Dynamic Message Sign (DMS) Implementation Plan

Final Technical Memorandum

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Subject: DMS Implementation Plan Evaluation and Recommendations

Executive Summary

Kimley-Horn, Apex Design, and VAg worked together with the Town of Vail to develop a Dynamic Message Sign (DMS) Implementation Plan for Vail. DMS is proposed within the Town of Vail to convey real time, accurate information to visitors, guests, and residents of Vail. Primarily, these DMS will be used to inform drivers of the status (Open or Full) of the various parking structures during the Winter, Vail Pass Closures, incidents, events, and other pertinent information. This Implementation Plan included recommendations pertaining to recommended locations, recommended sign types, recommended sign manufacturer, recommended software, and recommended sign foundation/aesthetics. The following describe the project results, conclusions and recommendations:

Sign Location Recommendations

The westbound and eastbound Interstate 70 off-ramps at the Main Vail interchange are recommended locations for new DMS installations. The main purpose of these DMS would be to inform the arriving visitor/guest of Vail the parking status of the parking structures. The existing DMS installed on these off-ramps are not effectively used or located. They are sometimes blocked by parked vehicles and/or are located somewhat outside of approaching drivers' view. Therefore, it is recommended that these signs be replaced with new signs, located closer to the off-ramp traffic. It would be preferred to have these signs mounted on an aesthetic overhead sign structure to provide the optimal sight visibility. The westbound off-ramp DMS direction is recommended for the first installation as it serves traffic arriving to Vail from the Front Range of Colorado and Denver International Airport. The eastbound off-ramp is recommended as the second priority for DMS installation.

Five additional DMS locations were identified and recommended for installation within the proposed median of the future five-lane South Frontage Road. These signs would be ground mounted and include an architecturally design base. All five of these locations are recommended to be double sided to convey information, possibly different messages, for eastbound and westbound traffic along the South Frontage Road. In priority, these signs are recommended in the following locations:

1. Solaris

2. Middle Creek or Four Seasons (dependent upon US Bank East Access converted to right-in/right-out movements only)
3. Between North Day Lot and future Ever Vail Roundabout
4. Ford Park
5. Vail Village Parking Structure

All of these signs could be used to convey many different types of messages and for many different purposes. These locations were chosen to provide optimal location to inform drivers of the parking structure status, of Vail Pass Closures, and on entry to the Vail Village and Lionshead core areas.

On a routine basis, the Solaris sign could provide information pertaining to the Vail Village Parking Structure status and of possible Vail Pass Closures. This is the most typical location of the portable sign today. The Middle Creek or Four Seasons DMS location could provide information for the Lionshead Parking Structure for westbound traffic and Vail Pass Closures for eastbound traffic. The DMS to be installed between North Day Lot and the future Ever Vail Roundabout is recommended for use to provide Ever Vail parking status for westbound traffic and Vail Pass Closures for eastbound traffic. The Ford Park DMS would inform drivers of parking status in Vail as they arrive for westbound traffic and of possible Vail Pass Closures and "Road Closed, Local Traffic Only" messages for eastbound traffic. The sign adjacent to the Vail Village Parking Structure has been assigned the lowest priority due to the Dynamic Message Signs recommended at Solaris and Ford Park may effectively convey the necessary information through the Vail Village area that this sign may not be found to be needed.

Two Dynamic Message Signs were identified to be side mount and single sided locations. These are recommended at locations along the south side of both the South and North Frontage Road for eastbound traffic on the approach to the proposed future Simba Run Underpass roundabouts. These signs would be used to convey necessary information as traffic enters the main village core areas of Vail from the west.

Sign Type and Manufacturer Recommendations

To provide the most flexibility for future use, full matrix and full color DMS are recommended. Based on the technology available today, as well as the purpose of the signs to be used, it is recommended that Daktronics VL-3500 series signs be used.

Sign Software Recommended

It is recommended that the Vanguard software provided by Daktronics be used with these new signs. This software is compatible with industry standards. A seat of the CTMS software is also being provided to the Town of Vail from CDOT. Use of this software will also control the signs if desired, but in this case the Town will not need to rely on CDOT for software upgrades.

Sign Base Aesthetics

The DMS are recommended to be installed with decorative, architecturally designed sign bases. The Interstate 70 off ramps are recommended to include an overhead cantilevered sign support structure. The other installations within the median and side mounted are recommended to include a decorative base for an aesthetically pleasing Dynamic Message Sign installation.

Introduction

The Town of Vail is currently experiencing a high level of on-going development and redevelopment. With this new development, an increased level of traffic is anticipated. Therefore, it has become more important than ever before that there be an accurate, reliable, and real-time way to provide information to Vail's guests, visitors, and residents. This project includes an overall Dynamic Message Sign Implementation Plan for the Town of Vail to provide this purpose. We understand that this project has been of interest to the Town for several years and came to fruition through input from internal staff and Vail Resorts Development Company personnel.

As part of this project, we have strived to do the following:

- Assist the Town in selecting the most appropriate locations for DMS along the frontage roads to inform travelers and upgrade or replace the existing devices to ensure compatibility.
- Advise Vail of DMS technology options available, and the associated pros and cons, to create an integrated system with real-time communications.
- Prepare a conceptual design, which includes an aesthetic layout.

As the Town is well aware, the current DMS is a patchwork of different types of signs and technologies. They are not compatible with each other to be used effectively and efficiently. Existing signs are either not used at all or are not utilized to their full potential. We have identified the following key design considerations for the Town of Vail:

- Uniformity and consistency of DMS signs and messages to facilitate wayfinding.
- Proper placement of signs to relay the right information at the right time to help prevent driver confusion, frustration, and unnecessary "wandering" around Town.
- Planning and designing a system of DMS that supports the immediate needs of Vail while accommodating expansion. For example, the DMS system should have a coordinated and an intuitive and user-friendly software interface capable of updating all DMS quickly.
- DMS shall fit in with the aesthetics of the environment and overall culture of the Town.

DMS IMPLEMENTATION PLAN

This section of the Technical Memorandum contains the evaluation of the existing sign locations and provides recommendations for the ultimate DMS location plan.

Existing Conditions Evaluation

The Town has already had internal discussions about this project. We obtained, reviewed, and discussed stakeholder meeting items to have a clear understating of the history, goals, and vision of the Town. From a technical perspective, we collected

information from Town staff about the existing DMS, including models, communication topologies, messaging, software, and so forth. This included field verification and data collection as necessary. In addition, we worked with the Town to identify and define the functional and operational user needs for the DMS system.

Existing Use of Signs

The Town has existing DMS infrastructure deployed at the I-70 off-ramps (eastbound and westbound), at roundabouts and at parking garages. Portable DMS signs are also utilized to supplement these permanent DMS locations as seen necessary by the Town. The current signs on the off-ramps mostly display "canned" messages uploaded from the Police Department. The parking structure signs, controlled separately by parking structure employees, indicate parking structure status. The signs in the roundabout are not used.

Photo 1 - Existing I-70 Off ramp DMS

The off-ramp DMS signs are located toward the end of the ramps to the driver's right. These signs are offset approximately 20' minimum in order to provide the required clear zone with no guard-rail requirements based on the ramp speed limit. The current locations allow full use of the shoulder for pull off areas for vehicles as well as snow removal and storage. The use of these signs, outside of the canned messages, has been identified as being limited and ineffective. The existing DMS for the eastbound off ramp is shown in **Photo 1**.

The parking structure signage is used to address the common issue of the parking structures being full and needing to inform arriving visitors. These signs are located directly at the parking structures adjacent to the driveway access along the South Frontage Road. **Photo 2** is of the Lionshead Parking Structure sign.

Photo 2 – Parking Structure Sign

Photo 3 – Roundabout Directional DMS

In addition to the signage noted above and various static signs throughout the area, there are two existing DMS signs in the roundabout. These are located at the exit roadways of the roundabout and are included with the directional sign assembly. The DMS portion of these signs are rarely, if ever, in use due to size and driver's ability to comprehend in roundabout. **Photo 3** is of the Lionshead Parking directional sign with the DMS board.

Portable signs are used when Town events or circumstances warrant, and are placed accordingly. Generally these are located on the South Frontage Road, close to the Main Vail Roundabout. Often, a portable DMS is located east of the Main Vail Roundabout along South Frontage Road in front of the Solaris. The signs are updated and programmed locally at the sign and indicate various information based on the situation. While the use of these signs is generally effective at conveying the information contained in brief messages, these are labor intensive and aesthetically unappealing. The almost continual use of these portables indicate the overwhelming need for a more permanent and flexible system to keep up with the times.

Concerns with Existing System

As noted, the existing signage system warrants improvement. The sign locations, type, and operation lack effectiveness, are labor intensive, and not up to the Town of Vail expectations for aesthetics.

The existing signs on the eastbound and westbound Interstate 70 off-ramps are not as visible as desired. They are located a fair distance off the ramp, due to clear zone requirements. Due to the horizontal offset location, despite the sign size, the message information is often missed by drivers, making their use even less effective. Further, the signs being side mounted creates visibility issues when vehicles, especially trucks, are parked adjacent to the signs. In addition, the use of "canned" messages may decrease the effectiveness of the signs. Although providing information, drivers may not always perceive the information as being relevant. Therefore, drivers may begin ignoring the signs thinking that it always displays a message of "Slow Down Enjoy the View" for example.

The signs at the Vail Village and Lionshead parking structures are used and they are operated by the parking structure personnel. Although, these signs could display when the parking structure is "FULL", these signs typically do not as they are too small to be effective. Likewise, they are located at the parking structure itself, which would only be effective from keeping vehicles from entering the parking structure, they are not effective from keeping vehicles driving to the parking structure. The location and timeliness of this information is not effective in efficiently directing visitors to the available parking

areas as they arrive in Vail. Currently drivers typically travel first to the Vail Village Parking Structure to learn that it is full. Then they need to turn around, causing numerous other traffic and circulation issues. The improved system shall provide timely information to guests to inform them the "OPEN" or "FULL" status of the Vail Village and Lionshead Parking Structures and be located prior to the decision point of traveling to one structure versus the other.

The dynamic message portions of the directional signs at the roundabout were identified to be seldom, if ever, used. The directional signs are good at serving the purpose of identifying the direction of Vail Village and Lionshead for traffic traveling within the roundabout, although there is a lot of signage in the area and other conflicts requiring driver attention. However, the dynamic message portion of these signs is too small to be effective. It would be useful to have signs such as these identifying the status of each parking structure as "OPEN" or "FULL", but these would require a modification with a blank out message board and be much larger in size. This would also require an operational procedure of providing the message of the structure being "OPEN" or "FULL" from the parking attendant to provide reliable real time information.

Currently the portables are used often and consistently to convey the time-dependent messages to visitors though they are not always updated in "real-time". Often times these messages are longer in length than a traveler will have the ability to process, or are very short and abbreviated due to the limited number of characters and lines. Use of new permanent frontage road Dynamic Message Signs for this purpose is needed to effectively display this information.

In summary, the existing system does not properly help to channel traffic to the desired locations, minimize traffic confusion, and does not live up to the rest of the world-class Town elements. The signage technology is out-dated and not easily updated or tied into other traffic information systems. This Implementation Plan identifies recommendations for a new system of signs to be used effectively by the Town.

Implementation Plan

This Implementation Plan was developed based upon the user needs identified and defined. DMS locations were chosen based upon the ability to accomplish the following:

- Effectively relay wayfinding information for parking and special events, Vail pass closures, construction, detours, and other relevant information to guests.
- Provide messages that are readable by drivers and conform to the *Manual of Uniform Traffic Control Devices (MUTCD)* character height guidelines for legibility and travel speed.
- Not conflict with other signs or create a hindrance for vehicle maneuvers.
- Located within the recommended clear zone offset and height according to the *MUTCD* and *AASHTO Roadside Design Guide*.

- Fit into the existing geometry and planned developments, such as the South Frontage Road medians near the Four Seasons and Solaris projects as well as the core area throughout Vail.

The Town of Vail has a desire to improve the existing signage system in place. It is believed that the motorists visiting the Vail Village and Lionshead areas would benefit from more efficient and effective use of signage and has retained the project team to determine recommendations on signage use, location, technology, and architectural installation concepts.

The primary purposes for employing Dynamic Message Signs (DMS) at the Interstate-70 off-ramps and along the frontage roads are to perform the following:

1. Provide motorists with advance notice of where to park, especially during the ski season.
2. Provide motorists with useful information about a problem they may encounter along their planned route such as crashes, construction delays, detours and I-70 closures due to inclement weather.
3. Provide information as it relates to special event traffic management.

The desire from the Town of Vail is that this DMS system shall be fully controllable by remote access so that the system updates could be simply managed and would be timely as well as accurate. Additionally, the upcoming frontage road improvements will allow additional placement options that will provide additional and more effective signage locations. The South Frontage Road is being improved to include a five-lane cross section with a raised median through much of the core area of Vail to accommodate the projected future traffic volumes.

The next phase, not included within this project scope, may include pedestrian level kiosks to provide information (such as Vail Pass Closure and travel information) as skiers leave the mountain. The scope of this project is to include the Off-Ramps and Frontage Roads and relate to the recommended DMS placement and functionality.

DMS Location Recommendations

Various considerations were taken into account in determining the proposed DMS locations and functionality of the signs. The balance of cost, effectiveness and safety are critical elements to this decision making process. The preliminary location recommendations provided by the Town, knowledge of the project area, and analysis of sight distance requirements were the basis of the initial location selections. These locations can be seen on the overall maps (**Figures 1, 2A and 2B**) and described more specifically below.

Interstate 70 Off-Ramp Signage

It is agreed by the Town and the design team alike that the I-70 off ramps provide an excellent opportunity to convey valuable information to visitors as they first arrive while exiting at the Main Vail Interchange. In order to improve visibility and effectiveness of the signage, both physical location and sign technology are important. In order to

improve visibility, two options are available. One approach would be to provide a cantilevered support system with an overhead sign so that it is located above the roadway. This would improve visibility due to the vertical curvature of the off ramps as well as placing it above any possible parked vehicles along the off ramp. A second approach would be to locate the DMS (one each per off-ramp) on a ground-mounted monument base closer to the shoulder. Both approaches would require guard rail protection since the base and sign structure would be in the designated clear zone.

While it is known that a fully variable DMS sign would provide the greatest flexibility of messages and convey a variety of information to the visitors, the primary goal of the off-ramp signs is to provide parking information to the visitor. Due to budget constraints, static signs with DMS blank out inserts could be used in these locations for this purpose (See **Figure 3** for location information). The static portion of the sign would list the parking structures and the dynamic portion of the signs would illustrate the status of these structures (i.e. "FULL" or "OPEN"). These could be expanded to include future parking structures or an additional sign could be installed. The signs used at the off-ramps would be single sided and larger in size due to the speed limit (see Sign Technology section for sign details). This type of sign can be very useful to display the necessary parking status information, possibly even better than a fully operational DMS.

Frontage Road Signage

In order to supplement the information provided at the Interstate 70 off ramps, DMS are recommended along the South Frontage Road. These signs could be used to provide additional information related to weather, incidents, special events, or other pertinent information. The available locations for these signs were based on an analysis of sight distance for vehicles turning to and from the Frontage Road. Sight distance is needed at minor street and driveway intersections to allow drivers of stopped vehicles a sufficient view of the intersecting frontage road to decide when to enter the roadway. If the available sight distance for an entering vehicle is at least equal to the appropriate stopping sight distance for the major road, the drivers have sufficient sight distance to anticipate and avoid collisions. Specified areas along intersection approaches and across their corners should be clear of obstructions that might block a driver's view of potentially conflicting vehicles. The sight distance required for vehicles making a left-turn movement from the minor roadway onto a major roadway is 280 feet in a 25 mph speed zone, and 500 feet in a 45 mph zone. Additionally, the sight distance required for vehicles making left-turn movements from the main roadway (South Frontage Road) onto the minor roadways or driveway access points was considered. These movements require 205' in a 25 mph speed zone, and 365' in a 45 mph zone. All proposed sign locations are within the 25 mph speed limit zone with the exception of the areas east of Ford Park and west of the proposed Ever Vail and Simba Run Underpass roundabouts.

The proposed improvements to the South Frontage Road in the Vail Village and Lionshead areas include a five lane roadway which includes a raised median island in the center of the roadway in various locations. These 16-foot (edge of pavement to edge of pavement) raised medians allow for additional landscaping, provide traffic calming, as well as locations suitable for the proposed Dynamic Message Signs. Placing the signage in the medians also allows for the use of double-sided DMS signs so that both eastbound and westbound travelers receive valuable information pertinent to the direction they are traveling. The use of these double-sided signs helps to reduce costs for the sign support monuments, power routing to the sign, and minimizes the

impact to landscaping than if the signs were single-sided and/or mounted on the side of the roadway. Having signs located in the center of the roadway may also minimize the potential for vandalism since they are not located in a standard path of pedestrian travel.

Three full DMS locations east of the Main Vail Roundabout along the South Frontage Road were determined based on the items noted above as well as discussions with the Town. The recommended sign locations, in order of installation priority, are the following: in front of the Solaris, east of Ford Park, and between Ford Park and the Vail Village parking structure. All of these sign are recommended to be installed within the median (the median provides 13' from back of curb at full width), a minimum of 1.5 feet from behind the face of curb for clear zone requirements, outside of sight distance restriction areas, and be double-sided.

The Solaris DMS is recommended to be installed after the South Frontage Road median construction is complete. This sign is recommended in the approximate location shown in **Figure 4**. This location was chosen since it is in close proximity to the Vail Village Parking Structure, is in between the Main Vail Roundabout and the Vail Village Parking Structure, is the typical location of the portable today, and could provide information relative to the Vail Village Parking Structure for eastbound traffic as well as messages relative to the Vail Pass Closure for both directions of travel on South Frontage Road.

The Ford Park DMS is recommended to be installed at such time Ford Park is further developed (i.e. cultural / recreation center, parking, etc.), access is identified, and the roadway improvements are in place. The DMS should be installed east of the proposed future Ford Park parking structure access, shown in the approximate location of **Figure 5**. This location was chosen since it will be able to be used as the first sign for westbound traffic as it enters Vail. This will allow the east facing DMS to be used to inform drivers of the status of the various parking structures. The location would also allow for the west facing DMS to inform drivers of Vail Pass closures and subsequent South Frontage Road closures to "Local Traffic Only".

The necessity of the third sign installation (thought to be the location between Ford Park and the Vail Village parking structure) would be confirmed in the future, following the installation and operation of the other two signs. The location of this DMS could be installed in a location shown in **Figure 6**. This location was chosen since the Solaris DMS could provide Vail Village Parking information and this DMS could provide information regarding Ford Park Parking. However, it may be found that the Solaris DMS would adequately convey these messages. The location of the other two recommended DMS and the messages being displayed may mean that this location is optional.

Three full DMS locations west of the Main Vail Roundabout along the South Frontage Road were determined based on the items noted previously as well as discussions with the Town. The highest priority sign location for this Lionshead Village side should be located along the South Frontage Road between the Main Vail Roundabout and the Lionshead Parking Structure. This location was chosen to provide information relative to the Lionshead Parking Structure for the east facing DMS and Vail Pass Closures for the west facing DMS. It is desired by the Town that the first signage to the west of the roundabout be located as close to the roundabout as practicable. We agree that this would be the most effective location for a DMS. This area contains access to the Four

Seasons and US Bank to the south and the Town of Vail Municipal Buildings to the north. Each of these facilities have full-movement accesses allowed, which bring the sight distance parameters noted previously into consideration for both directions of travel along the South Frontage Road. Due to these safety considerations, a DMS is not available to be installed within the proposed medians of the South Frontage Road in this area. However, if the eastern access of US Bank is available to be restricted to right-in/right-out movements only, then the proposed median between the Four Seasons and Town of Vail buildings would allow for a DMS installation. This location is shown in **Figure 7A**. If the eastern access of the US Bank property is not possible to restrict to right turn out movements only, then the sign should be located further west (in the approximate Middle Creek crossing area) as shown in **Figure 7B**. Either location would allow for information to be conveyed to visitors prior to reaching the Lionshead Parking Structure; however the location closer to the roundabout would allow for more timely information to Vail guests.

The second priority western DMS location recommended is west of the North Day Lot and east of the proposed Ever Vail roundabout. This sign should be installed after the South Frontage Road improvements being proposed as part of the Ever Vail project. This sign is recommended to be double-sided in the median as shown in **Figure 8**. This sign location is preferred to provide information relative to future Ever Vail parking for westbound traffic as well as Lionshead, Vail Village, and future Ford Park parking structures for eastbound traffic.

A third DMS location was discussed, which is proposed and recommended west of Ever Vail; however, the location for this installation would depend on the future roadway developments of the South Frontage Road and possible future Simba Run Underpass and roundabouts. The current design does not include median improvements in this area along the South and North Frontage Roads, so single-sided signs along the south side of the North and South Frontage Roads for eastbound traffic would be the only option at this point. It was discussed that signage should be located close to the western side of the Simba Run Underpass for eastbound traffic prior to entering the roundabout for both the South and North Frontage Roads, but not be in conflict with other necessary signing as a vehicle approaches the roundabout. Exact locations would be determined with Frontage Road and Simba Run Underpass roadway work and other developments in the future. These DMS would be available to provide status and information relative to Vail events and parking status of all structures. These tentative locations are shown in **Figure 9**.

In all situations, the recommended sign locations may impact existing or planned landscaping for these areas. This will need to be addressed in the design of the roadway improvements or upon sign installation. Maintenance of proper sight distance for vehicular movements must take precedence over location selection or landscaping aesthetics.

Roundabout Signage

The Main Vail Roundabout was discussed as being an opportunity to convey directional information. The concerns were that the static signage that exists at the South Frontage Road roundabout exits are not effective or efficient in delivering messages to visitors unfamiliar with the area as to which direction Lionshead or Vail Village is located from the Main Vail Roundabout. Based on this discussion, a recommendation would be to

include a ground-mounted static monument sign located within the center of the roundabout. This sign should be located such that it would be visible to a driver traveling south under the Interstate 70 bridges from the north side of Interstate-70. This monument signage should be simple in the message and identify that Lionshead is located to the right and that Vail Village is around the circle (with a hook left visual) to the left. This sign will provide an aesthetically pleasing approach to the main Vail areas and could be incorporated as an overall "Welcome" sign for Vail.

Likewise, more visible post directional signs at the South Frontage exit roadways along the Main Vail Roundabout identifying Lionshead and Vail Village could be installed. These signs could include blank out message boards identifying if the parking structures are "OPEN" or "FULL." This type of sign system should be made expandable with the possible future inclusion of Ford Park and Ever Vail parking structures. These signs would reiterate and reinforce the information conveyed to the drivers at the I-70 off-ramp signs. Based on current budget plans and considerations, this recommendation is believed to be lower in priority.

Based on the above evaluation, the following **Table 1** identifies the recommendations and provides a priority for deployment.

Table 1: Vail DMS Prioritized Deployment Plan

Priority Level	Location	Type of Sign	Notes
1A	I-70 Westbound Off Ramp	Full Matrix or Static Parking with DMS Blank Out	Sign to be mounted to increase visibility. Higher Level 1 priority off-ramp due to traffic arriving from Denver.
1B	I-70 Eastbound Off Ramp	Full Matrix or Static Parking with DMS Blank Out	Sign to be mounted to increase visibility.
2A	South Frontage Road - Solaris	Double Sided DMS	Sign to be located in median. Higher Level 2 priority since Vail Village Parking Structure is typically more utilized. Location could provide Vail Pass Closure information.
2B	South Frontage Road – Middle Creek Four Season (Alternate)	Double Sided DMS	Sign to be located in median. Could be located adjacent to Four Season if Eastern US Bank Access restricted to Right-In/Right-Out movements only.
3A	South Frontage Road – between North Day Lot and Ever Vail Roundabout	Double Sided DMS	Sign to be located in median. Installed with new Ever Vail development and parking structure. Higher Level 3 priority due to anticipated project timing.
3B	South Frontage Road – East of Ford Park Entrance	Double Sided DMS	Sign to be located in median. Installed with new Ford Park parking structure.
4A	South Frontage Road – between Ford Park and Vail Village Parking Structure	Double Sided DMS	Sign to be located in median. Sign installation dependent upon evaluation of other DMS installed. May not be needed since the other two on the East side may effectively convey the necessary information.
4B	South Frontage Road – west of Ever Vail	Single Sided DMS	Sign to be side mounted for eastbound traffic. Should be located west of possible future Simba Run Underpass roundabout.
4C	North Frontage Road – west of Simba Run Underpass	Single Sided DMS	Sign to be side mounted for eastbound traffic. Should be located west of possible future Simba Run Underpass roundabout.
5	Roundabout Directional at South Frontage Road for Lionshead and Vail Village	Directional Signage Blank Out Boards	Signs to identify parking structure status “OPEN” or “FULL” at roundabout exit to South Frontage Road

Figure 1

Figure 2A

Figure 2B

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7A

Figure 7B

Figure 8

Figure 9

DMS DESIGN

This section of the Technical Memorandum explores Dynamic Message Sign (DMS) technologies, provides options for each, and makes design and procurement recommendations.

Existing DMS Infrastructure

The Town has existing DMS infrastructure deployed at I-70 off-ramps (eastbound and westbound), at roundabouts and at parking garages. Portable DMS are also utilized to supplement the previously mentioned permanent DMS locations. All DMS, permanent and portable, utilize Light Emitting Diode (LED) technology for its light source. See **Table 2** for additional detail on existing DMS infrastructure.

Table 2: Town of Vail's Existing DMS Infrastructure

Location	Quantity	Manufacturer	DMS Model
I-70 Off-Ramps	2	Daktronics	Galaxy 24x64 matrix (monochrome)
Roundabouts	2	Daktronics	Galaxy 16x96 matrix (monochrome)
Parking Garages	2	Daktronics	Infonet 6x48x1 matrix (monochrome)
Portables	2	Precision Solar	N/A

All of the existing Daktronics DMS listed in **Table 2** utilize an internal display controller (Version 2). Initially it was believed that the Galaxy signs could be modified to be National Transportation Communications for ITS Protocol (NTCIP) compliant by simply upgrading the firmware, however conversations with the Daktronics applications engineer indicated that both the display controllers (v2) and firmware must be replaced. Additionally, the Infonet series of signs have been discontinued by Daktronics and are no longer available.

Photo 4 - Existing Roundabout DMS

The existing Precision Solar portable signs are old and not very functional. They need to be programmed locally and do not currently have any remote control and configuration capabilities.

Remote control and configuration of the existing Daktronics signs are performed using the Venus 1500 display control software (version 3.7) hosted on a Citrix server. Connectivity is Ethernet-based with the Galaxy signs using a 2.4 GHZ unlicensed wireless infrastructure. The Infonet sign at the Lionshead Parking Structure is connected via Digital Subscriber Line (DSL), while the Infonet sign at the Village Parking Structure is directly connected. The parking structure attendants currently control the Infonet parking structure signs, while the Vail Police Department controls the Galaxy I-70 off-ramp signs. The Galaxy roundabout signs, shown in **Photo 4**, are not used anymore because the Town feels that the character heights are too small to provide useful

information to motorists. Feedback from the current users of the Venus 1500 display control software have indicated that it is not a user-friendly, intuitive product.

Need for new DMS

The existing DMS signs are comprised of different models, all of which are outdated and not utilized. Furthermore, these signs are commercial grade and do not support standards in the transportation industry (this is discussed further in the subsequent NTCIP section). In addition to the inadequate functionality, the current DMS are located such that they are difficult to read and do not display relevant information at the appropriate time to ensure proper driver decision making.

Since the original signs were installed, there have also been significant advancements in technology. For example, full color signs are now available in the transportation market and accepted by industry standards.

Existing DMS Messages

Based on the message library dated August 31, 2007, the Town currently has 71 messages developed with 36 message sequences. The longest message is message #264 which has 25 characters and reads FORDPARK SOCCER FD PKG $5. The message sequences range from a single line (sequence #13) up to five lines (sequence #43). A breakdown of message sequences appears in Figure 2.

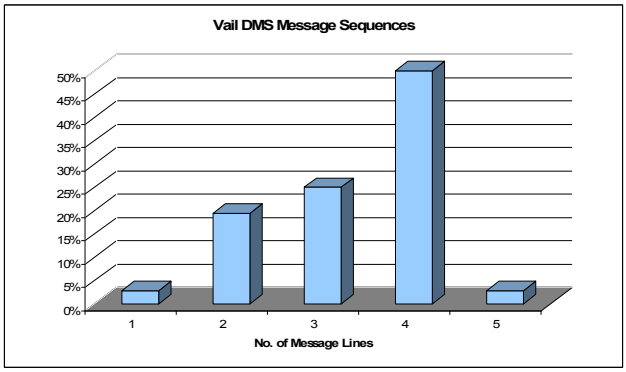

Figure 10 – Vail DMS Message Sequences

As indicated by the bar chart in **Figure 10**, 50% of the message sequences contain at least four message lines. This needs to be considered in assessing any new DMS technology as well as determining the amount of information that motorists can comprehend in the short time they have available to read the message.

Messaging Issues to Contemplate for the New DMS Implementation

DMS technology is and will continue to be one of the most visible links to the Town of Vail's Public Works Department. As such, an improperly designed or operated DMS message will have a negative impact on motorists' perception about the credibility of the information being provided. Messaging issues to consider include:

A. The motorist's available exposure time, within the viewing range of the DMS, should control the maximum length of message that can be displayed. Exposure time is directly related to the prevailing driving speeds and the message legibility distance.

B. Displaying messages that are too long for motorists to read at prevailing roadway driving speeds or are much too complex can lead to motorist uncertainty, hence negatively affecting traffic flow as vehicles slow down to read the DMS.

C. Viewing ranges provided by DMS manufacturers tend to be based on ideal conditions along with the viewing angles associated with the sign. However, actual deployments are not typically blessed with ideal conditions. The placement of the DMS will have to account for:

   1) Operating speed of traffic on the roadway.
   2) Horizontal curves and obstructions (e.g., trees, landscaping, etc.) upstream of the proposed DMS location that could hamper sight distance.
   3) Vertical curves upstream of the proposed DMS location that could affect sight distance.
   4) The presence, number and information on static guide signs in the vicinity of a proposed DMS to prevent information overload for motorists.
   5) Mixture of tour buses, construction-related heavy equipment and other large vehicles in the traffic stream that can obscure and reduce the viewing time for passenger cars and SUVs.
   6) East-west routes need to consider the impacts of message legibility during sunrise and sunset hours.
   7) The brightness of the DMS can be reduced during adverse weather conditions such as blizzards, fog, rain and snow, thus reducing the viewing range for motorists.

D. DMS messages must be displayed and changed in a timely manner to provide accurate and reliable information. The significance of accurate and timely DMS message displays cannot be overemphasized; it correlates back to credibility and trust in the Town's DMS system.

Minimum Viewing Distance of New DMS

The maximum length of message that should be shown on a DMS at a location depends not only on the perception, visual acuity and information processing capabilities of the motorist, but also on how far away they can see the DMS, read its message and make a decision.

Candidate locations for DMS placement in the Town are the North and South Frontage Roads. The posted speed limits along the frontage roads appear in **Table 3**.

Table 3: Vail Frontage Road Posted Speed Limits

Location	Posted Speed Limit
South Frontage Road: Between Ford Park and Ever Vail	25 mph (37 fps)
All other frontage road locations	45 mph (66 fps)

The viewing and legibility of a DMS are composed of two parameters: the perception/reaction time and the reading/decision time. All of this must be accomplished within the viewing angle of the selected DMS. We also know from the existing DMS message sequences previously discussed that at least 50% of the message displays contain four lines of information, which will require a longer comprehension time for motorists. Accordingly, **Table 4** contains an estimate of minimum DMS viewing distances.

Table 4: Estimated Minimum DMS Viewing Distances

Location	Minimum DMS Viewing Distance	Perception/ Reaction Time	Reading/ Decision Time
South Frontage Road between Ford Park and Ever Vail	296 feet	1 seconds	7 seconds
All other frontage road locations	528 feet	1 seconds	7 seconds

DMS Technology Choices

The vast majority of DMS manufacturers utilize LED technology in either a line matrix or full matrix configuration. The current DMS are line matrix signs and it is recommended that the Town consider full matrix signs for its next deployment. Full matrix signs offer more flexibility to the user in that they support graphics capabilities in addition to text displays. Furthermore, full matrix signs are available in both amber (monochrome) and full color. A full color, full matrix sample sign is shown in **Figure 11**. None of the Town's current signs have graphics capabilities or the ability to display more than one color.

A human factors study assessed the effects of adding graphics to DMS messages. Two approaches were employed in the study – a questionnaire survey and a video-based driving simulation experiment – were reported along with the findings. The questionnaire surveyed drivers' preferences concerning the addition of graphics to a text message, the color of the message, alternative graphic images, placement of the graphic image,

image contrast, flashing and the framing of graphic images. Statistical analysis of survey results uncovered the following conclusions:[1]

1. Drivers had a strong preference for graphic-aided messages over text-only messages.
2. Drivers preferred amber or color messages over green or red colored messages.
3. Drivers expected the location of graphics to be left of the text.
4. Drivers expected specific graphics to accompany certain text messages. These specific graphics tended to be familiar images such as the Manual of Uniform Traffic Control Devices (MUTCD) standard shapes.

Figure 11 – Full Color, Full Matrix Sample

Based on the survey results, a video-based driving simulation experiment was designed and utilized to test drivers' responses to selected DMS messages surveyed in the questionnaire. Results of the experiment showed the following:[1]

5. Graphic-aided messages displayed in amber or green were responded to nearly 35% faster than other settings.
6. Older drivers' responses were slower and less accurate than others; nevertheless, their responses improved significantly when the DMS messages were enhanced with graphics.
7. Graphic-aided messages helped improve the responses of non-native English speaking drivers.

The results of the experiments establish a compelling reason for the Town to seriously consider the use of full color, full matrix DMS.

Preparing for NTCIP in Conjunction with the Use of CDOT's Colorado Traffic Management Software (CTMS)

NTCIP is a family of standards that define protocols and profiles that are open, consensus-based data communications standards. The continual development and version control of these standards documents are overseen by the following Standards Development Organizations (SDO):

- American Association of State Highway and Transportation Officials (AASHTO)
- Institute of Transportation Engineers (ITE)
- National Electrical Manufacturers Association (NEMA)

[1] Collyer, C.E., Hesar, S.G., Wang, J.H. *Adding Graphics to Dynamic Message Signs*. Transportation Research Board, Volume 2018, 2007, pages 63 – 71.

The Town will need to adopt NTCIP for their DMS deployments in order to facilitate remote control using the CTMS application. The use of NTCIP will help the Town achieve interchangeability for its DMS infrastructure (i.e., not locked in to a specific DMS manufacturer) and interoperability through CTMS.

Since NTCIP is new to Public Works and IT, a standards framework appears in **Figure 12** below that can be matched up to the International Organization for Standardization's (ISO) Open Systems Interconnection (OSI) seven layer reference model. In the case of NTCIP, there are only five layers: Plant, Subnetwork, Transport, Application and Information.

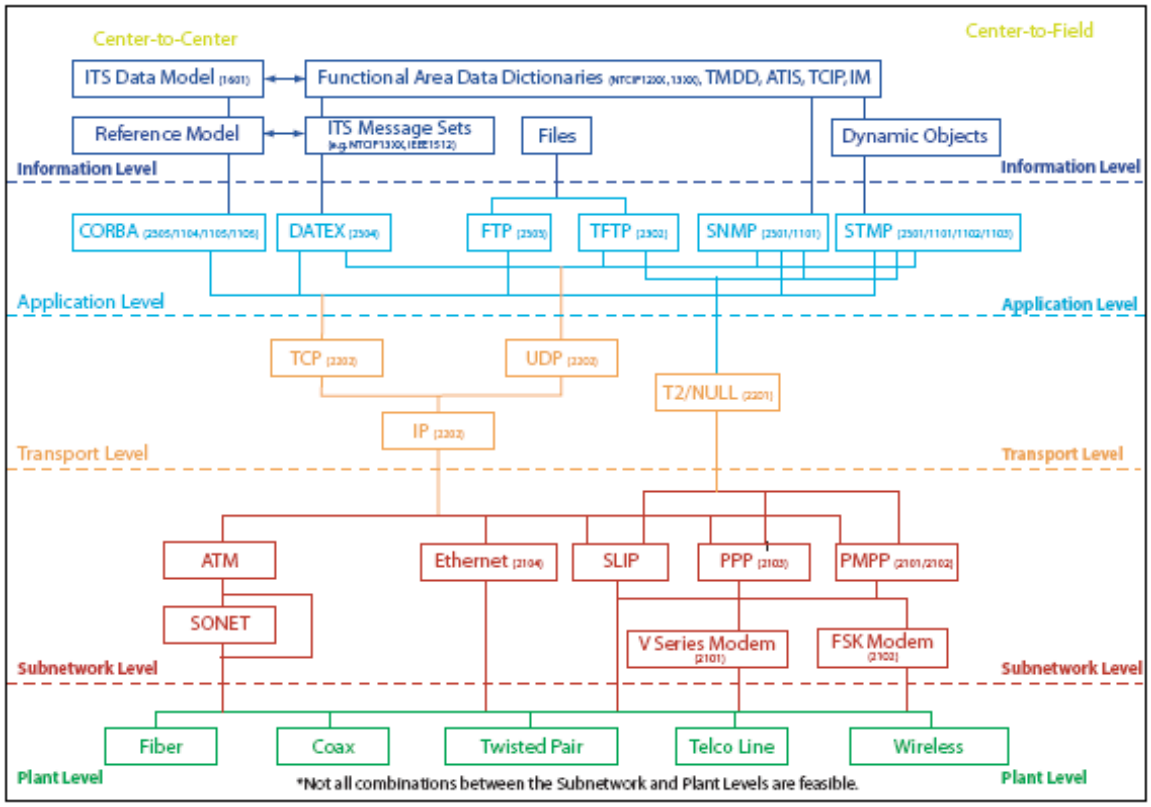

Figure 12: NTCIP Standards Framework

The standards related to the Town's first implementation of NTCIP-compliant DMS appear in **Table 5** below.

Table 5: NTCIP Related to DMS

Document Number & Version	Document Title
NTCIP 1101:1996 v01.12	Simple Transportation Management Framework (STMF)
NTCIP 1102:2005	Octet Encoding Rules (OER) Base Protocol
NTCIP 1103 v02.10b	Transportation Management Protocols (TMP)
NTCIP 1201:2005 v02.32	Global Object (GO) Definitions
NTCIP 1203 v02.35a RS	Object Definitions for DMS
NTCIP 2001:1996 & Amendment 1	Class B Profile
NTCIP 2104:2003 v01.11	Ethernet Subnetwork Profile*
NTCIP 2201:2003 v01.15	Transportation Transport Profile
NTCIP 2202:2001	Internet (TCP/IP and UDP/IP) Transport Profile
NTCIP 2301:2001	Simple Transportation Management Framework (STMF) Application Profile

**Assumes Point-to-Multi Point Protocol (PMPP) and Point-to-Point Protocol (PPP) using RS-232 will not be utilized by the Town of Vail.*

Finally, the procurement of DMS-related hardware and software from manufacturers must undergo a conformance and certification process to ensure compliance with the NTCIP standards. The Town, at its option, may opt to have IT perform the NTCIP certification process in-house for each DMS manufacturer that it utilizes. However, the best option is to allow for a 3rd party Independent Verification and Validation (IVV) to be performed and a certificate issued to the Town. The cost of the IVV should be considered as included as part of the cost of procuring the DMS and not paid for separately.

Recommended Manufacturer

Daktronics full-color, full-matrix Dynamic Message Sign

DMS manufacturers of interest to Vail were compared based upon their signs functions, features, and characteristics. Comparisons were presented to Town staff and are attached in **Appendix A**. The consultants and Town staff both agreed in selecting Daktronics as the DMS manufacturer. More specifically, the Daktronics full-color, full-matrix signs were chosen. Daktronics conducted a field demo to compare various DMS technologies. A 12" character height was recommended for the freeway off-ramp DMS and a 9" character height for frontage road DMS.

DMS Options

VL vs. VF Series

There are two different DMS series under consideration; the VL and VF series. Both support the NTCIP transportation standards. However, the VL series was adapted from Daktronics commercial product line and does not have all of the transportation industry functions and features that the VF series has. A side-by-side comparison is provided in **Appendix B**. The main features not available in the VL series are that there is no redundant power supply and no diagnostics feedback. However, the VL series is less expensive than the VF series. If the additional features are not critical relative to the additional expense, then the VL series could be a viable option. Spare parts could be ordered and stocked to help minimize downtime of components.

Louvered vs. Masked Face

The masked face is a polycarbonate panel protecting the LED housing whereas the louvered face has exposed LEDs. The masked face provides greater protection against vandalism. However, the masked face is not available in the less expensive VL series, as discussed in the previous section. The louvered face offers the advantage of a greater viewing angle (70 or 90 degrees vs. 30 degrees). However, viewing angle is not a critical design feature for the anticipated installations since traffic will be approaching the DMS on a relatively straight sightline.

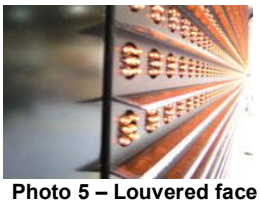

Photo 5 – Louvered face

Photo 6 – Masked face

Ground-Mount vs. Overhead DMS Installations

Two different DMS installations are being considered for the off-ramp locations; the overhead DMS and the ground-mount DMS. The frontage road DMS will all be ground-mount in the median.

Pros of Overhead DMS

- Best viewing location
- No occlusion from other vehicles (i.e., view of sign will not be blocked by vehicles in front of driver or by trucks parked on side of ramp)
- Less susceptible to vandalism

Photo 7 – Overhead DMS example

Pros of Ground-Mount DMS

- Easier access for maintenance
- Less obtrusive design
- Could be less expensive, depending upon mounting option

Photo 8 – Ground-mount DMS example

There are different installation methods for each mounting option. **Photos 7 and 8** illustrate two different examples of ground-mounted VMS types. Please note that these are only samples of existing installations and are note representative of the aesthetics proposed for the Town of Vail.

The example in **Figure 13** shows the less expensive ground-mount option that could be used for either Full DMS or the Static Panel with DDMS insert.

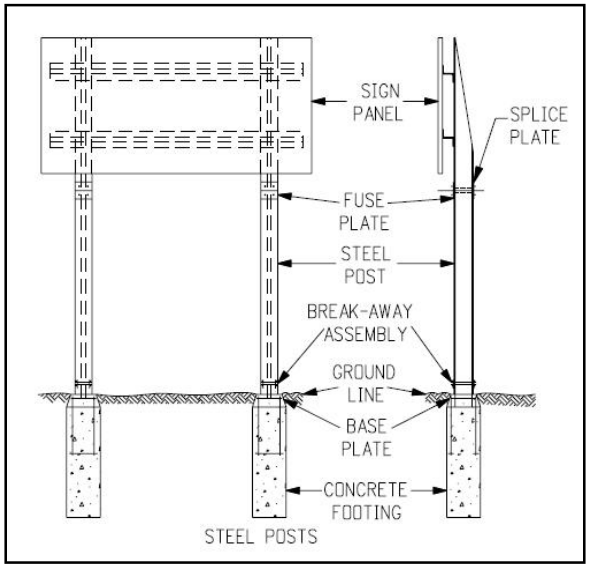

Figure 13 – Ground-mount steel posts support example

Off-Ramp Design Alternatives

This section discusses design alternatives for the freeway off-ramps, along with the pros and cons of each choice. The median signs installation is not under evaluation because it has already been agreed upon that it should be a ground-mount, full DMS.

The two alternatives under evaluation for the off-ramps are:

- Full DMS (see **Figure 14**); and
- Static sign with DMS panel (see **Figure 15**)

Each of the two alternatives also has various installation and aesthetic options.

Figure 14 – Full DMS message set

Pros of Full DMS

- Can be used for other messages besides parking
- Can display multiple message sets
- Lends itself better to aesthetic enhancements

Pros of Static Sign with DDMS Panel

- Slightly less expensive than Full DMS
- Easier maintenance due to fewer components
- Fully NTCIP compliant and would work with the same software as the Full DMS
- A larger sign can be used to display all of the information shown in **Figure 15** in a single panel
- DDMS modules can be added and the static sign can be remanufactured to add information about future parking structures (e.g., Ford Park or Ever Vail)

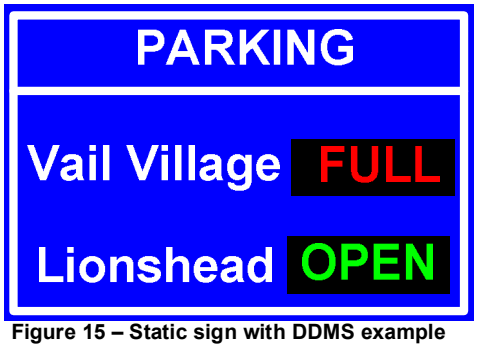

Figure 15 – Static sign with DDMS example

Recommended DMS Series

Daktronics VL-3500 Series Full Dynamic Sign:

- **Off-Ramp - 3' 10" x 12' 0" x 8", louvered, 20mm pixel pitch**
- **Median - 3' 10" x 6' 9" x 8", louvered, 20mm pixel pitch**

Software

This section compares two different software packages to communicate with the DMS.

Vanguard vs. CTMS software

Vanguard is the DMS software developed and supported by Daktronics. The Colorado Transportation Management Software (CTMS) is the DMS software developed by CDOT. The Daktronics software comes free with the DMS. The CDOT software would also be provided free. However, a Daktronics software driver would need to be developed in order for the CTMS application to accept the DMS. Daktronics will provide a Software Developers Kit (SDK) to CDOT for computer programmers to create the interface with the DMS display.

Figure 16 – Vanguard software screenshot

Pros of Vanguard Software

- Works with, and supported by, Daktronics. CDOT does not currently operate any full-matrix or full color signs. CDOT claims to have developed an interface for such DMS, but it is a risk as to whether it will work without further modifications and programming. Whereas, the Daktronics software does not need driver development
- Does not rely on CDOT programming and support for upgrades and troubleshooting with new operating systems or other updates
- Compatible with Wanco portable DMS since they are NTCIP compliant

Pros of CTMS Software

- Would provide viewing and sharing of operational control between CDOT and Vail staff
- Also works with Wanco portable signs
- Can view other CDOT ITS devices, excluding CCTVs. However, this can be accomplished through CDOT's CoTrip.org website, if desired.

Software Recommendation

- **Daktronics Vanguard software for initial deployment**
- **Test CDOT CTMS application if interested**

Costs

Below are costs for each of the DMS under consideration. The tables are separated by location; freeway off-ramp or frontage roads. It should be noted that numerous DMS sizes are available from Daktronics. The recommended DMS series are highlighted in yellow.

Costs for DMS Equipment Only

Table 6: Off-Ramp DMS Costs (12" Characters, 3 lines by 13 characters)

DMS Series	Type	Size	Cost
VF-2300	Full Matrix (louvered) / 20 mm	4' 2" x 10' 5" x 1' 1"	$ 46,455
VF-2400	Full Matrix (masked) / 34 mm	6' 7" x 10' x 1' 2"	$48,695
VL-3500 *	**Full Matrix (louvered, no diagnostics) / 20 mm**	**3' 10" x 12' 0" x 8"**	**$22,570**
VM-1000	DMS insert for static panel / 46 mm	1' 10" x 4' 8" x 2"	$13,766

**Recommended sign*

Table 7: Frontage Road DMS Costs (9" Characters, 3 lines by 12 characters)

DMS Series	Type	Size	Cost
VF-2300	Full Matrix (louvered) / 20 mm	4' 2" x 7' 3" x 1' 1"	$35,595
VL-3500 *	**Full Matrix (louvered, no diagnostics) / 20 mm**	**3' 10" x 6' 9" x 8"**	**$14,157**

**Recommended sign*

Costs for Installation

This section provides preliminary opinions of probable costs for installing DMS in each of the configurations under evaluation. Detailed line item costs can be found in **Appendix C**. Costs include a 30 percent contingency for the installation and architectural costs.

Table 8: DMS Construction Costs

Installation Option	DMS Cost	Approximate Installation Cost	Approximate Architectural Cost	Approximate Total Cost
Overhead – Full DMS	$22,570	$65,000	$50,000	$140,000
Overhead – Static Sign with DDMS Panels	$13,766	$70,000	$45,000	$130,000
Ground-Mount – Full DMS on off-ramp	$22,570	$45,000	$50,000	$120,000
Ground-Mount – Full DMS on steel posts on off-ramp	$22,570	$40,000	$25,000	$90,000
Ground-Mount – Static Sign w/DDMS on steel posts on off-ramp	$13,766	$35,000	included	$50,000
Ground-Mount – Full DMS Double Sided in median	$28,314*	$45,000	$50,000	$125,000

Full DMS is assumed to be a Series VL-3500
** Two signs*

Maintenance

Routine preventative maintenance should be performed on the DMS. A DMS Preventative Maintenance Checklist prepared by Daktronics is included in **Appendix D**.

The following spare parts are recommended for quicker maintenance and repair:

- Controller
- Power supply
- I/O Board
- Two modules for each display type

Annual maintenance costs are estimated to be between $1,000 and $3,000. The lower end of the cost range is for the VMS panels within the static sign and the higher end of the cost range is for the Full VMS installed over traffic. The frequency of maintenance events may be more in Vail given the snow patterns. For example, the front panel may need to be cleaned after each major snowstorm event.

Operations

Operations costs are directly related to the time spent by personnel operating the VMS and by the power consumption (i.e., utility bill) of the sign. Operations costs are likely to be absorbed into the current duties and responsibilities of personnel. Until operational guidelines are established and roles and responsibilities are clearly defined, the associated operational costs cannot be determined. Operational roles and responsibilities will, at a minimum, include:

- Determining messages
- Posting, and removing, messages (with an emphasis on parking initially)
- Coordinated with other stakeholders (Vail Resorts, CDOT, Eagle County)

Based on information provided through the United States Department of Transportation (USDOT) ITS database, the average life cycle for DMS and portable DMS are 10 years and 14 years, respectively. The life cycle is based on the reported length of time before failures forced a transportation agency to consider replacement of a DMS.

For the Town of Vail's estimated annual DMS operating cost, the following assumptions have been made:

- The typical power usage for each DMS will be based on a partially illuminated LED sign (15% of the pixels utilized at full intensity), the sign controller and ventilation fan or defogging system (if equipped). It excludes maintenance convenience receptacles, equipment cabinet, external communications equipment, lights and other auxiliary equipment.
- The average annual operating time for each DMS will be based on 12 hours per day, which results in an annual operating time of 4,380 hours each year.

- The cost of each kilowatt-hour (KW/hr) is 7.92¢ based on the average retail price of electricity for the commercial sector in Colorado during May 2009 as reported by the United States Department of Energy.

The resultant operational cost for each DMS type appears in **Table 9**. The recommended DMS series are highlighted in yellow.

Table 9: Off-Ramp DMS Construction Costs

DMS Series	Size	Typical Power Usage (KW)	Annual Operating Hours	Cost per KW-hr	Annual Operating Cost per Year (2009 dollars)
Off-Ramp					
VF-2300	4'2" x 10'5" x 1'1"	2.191	4,380	7.92¢	**$760**
VF-2400	6'7" x 10' x 1'2"	0.665	4,380	7.92¢	**$231**
VL-3500	**3'10" x 12'0" x 8"**	**0.616**	**4,380**	**7.92¢**	**$214**
VM-1000	1'10" x 4'8" x 2"	0.190*	4,380	7.92¢	**$66**
Frontage Road					
VF-2300	4'2" x 7'3" x 1'1"	1.071	4,380	7.92¢	**$372**
VL-3500	**3'10" x 6'9" x 8"**	**0.354**	**4,380**	**7.92¢**	**$123**

** Maximum power usage based on based on two LED panels for Lionshead and Vail Village parking info. Power usage will increase 0.095 KW for each additional LED panel installed for future parking garages. Basis for usage assumes that each LED panel is fully illuminated (50% pixels at 100% intensity) along with sign controller, DDMS cabinet ventilation and external communication equipment within DDMS cabinet.*

Life Cycle Costs

Life cycle costs are presented in this section and include capital costs, annual maintenance costs, and annual operating costs. As mentioned in the previous section, the "life" of the sign is assumed to be 10 years.

Off-Ramp DMS

- Capital costs – $140,000
- Annual maintenance costs – $2,000
- Annual operating costs – $214

Total 10-year life cycle cost - $162,140

Median DMS

- Capital costs – $125,000
- Annual maintenance costs – $1,000
- Annual operating costs – $123

Total 10-year life cycle cost - $136,230

Portable DMS

This section recommends Wanco portable DMS to replace the Precision Solar portable DMS currently owned by the Town. It is recommended that the Wanco Mini Matrix Message Sign, Model WVTM be procured. This sign is a full-matrix, solar DMS that is tower by a trailer. The sign display is 4' 7" high x 8' wide.

Figure 13 – Wanco Portable DMS

Wanco is recommended because CDOT uses them and they are proven to work in the Vail Valley. Also, CDOT has written a driver for Wanco signs through the CTMS application. As mentioned previously, staff would be able to communicate to both the Daktronics and Wanco signs via a single software program (either Daktronics' Vanguard software or CDOT's CTMS application) assuming remote communications are in place.

The price is approximately $15,500 per portable DMS. This price includes the complete DMS and a more substantial solar panel for use in Vail. Additional information, and specifications, can be found at www.wanco.com.

Portable DMS Recommendation

Wanco Mini Matrix