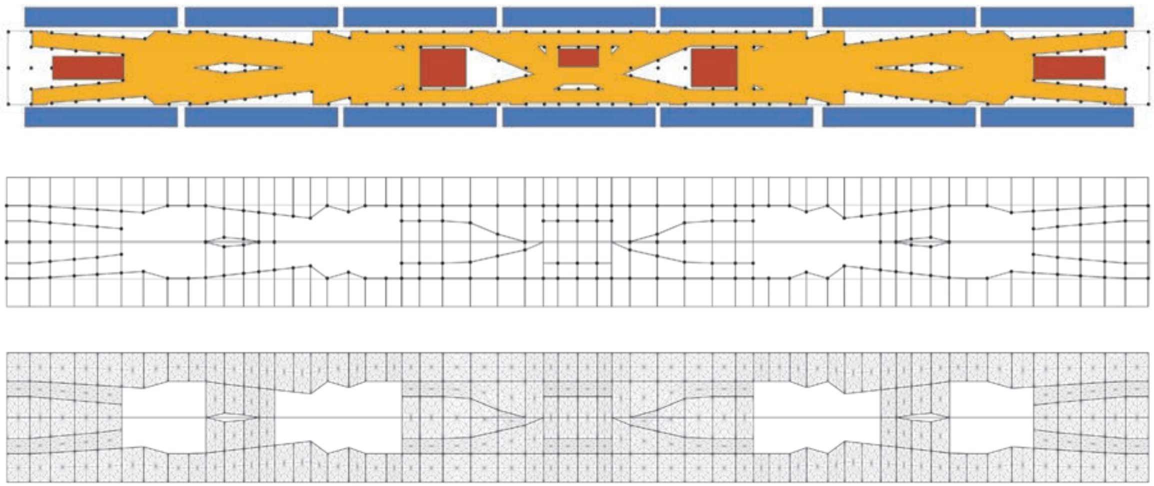


FIGURE 89 - TESSELATION ATTEMPTS



1. COLUMN GRID

DIAGRAM EGRESS FROM TRAINS TO EXITS

COLUMNS DEFINE ROUTE EDGES

CABLE WEB SUPPORTS ETFE PANELS

2. PRIMARY STRUCTURAL GRID

SUPPORTS ETFE PANELS AND LOADS

3. TESSELATION

DETERMINES ROOF ETFE MOSAIC

CABLE WEB SUPPORTS ETFE PANELS

FIGURE 90 - COLUMN GRID, PRIMARY STRUCTURAL MEMBERS, AND TESSELATION

FIGURE 91 - PLATFORM COLUMN TREE MASSING

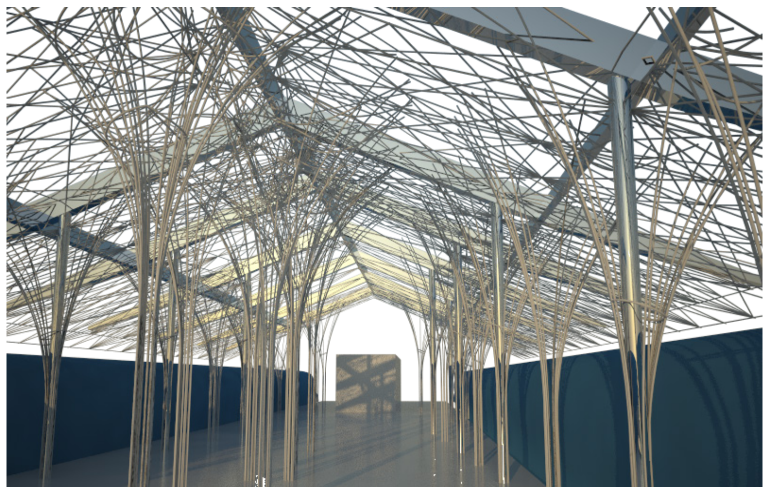


FIGURE 92 - STRUCTURAL SYSTEM

FIGURE 93 - ETFE VISUAL EFFECT

4.2.4 – Fourth Iteration

The fourth and final iteration refines the visual language and re-attacks the master plan. The driving principles for this version attempt to unify the tree concept into a functional structure, improve usability of the space, and apply the language beyond the platform.

Both the trumpet tree form and tessellation are refined, but the projection process remains the same. The one-inch bar colonnettes are replaced with four-inch diameter structural tube steel, which is carried into the top roof layer. This approach is inspired by McAslan's design for King's Cross. The four-inch tube steel is only used along structurally significant projection lines, and remaining projection lines are used to delineate a web of steel cables, which support the ETFE panels. This reduces both the physical and visual weight of the structure, and communicates a more concise structural rationale.

To improve usability of the platform and to provide a modular space within the station, a mezzanine level is added to the center of the platform. Mezzanine vertical circulation fits nicely within the platform's horizontal circulation diagram, and accommodates the requisite egress and accessibility requirements. The mezzanine allows passengers to escape the hustle and bustle of the platform level and to occupy the tree canopy. This also provides a space that can be used for various events without impacting station functionality, and provides a unique view for all of the station design concepts to be appreciated.

This iteration also confronts an aesthetic problem arising from what would be 600 linear feet of continuous glazing along the edge of the platform. The reflection and severe frontality of this façade would make the exterior uninteresting and would fail to reflect the variation of the interior column grid. As a response, this iteration defines the platform edge as only those areas where train vehicle doors meet the platform. Curtain walls are then drawn between columns bordering the circulation paths, which allows the platform glazing to pull away from the train and change direction, thereby breaking up the platform façade and creating outdoor balconies from which passengers can look across the valley. This also takes advantage of the gothic undertones and allows the entire façade to be comprised of an irregular series of pointed arches, which are subdivided into thirds by curtain wall mullions. Balconies are accessed through pivoting window panels, which allow for cross ventilation during summer while still diffusing high winds in the area.

The roof system in this iteration is refined on a more functional level. Since this station will not be constructed for another ten to fifteen years, some degree of speculation is made in regards to material performance. The ETFE panels are expected to be comprised of numerous layers, each of which with a different purpose. Thick outer layers of ETFE provide strength and protection for the delicate layers within. These include a translucent photovoltaic layer and a translucent electrically activated color-changing layer. These allow the roof to illuminate the space with natural light while providing a sustainable power source and the ability to change the color of the space at will.

This iteration also proposes a new way finding and interface system. Rather than installing LED screens throughout the platform and terminal, this system suggests embedding a technology similar to kindle's paper white within the laminated sheets of glazing. Either through touch or optical tracking, the glass walls are able to display arrival and departure information, train vehicle seat availability, and can be used to buy or change seats. Since the column arrangement automatically directs passengers to train doors or exits, large signage penetrating into aisles is unnecessary.

At a master plan level, the main terminal is redesigned to respond to the environment and pedestrian approach. Two pedestrian entrances are oriented towards the two primary view corridors, one to the west and one to the east. These orientations allow passengers to experience the best possible views upon leaving the station. They also allow arriving passengers to enter facades that are canted in the direction of arrival rather than to the south as in previous iterations. The steep hill to the south ensures that few pedestrians will arrive from that direction on foot. To serve passengers from the bottom of the hill a short automated gondola is installed, which connects the planned main street for the Village at Avon, with the mixed-use area of the hilltop station. Within the terminal itself, the distribution of program is arranged to respond to the exterior elements. The café is placed to the west, and supports people using the ice rink and hotel to that side. Information, car rental, and tour desks are placed to the east, and in close proximity to the parking garage, which would be the next stop for passengers using these services.

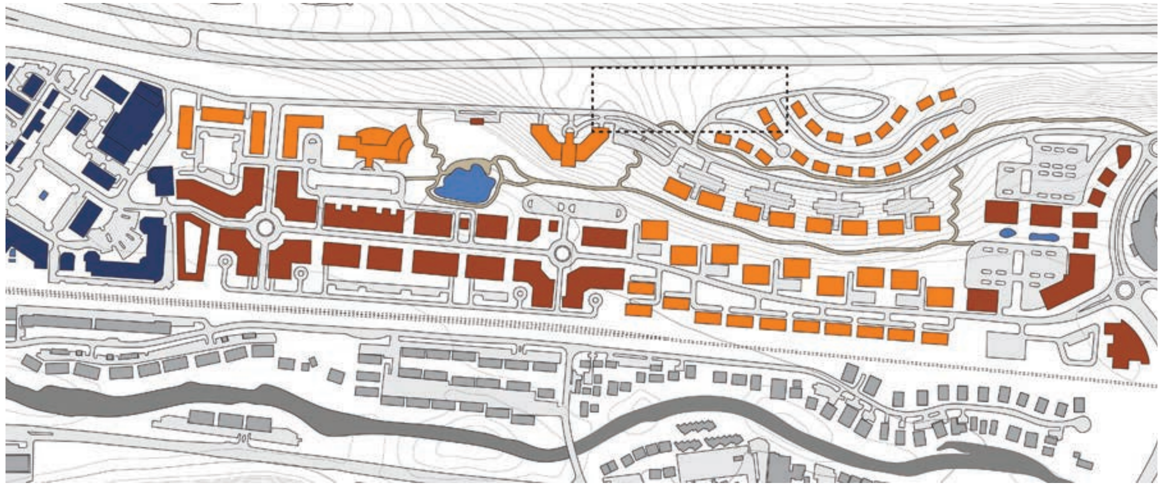


FIGURE 94 - APPROVED VILLAGE AT AVON MASTER PLAN

- MIXED USE COMMERCIAL
- MIXED USE RESIDENTIAL
- STATION
- MIXED USE STATION AREA
- POND, FOUNTAIN, ICE RINK
- EAST AVON DEVELOPMENT
- PATHWAYS
- ALIGNMENT
- OTHER STRUCTURES
- PROJECT SITE

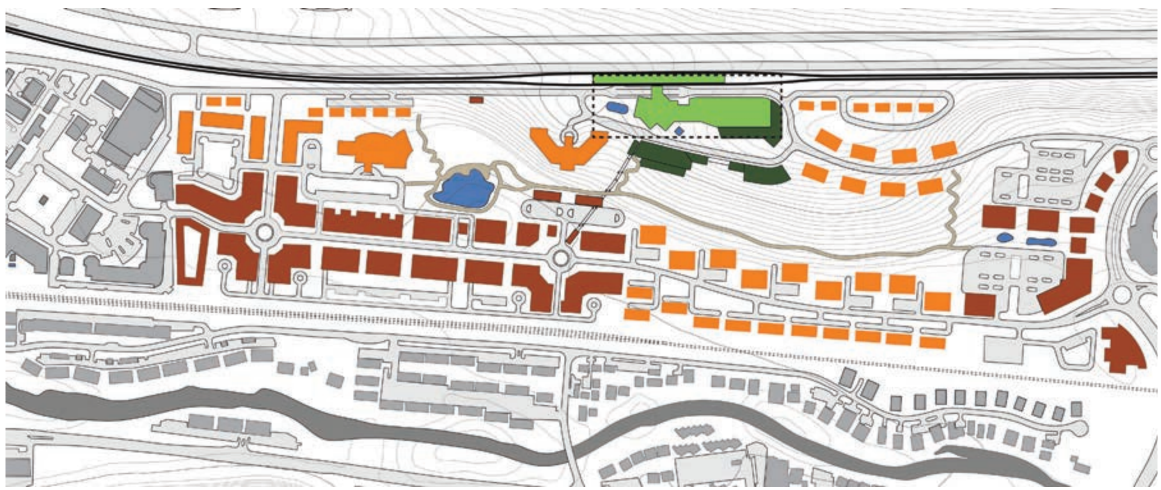


FIGURE 95 - MODIFIED VILLAGE AT AVON MASTER PLAN

The parking garage is further refined to reduce its footprint. With land value at a premium and the cost of excavation exorbitant, the smaller the footprint the better. Emerging automated parking garage systems enable higher vehicle densities than standard garages. The high cost of these systems is offset by the land and excavation savings they allow. Boomerang Systems, for example, is an American company whose technology can be installed at a lower cost than traditional underground parking, can accommodate large SUV's common throughout the mountains, and can operate fast enough to meet the demand of arriving and departing trains. The land saved with automated parking allows for the previous north/south oriented pedestrian plaza to run east/west in line with pedestrian arrival, and makes room for a 75,000 square foot mixed use structure to wrap around the garage. The roof of the parking garage houses both photovoltaic and solar hot water arrays. When added to the power produced by the ETFE panels on the platform and terminal, the power produced by the garage photovoltaics should be more than enough to power the station and much of the surrounding area. The solar hot water array augments the boiler system that provides radiant floor heating throughout the platform and terminal.

Although this iteration is the final one for this thesis project, subsequent iterations would produce further refinement to the structural and mechanical systems as well as to the architectural language (Fig. 94-122).

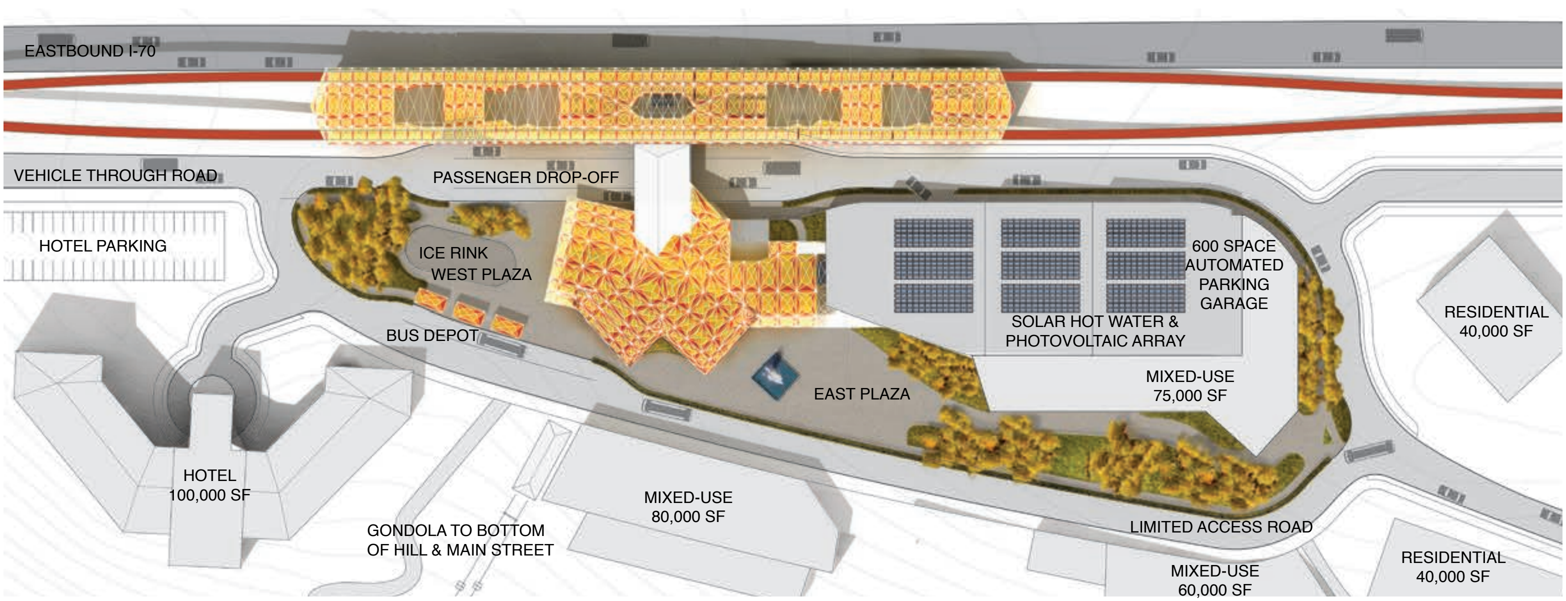
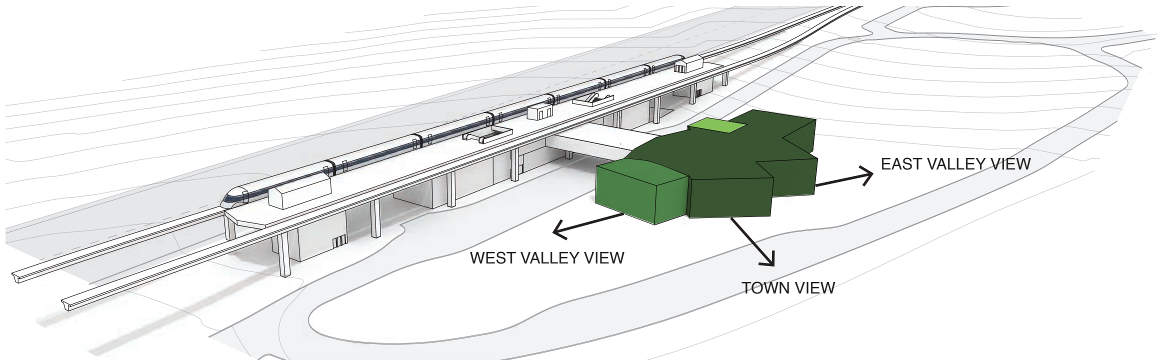


FIGURE 96 - FINAL SITE PLAN

1. TERMINAL FORM

FORM FURTHER ADJUSTED FROM SECOND ITERATION

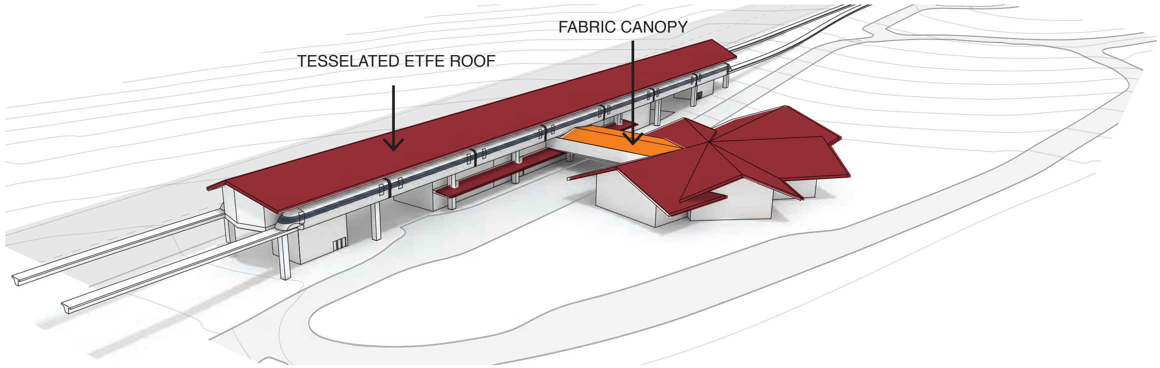
FACADES ORIENTED TOWARDS VIEW CORRIDORS



2. ROOF FORM

VERNACULAR GABLED ROOF IS A TRIBUTE TO MINING AND FARMING HISTORY

INORGANIC FORM CREATES TENSION WITH ORGANIC TREE COLUMNS



3. SUPPORTING PROGRAM

ARRANGED TO ENCOURAGE TRANSIT ORIENTED DEVELOPMENT GROWTH AND PLACE MAKING

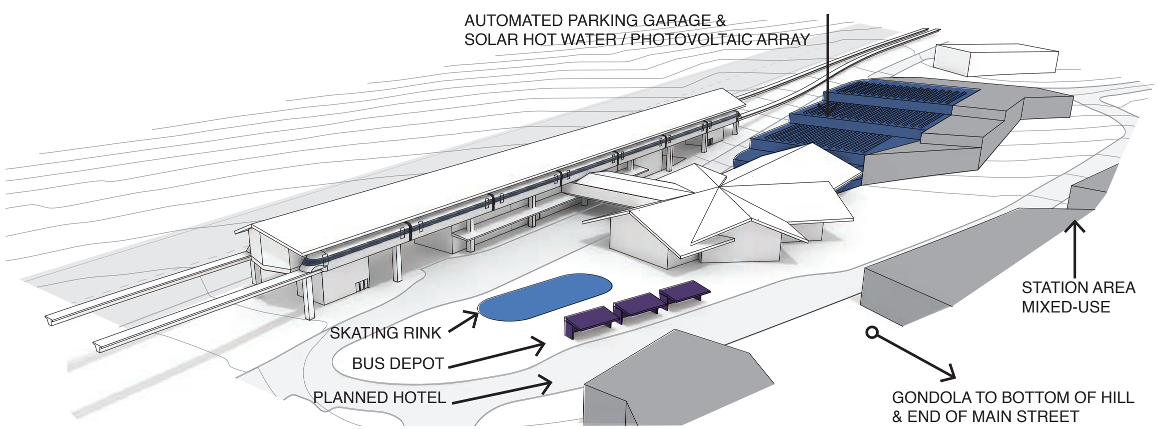


FIGURE 97 - FINAL STATION TEMPLATE ADAPTATION STEPS

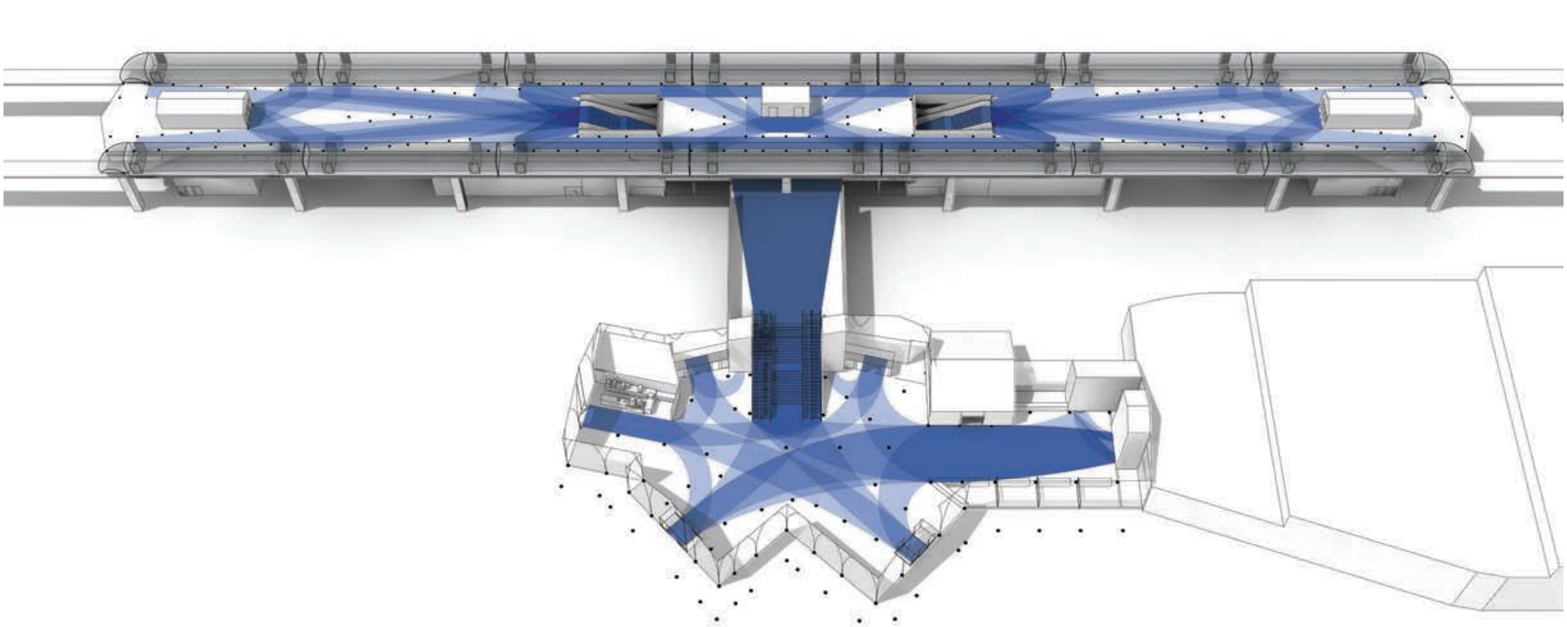


FIGURE 98 - REFINED CIRCULATION MODEL AND RESULTANT COLUMN GRID

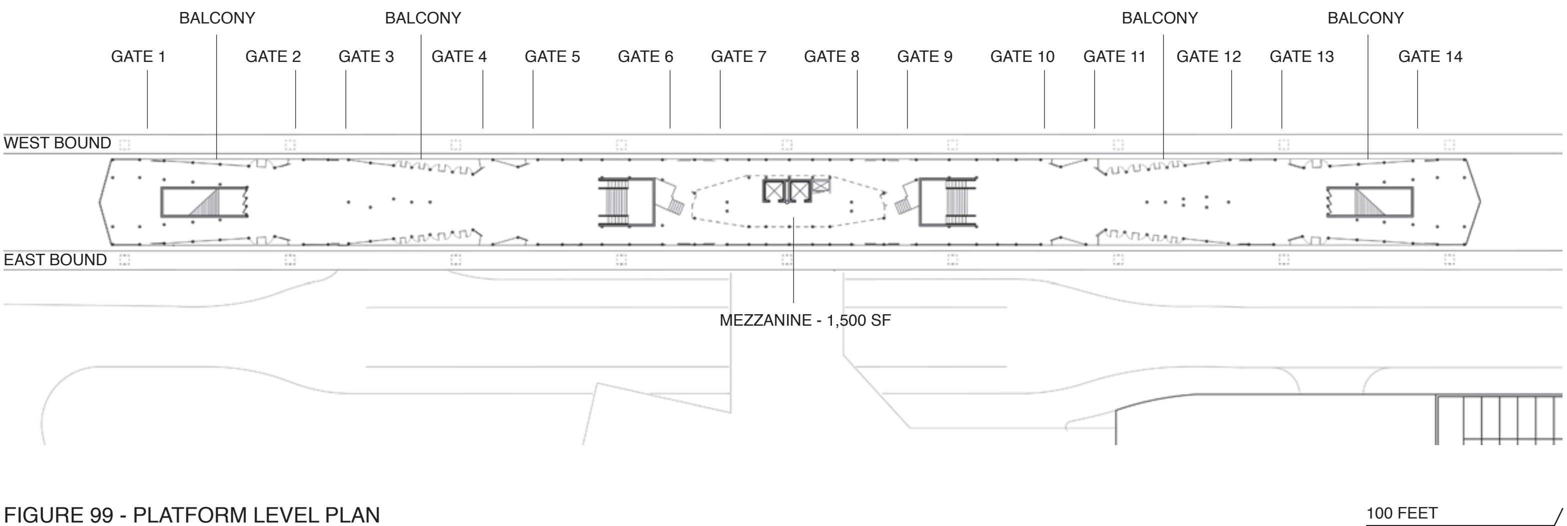


FIGURE 99 - PLATFORM LEVEL PLAN

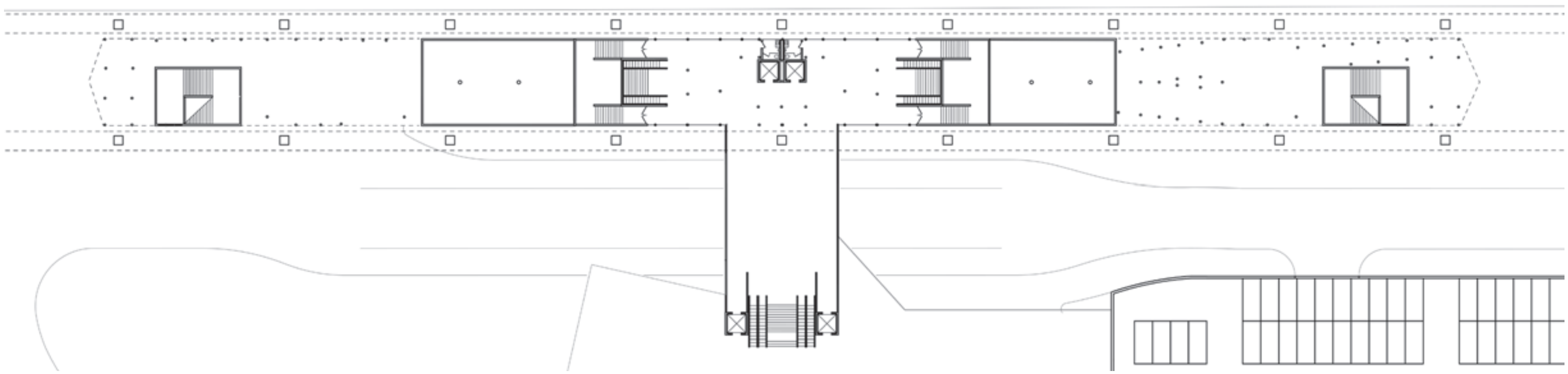


FIGURE 100 - BRIDGE LEVEL PLAN

100 FEET

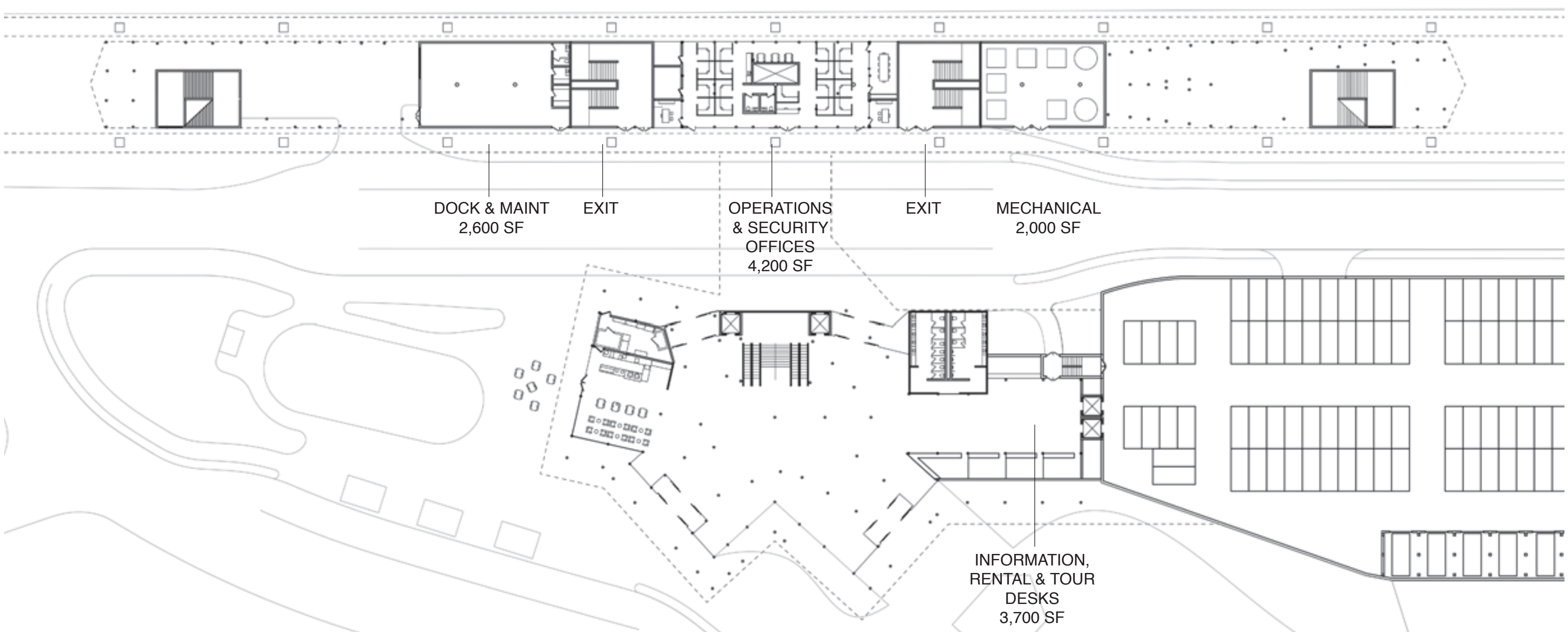


FIGURE 101 - GROUND LEVEL PLAN

100 FEET

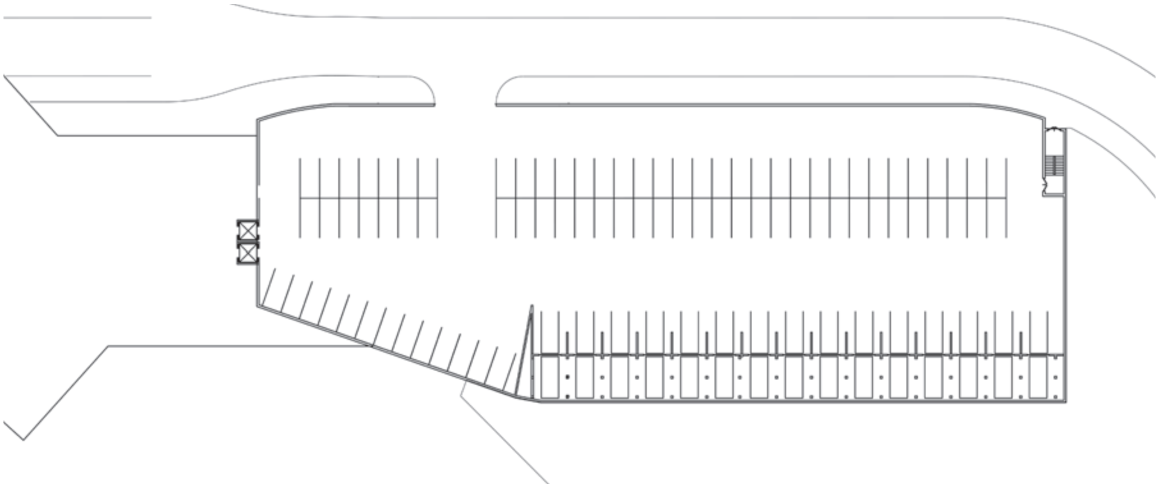


FIGURE 102 - GARAGE 2ND LEVEL

100 FEET

PUBLIC ACCESS

PARKING GARAGE ENTRANCE ON 2ND LEVEL DUE TO SITE TOPOGRAPHY

80 SELF PARKING / VALET SPACES

15 AUTOMATED PARKING BAYS

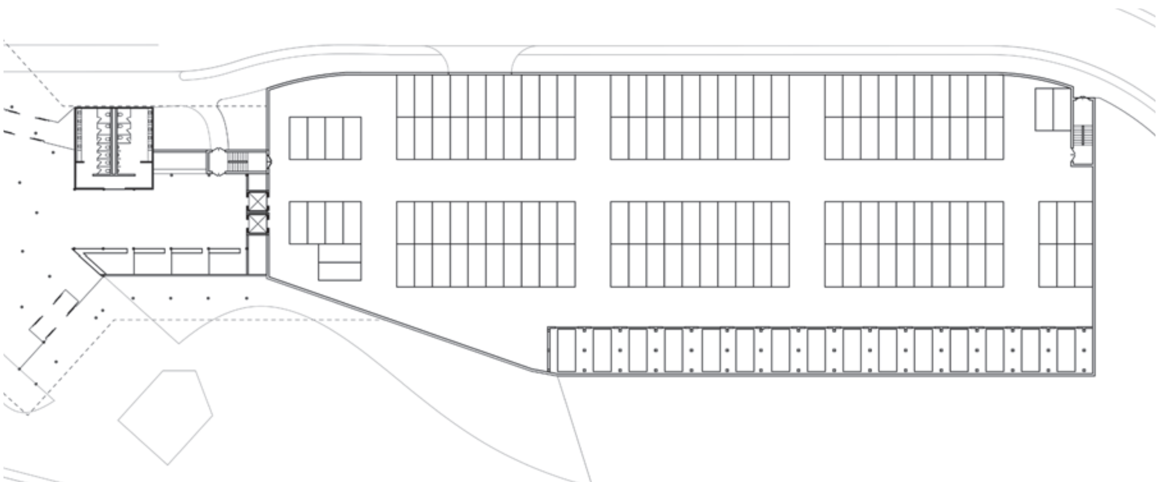


FIGURE 103 - GARAGE 1ST LEVEL

100 FEET

AUTOMATED STORAGE

138 AUTOMATED PARKING SPACES

BOOMERANG ROBOTIC PARKING SYSTEM ACCOMMODATES ALL VEHICLE TYPES AND SIZES USING ROLLING SLEDS AND ELEVATORS

FASTER AND MORE EFFICIENT THAN FIRST GENERATION CAROUSELS

BOOMERANG AUTOMATED PARKING MANUFACTURER REPORTS VEHICLE RETRIEVAL TIMES OF 60 - 90 SECONDS

FIGURE 104 - BOOMERANG PARKING BAY

FIGURE 105 - BOOMERANG ROBOTIC PARKING SYSTEM

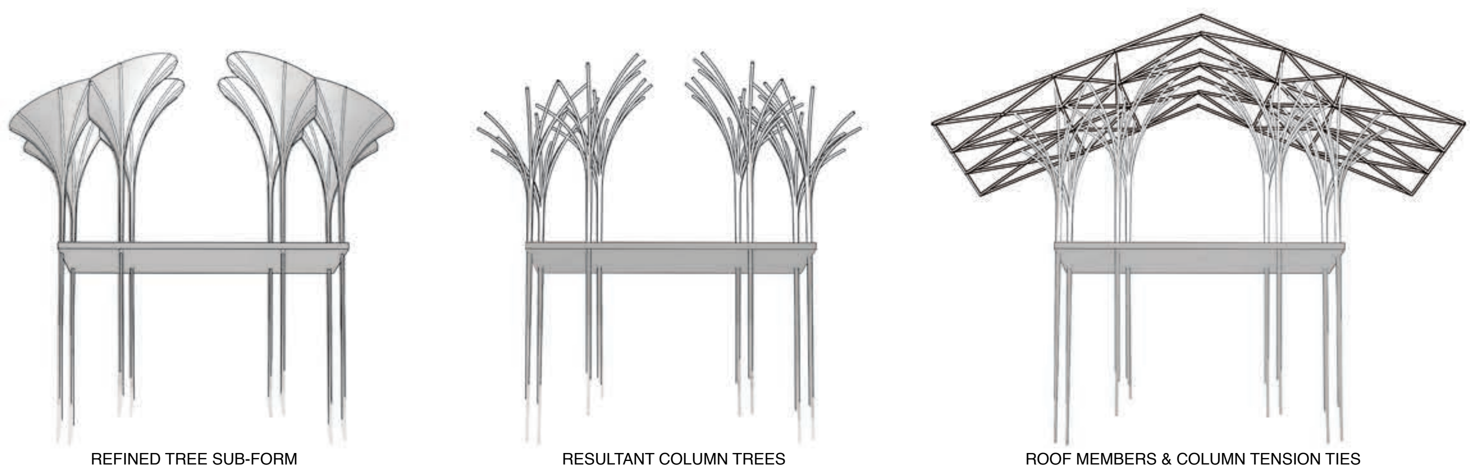


FIGURE 106 - REFINED COLUMN TREES AND RESULTANT STRUCTURE

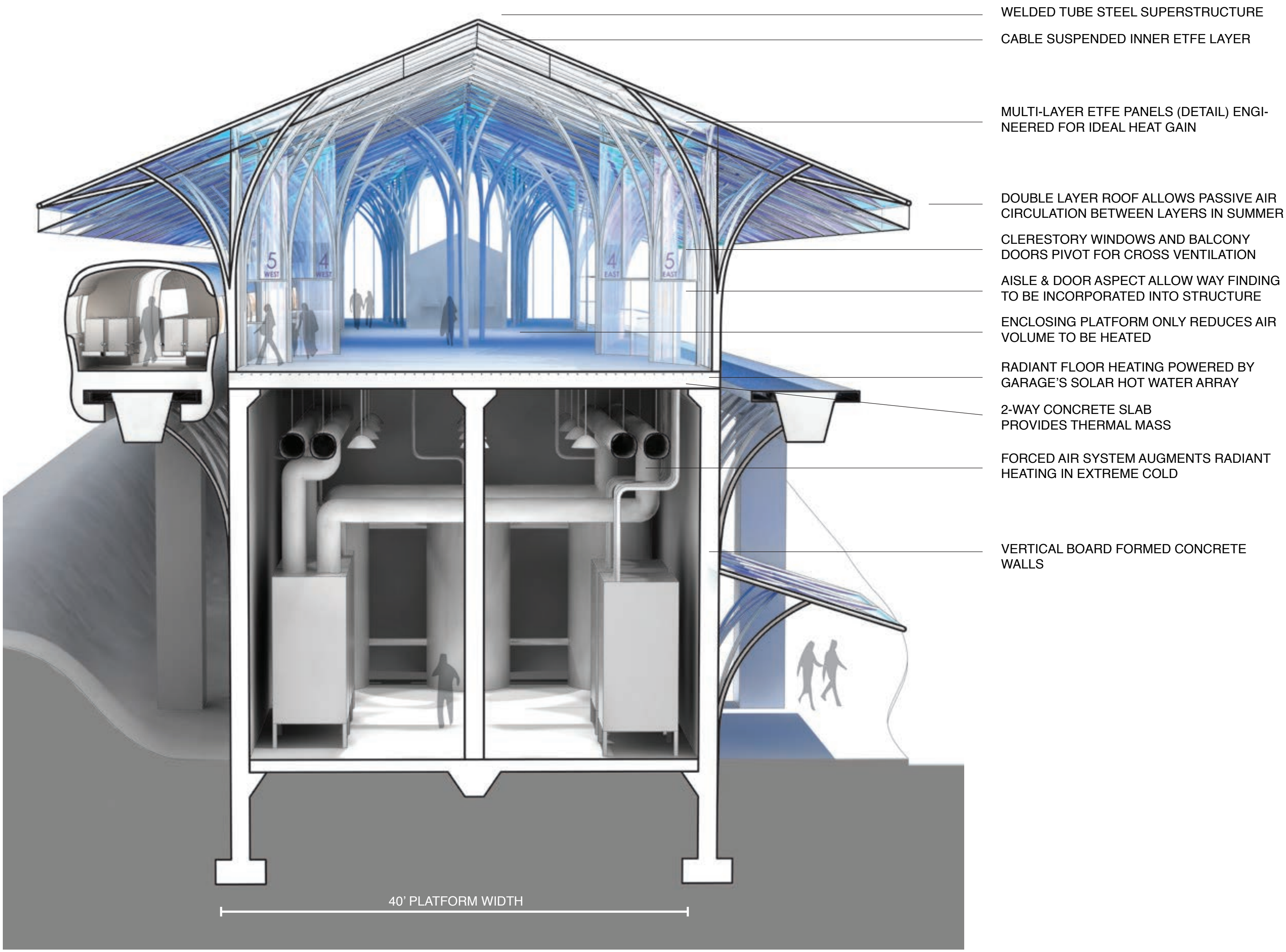


FIGURE 107 - SUSTAINABILITY & STRUCTURE - PLATFORM TRANSVERSE SECTION

FIGURE 108 - PERSPECTIVE SECTION

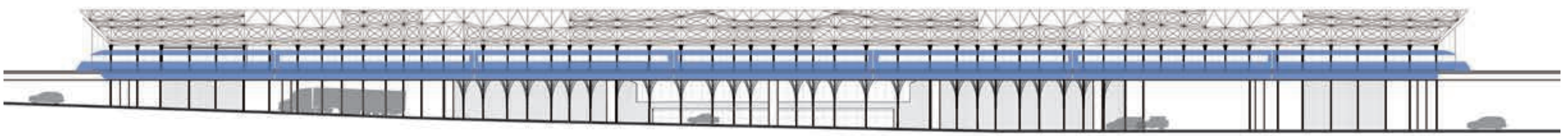


FIGURE 109 - NORTH ELEVATION

100 FEET

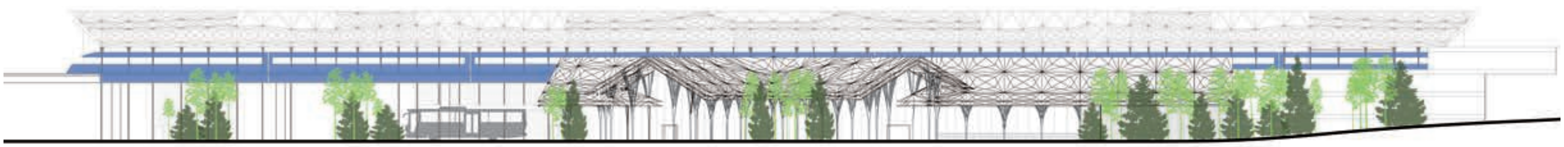


FIGURE 110 - SOUTH ELEVATION

100 FEET

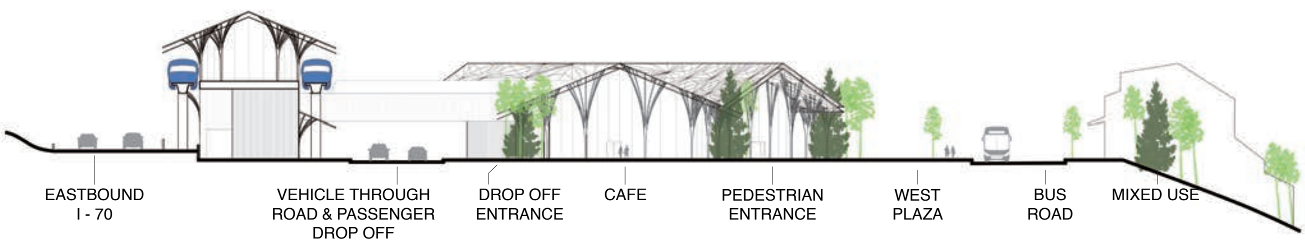


FIGURE 111 - WEST ELEVATION

100 FEET

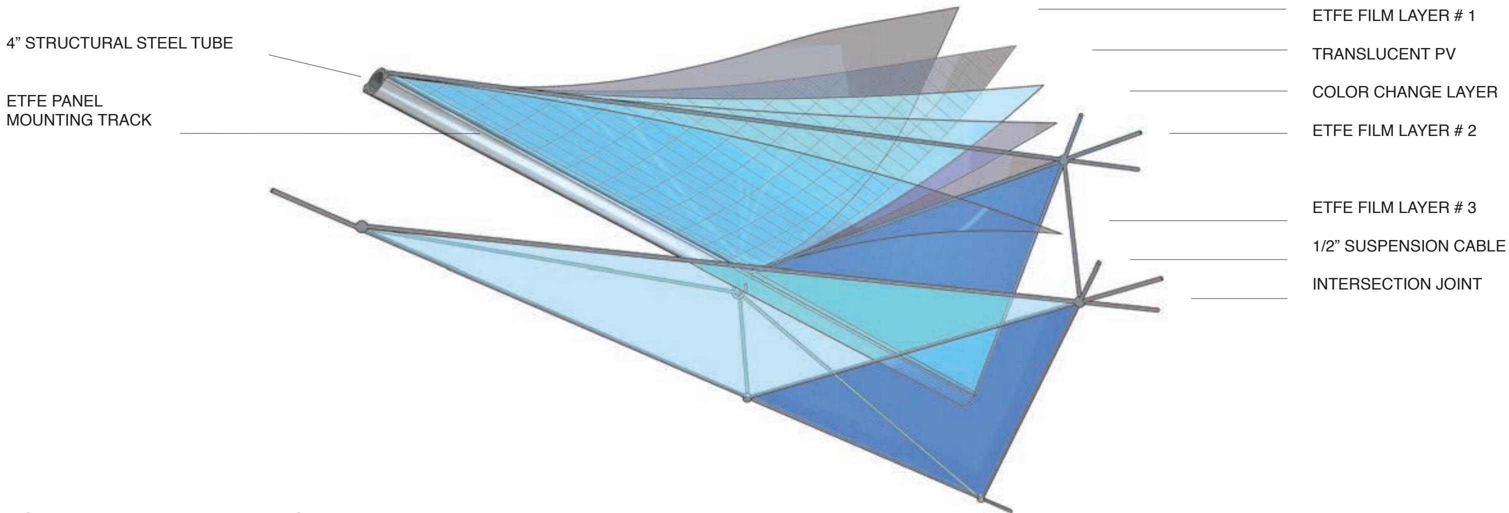
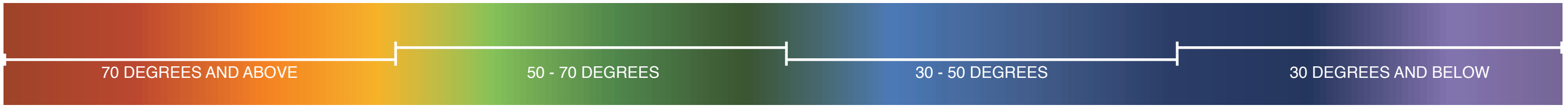


FIGURE 112 - ETFE LAYERING DETAIL

FIGURE 113 - WEST PLAZA EXTERIOR

FIGURE 114 - PLATFORM INTERIOR & COLOR CHANGING ROOF PANELS



ROOF PANEL COLORS REFLECT PREDICTED DAILY HIGH, AND ARE CHANGED THROUGH AN ELECTRICALLY MODULATED COLOR CHANGING LAYER WITHIN THE ETFE PANEL

FIGURE 115 - ROOF PANEL COLOR RANGE

FIGURE 116 - PLATFORM MEZZANINE

Coors Light
The Silver Bullet

Vail

Beaver Creek

FIGURE 117 - PRIVATE SPONSORS AND STAKEHOLDERS

FIGURE 118 - GATE AND THEORETICAL USER INTERFACE

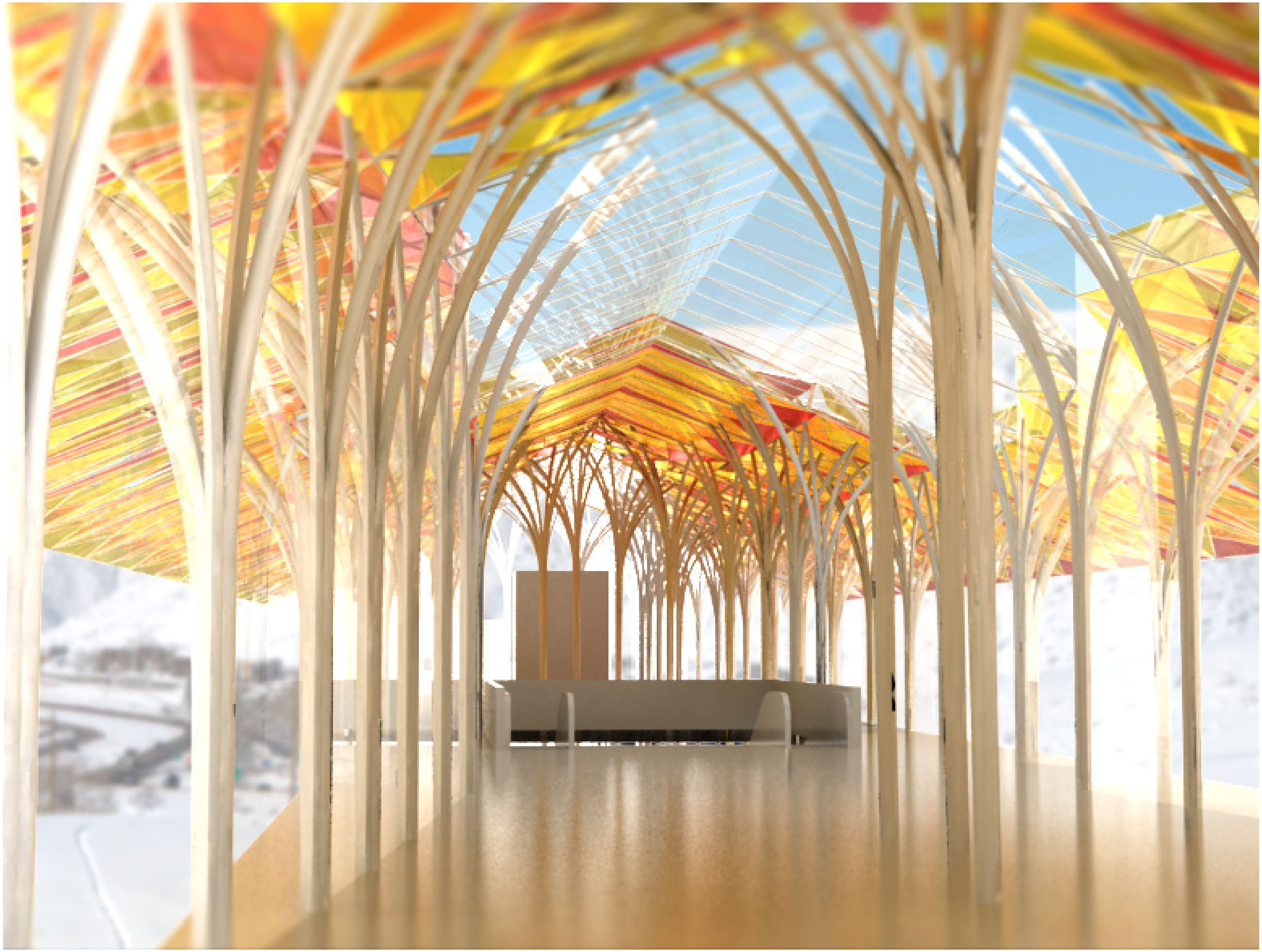
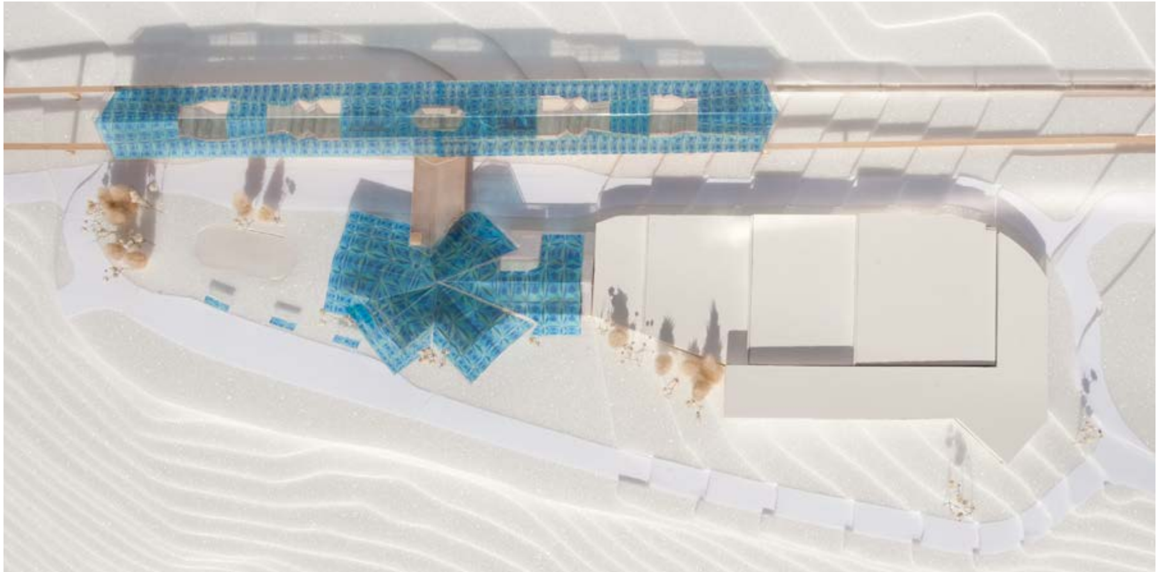


FIGURE 119 - EARLY PLATFORM RENDER

FIGURE120 - GROUND LEVEL VIEW OF PLATFORM STRUCTURE (NO GLAZING)



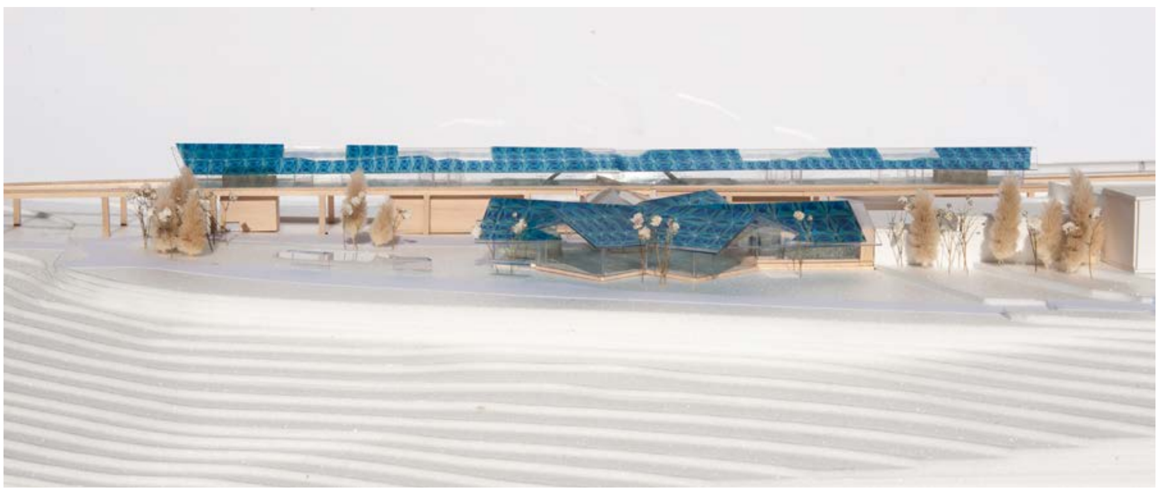


FIGURE 121 - MODEL IMAGES PART I

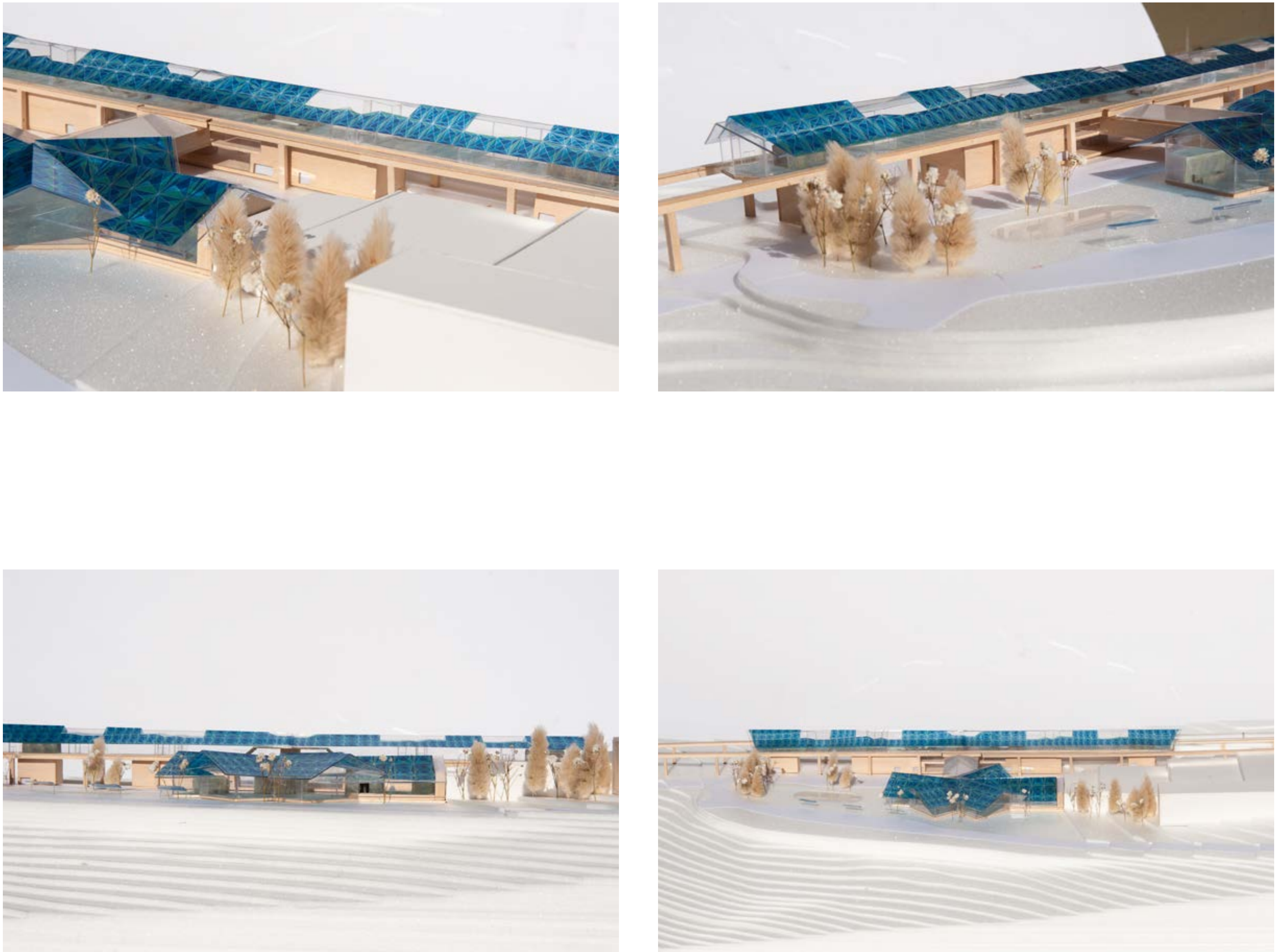


FIGURE 122 - MODEL IMAGES PART II

5.1 – Summary

In order to relieve the suffocating effects of traffic congestion upon Colorado's mountain corridor, the proposed hybrid MAGLEV AGS along I-70 is essential. Simply put, no other solution is able to create the same increase in capacity. Yet despite this obvious solution and the ever-worsening traffic conditions, garnering ridership is problematic, and America's auto-centric mentality is to blame. Developing stations as hubs for new Transit Oriented Developments has proven successful in overcoming America's aversion to transit, though, and is recommended for use in all of Colorado's station towns. This thesis proposed a station template for the mountain towns, which optimized the station typology by incorporating successful TOD principles. This template was adapted to Avon's master plan for the forthcoming Village at Avon development. The process culminated with the design for an iconic station structure, the unveiling of which could conveniently coincide with a 2034 Denver Winter Olympics.

5.2 – Observations

Exploration of the principles identified in research through application in the Avon station design showed that the premise for the thesis was largely successful. The master plan allows for a station area that is convenient for pedestrians, buses, and automobiles alike, and the design for the station itself proposes an iconic structure in keeping with research conclusions. Ultimately time would have to determine this process's success, though. The way in which the surrounding development evolves could vary greatly based upon the businesses that move into the area, and how they impact the TOD as a whole. The station, after all, is merely the hub of a much larger wheel, and there are stations in both France and Germany that stand as testaments to failed TOD's.

The mountain context provides a unique scenario for the success of TOD's but the terrain and subsequent route alignment often make station locations less than ideal. The station for Breckenridge is far from the center of town, and other stations, including Avon, will observe sub-optimal surrounding development due to their freeway adjacency or density.

Another obvious challenge to this thesis is the construction cost to erect a station that fully incorporates the identified TOD principles. The AGS Feasibility Study estimates $15 million per station, an amount, which, when broken down, allocates less than $2.5 million for the entire platform and terminal. Due to the limitations the budget would impose, this estimate was completely ignored for the proposed design. This is also a challenge for CDOT as well. The state's budget estimate for each station ignores the societal benefit of iconic architecture, and may actually hurt ridership more than help.

In the end, tackling a typology as monumental as the train station and adapting it to an untraditional environment and an emerging technology was itself a challenge. This thesis skims the surface on the subject and would require a significant amount of additional time to explore fully. The path down which this has started is sound, though, and warrants consideration in the eventual design and construction of the mountain stations.

5.3 – Suggestions

Every area of this thesis is open to further research and refinement. There is much to be improved upon in the master plan that is beyond the purview of architecture, and needs the eye of a true urban planner. More iterations of the station template to include more detailed programming could reveal additional efficiencies and spatial arrangements.

Adjusting the station template to multiple technologies is also worth exploring and would create an interesting variety of station solutions. For example, the proposed station accommodates a large train at 30-minute intervals. What would the station look like if it accommodated smaller vehicles at 10-minute intervals? The impact of train size on station cost is worthy of a thesis in another field of study entirely, and is a subject that CDOT should give more consideration.

Fortunately for the train typology, the transportation needs of the country are beginning to shift away from the automobile and more research into optimizing train stations should continue. Data on passenger waiting, embarking, and alighting times could aid in refining platform and terminal area requirements, and could possibly support a decision to keep platforms open air despite cold weather. Further research relating ridership increases to iconic station designs could convince CDOT to increase station construction budgets beyond current pittance estimates.

Finally, it would be interesting to study the potential for MAGLEV to reinvent how trains integrate into communities since noise, pollution, and vibration are no longer an issue. Accommodating this new technology in architecture begs a number of questions. Could the negative connotation of "down by the train tracks" begin to change? What effect would that change have on densification of urban areas? Could Futurism experience a revival? These are but some of the directions further research could pursue.

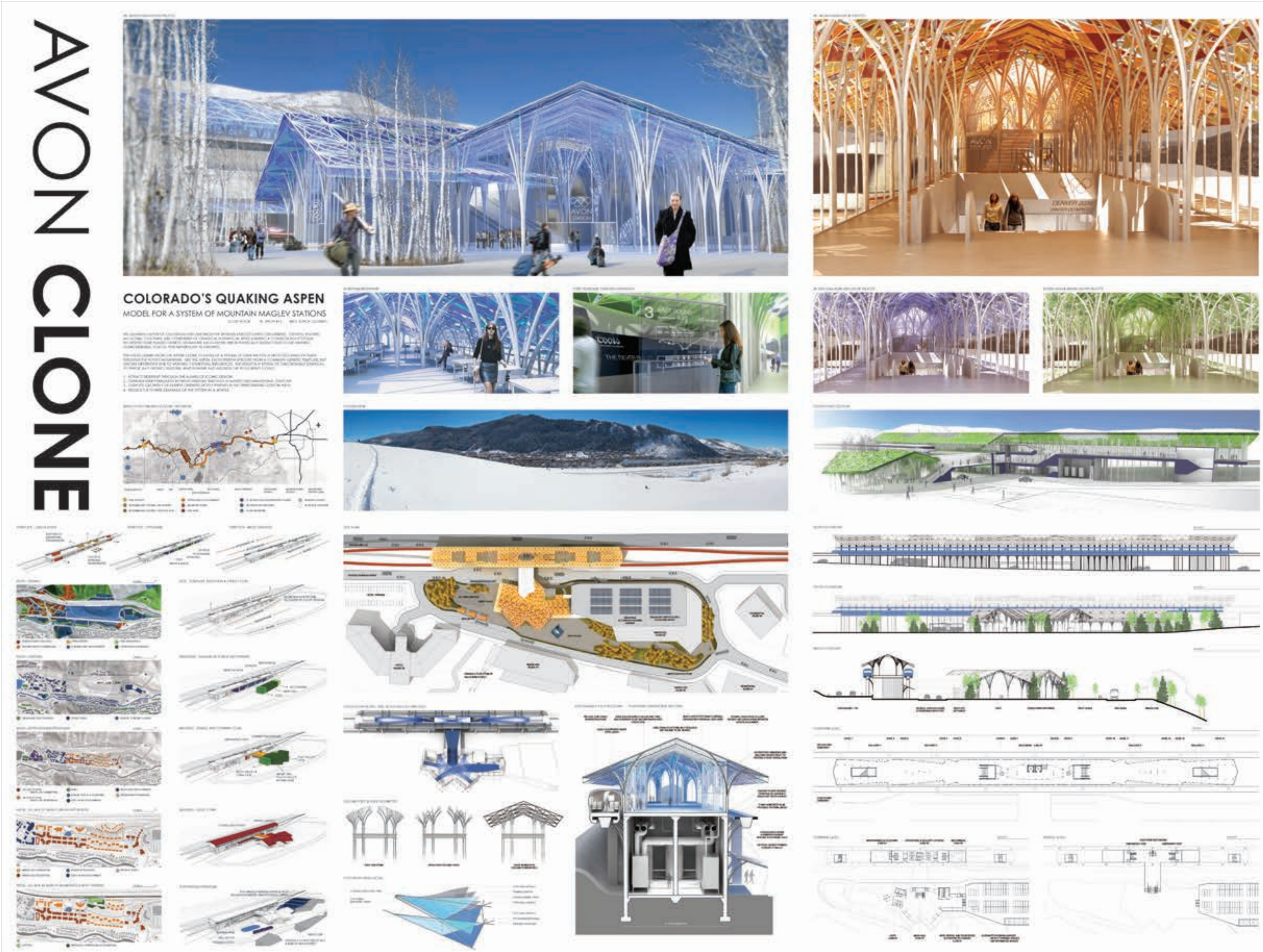


FIGURE 123 - AR-903 FINAL PRESENTATION BOARD (60 X 80)

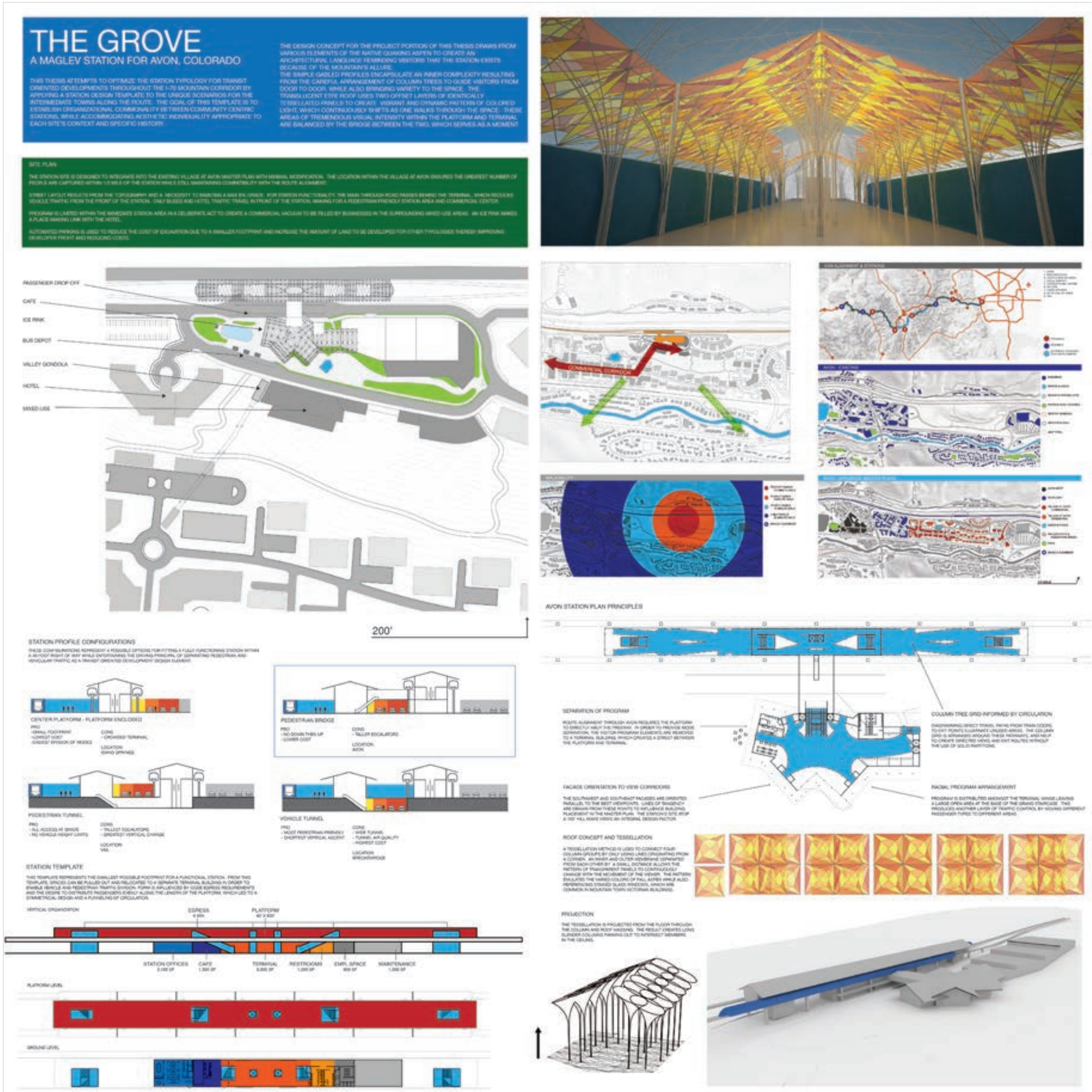


FIGURE 124 - AR-903 MIDTERM PRESENTATION BOARD PART I (36 X 36)

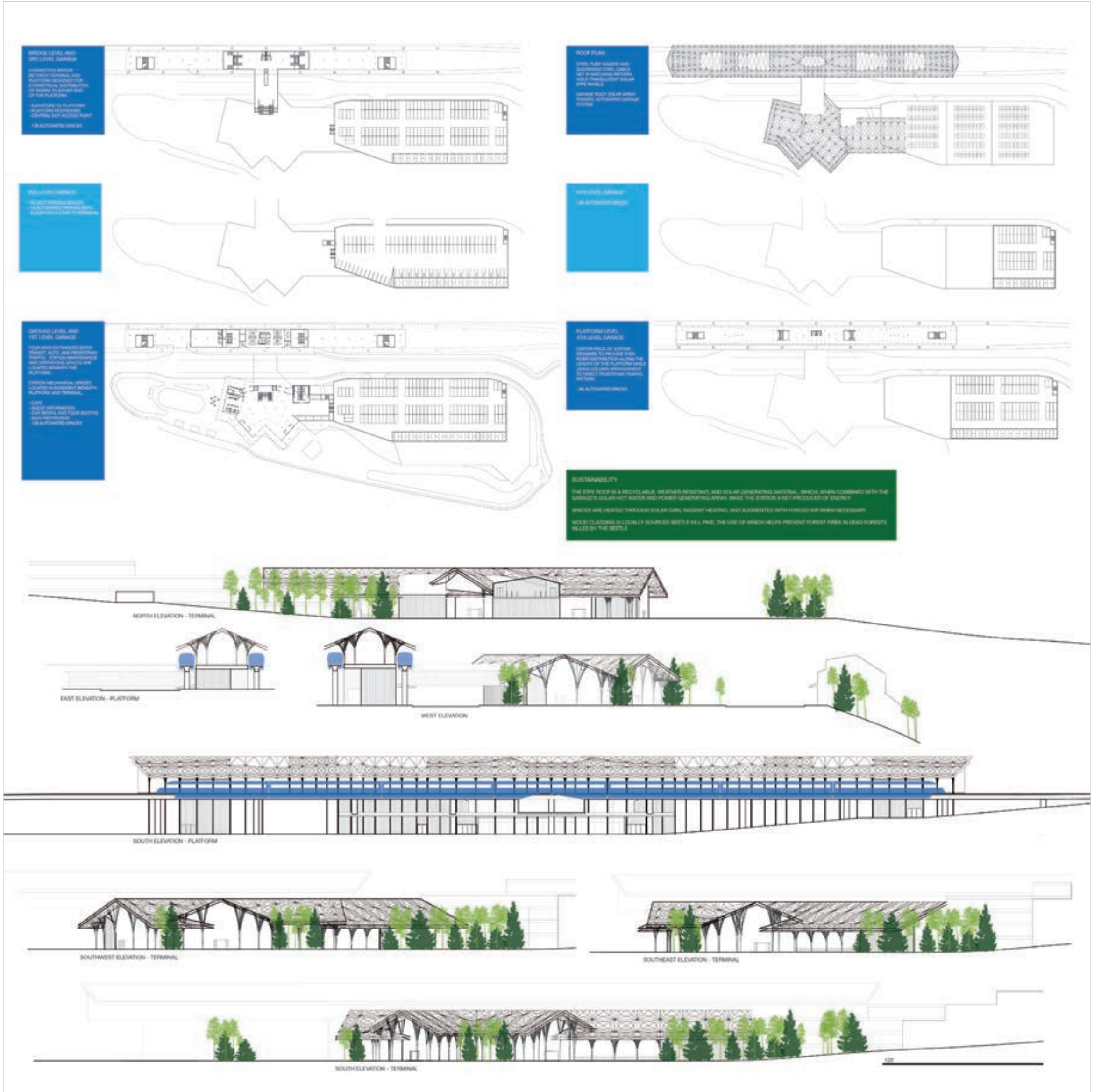


FIGURE 125 - AR-903 MIDTERM PRESENTATION BOARD PART II (36 X 36)

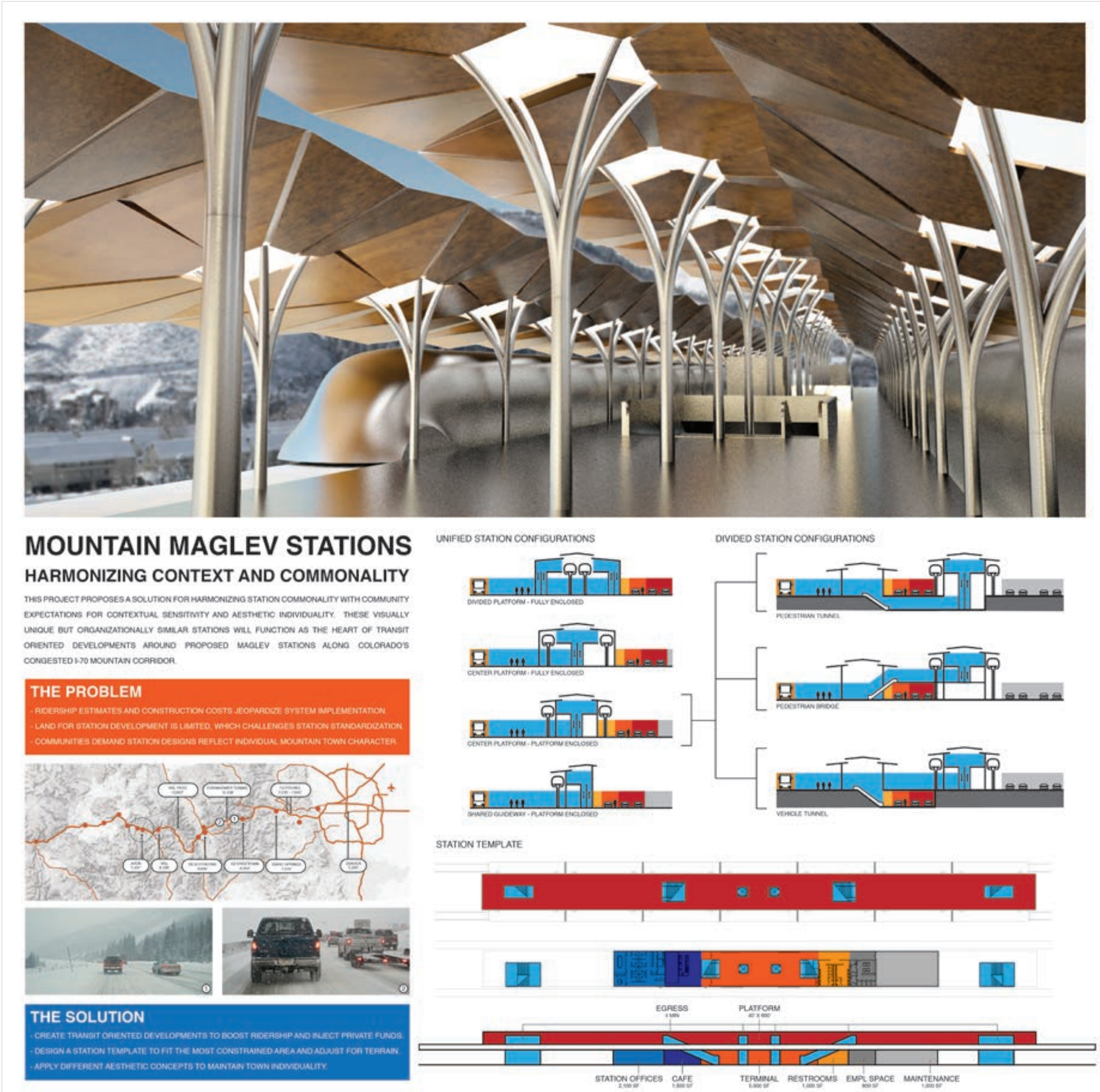


FIGURE 126 - AR-902 FINAL PRESENTATION BOARD PART I (36 X 36)

FIGURE 127 - AR-902 FINAL PRESENTATION BOARD PART II (36 X 36)

GLOSSARY

AGS – Advanced Guideway System.

Bogie – An undercarriage with four to six wheels pivoted beneath the end of a railroad car

CDOT – Colorado Department of Transportation

Consist – The set of vehicles forming a complete train

DIA – Denver International Airport

Eisenhower Tunnel – The highest tunnel and point in the US interstate system passing over Loveland Pass

HSR – High Speed Rail

Loveland Pass – One of two major mountain passes on I-70 through the Mountain Corridor

MAGLEV – Magnetic Levitation is a method of propulsion that uses magnets rather than wheels

Mountain Corridor – The portion of Interstate-70 between Denver and Glenwood Springs

RTD – Regional Transportation District. Denver's mass transit system operator.

TAD – Transit Adjacent Development

TOD – Transit Oriented Development

Vail Pass – One of two major mountain passes on I-70 through the Mountain Corridor

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