Automating Variable Speeds and Traveler Information with Real-Time Traffic and Weather

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ABSTRACT

The Highway 217 freeway in Portland, Oregon was the subject of several extensive studies over the past decade which recommended capacity and interchange improvements costing upwards of $1 billion. No projects were constructed and future funding prospects are deteriorating. Because of this, the Oregon Department of Transportation and our project team identified and evaluated several effective and feasible improvements that would immediately improve the highway's reliability, mobility and safety.

The proposed improvements include variable advisory speeds based on current traffic and weather conditions, variable message signs on the freeway and nearby surface streets to provide real-time travel time estimations and queue warnings by lane, and targeted shoulder widening to provide space for disabled vehicles and improve emergency vehicle access. The design augments the existing vehicle detection with Bluetooth and radar traffic sensors, adds roadway weather information stations to measure roadway grip factor and visibility, upgrades the corridor communication system, and installs 28 variable advisory speed signs and seven variable message signs.

Using archived traffic and weather data, the design team developed automatic control of the variable advisory speed signs and variable message signs. The field devices and electronic signs will not inhibit other planned freeway improvements should funding become available in the future. The project is currently under construction and is expected to be operational by the end of 2013.

HIGHWAY 217 CORRIDOR

Highway 217 is a 7.5-mile limited-access expressway that serves as a major north-south route through Beaverton and Tigard in Washington County, west of Portland, Oregon. There are numerous safety and mobility problems along Highway 217 including recurring bottlenecks, high crash rates, and unreliable travel times. Factors that lead to these problems include peak period demands that exceed capacity, lack of shoulders, and short weaving areas that create erratic changes in traffic. Most interchanges are well under one mile apart, which does not allow adequate space for the weaving that occurs between vehicles entering and exiting the freeway. There have been nearly 200 crashes a year along the highway, with 70% being rear-end collisions and over 50% occurring during the a.m. and p.m. peak periods. The extents of the Highway 217 corridor are shown below in Figure 1.

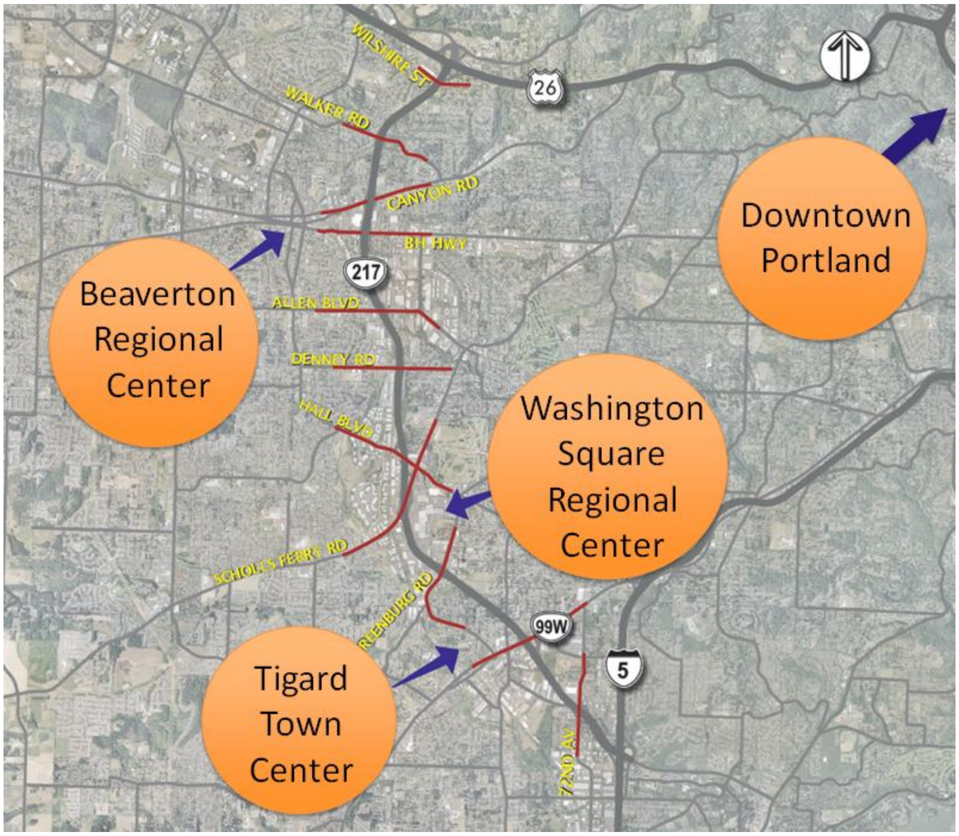

Figure 1. Highway 217 Corridor

PLANNING APPROACH

Previous studies addressed the Highway 217's mobility and safety problems with costly capital projects such as widening to six lanes, braiding ramps, and adding collector-distributor roadways. These high-cost improvements total nearly $1 billion for the corridor. Given past and projected funding levels for transportation improvements, no projects had been implemented in the corridor and there was no expectation that needed funding would be available soon. Tired of waiting, the public asked the Oregon Department of Transportation (ODOT) to do something to improve conditions in the corridor now. The planning objective became to identify and evaluate lower cost, fundable projects that could feasibly be constructed today to increase reliability, mobility, and safety.

Representatives from public agencies including ODOT, Washington County, City of Tigard, City of Beaverton, and Metro, as well as several consulting technical experts in freeway design, freeway operations, and water resources held a workshop and created a list of possible projects with potential to address reliability, mobility, and safety issues. Nearly 40 project concepts were developed as a result of the workshop.

The project concepts were evaluated and those offering high benefits with comparatively low costs were refined into best in class strategies. These strategies each offered reliability and safety benefits to Highway 217, and in general, individual projects could be implemented for less than $10 million. The degree of benefit varies based on the strategy.

SYSTEMS ENGINEERING

Three systems management strategies were selected for further evaluation and refinement. These were:

1. Arterial and Freeway Travel Time Estimation
2. Freeway Queue Warning
3. Freeway Variable Advisory Speed

The existing conditions and systems' needs were explored and combined into a single concept of operations and requirements documentation. The general goal of these three systems is to improve safety and travel time reliability along the corridor. For most drivers, access to information about overall traffic conditions is limited; drivers must rely on past experience and brake lights from vehicles in front of them for any indication of abnormal congestion or a severe incident. Variable message signs (VMS) on Highway 217 and on key arterial approaches will provide travelers with estimates of travel time and information about incidents, the end of queues, congested traffic, and inclement weather conditions. Variable advisory speed (VAS) signs will alert drivers to the recommended driving speed, based on current traffic and weather conditions. Providing relevant and timely information means drivers make better decisions, improve safety, and increase travel time reliability.

Arterial and Freeway Travel Time Estimation

The goal of the travel time estimation system is to reduce the impact of recurring (typically due to overcapacity) and nonrecurring congestion (due to crashes, incidents, weather events, etc.). By providing travel time information, drivers can choose an alternate route, change a trip, or delay a trip. The benefits of travel time information are expected to be greatest during peak congestion.

Estimated travel times for one or two destinations relevant to travelers are displayed on each VMS throughout the corridor. An example travel time estimation for a freeway VMS is shown in Figure 2. An analysis of regional travel demand forecast model data of origins and destinations was used to determine specific high-value locations for the Highway 217 corridor. In general, these are major interchanges or town centers. Intermediate destinations within the corridor are not be used because the short trip length makes travel time estimations less reliable and not useful to most drivers. Approximate sign locations were chosen so drivers would have enough time to make choices before committing to a particular route.

Figure 2. Example Freeway Travel Time Message

ODOT currently uses a midpoint algorithm for travel time estimations on freeways. The algorithm breaks the corridor into segments based on the location of traffic sensor stations. Each of these segments contains only one traffic sensor and the border of each segment is defined as half the distance to each adjacent sensor. The travel time for each segment is estimated based on the length of the segment and the current speed measured at the associated sensor. The travel time to any destination is simply the sum of the travel time estimations for each segment along the route. This algorithm was augmented to include segments defined by the area between two vehicle-matching sensors. This allows the travel time estimations to include locations where point traffic sensors are not well suited, such as freeway entrance ramps.

On Highway 217, the traffic sensors are typically composed of pairs of inductive loops and dual-beam radar. While the sensors were initially installed to support the adaptive ramp meter system, a common data acquisition module (DAC) collects and distributes the data to many different traffic applications. Individual vehicle speeds in each lane are averaged over sample periods of 20 seconds to one minute. The representative speed measurement for all lanes at each detector station is calculated as a weighted mean based on the traffic volume in each lane during each sample period. If a detector happens to be offline or fails, the system uses the nearest upstream and downstream traffic data.

ODOT partnered with Oregon State University to develop a custom Bluetooth sensor system. The Bluetooth traffic sensors are installed at each arterial VMS and at ramp meters. Multiple travel time segments are created by pairing sensors from each VMS to each ramp meter. Directional antennas are used to reduce false detection in tight interchanges.

Freeway Queue Warning

The goal of the queue warning system is to reduce the number of crashes, especially the rear-end type, by notifying drivers far in advance of slowed or stopped vehicles ahead. Queue may result from many causes, but its ultimate effect is a significant reduction in expected speed. Sudden braking by drivers can contribute to a decrease in safety.

Every VMS on the freeway can be used for queue warning. An example of a queue warning message is shown in Figure 3. The speed at each VMS is compared to the speed at several downstream traffic sensor locations, if the speed at the VMS is greater than 45 mph and any downstream speed is more than 30 mph slower, the queue warning system will activate. The queue warning system will generate a variety of messages based on the specific conditions – typically the lane and distance to the queue. When multiple messages are generated by different sets of traffic sensors, the message generated from the closest queue takes highest priority.

Figure 3. Example Queue Warning Message

Traffic jams can form and spread upstream quickly; therefore, queue warning messages are displayed as soon as a queue is detected. The traffic data is from the common sensor network used by the ramp meters, travel time estimation system, and variable advisory speed system. The 20 seconds to one minute data collection intervals are sufficient to detect queue formation and alert drivers.

Freeway Variable Advisory Speed

The variable advisory speed system will be used to proactively manage vehicle speeds. Two different VAS control systems are being implemented: a congestion responsive VAS system and a weather responsive VAS system. The goal of the congestion responsive VAS system is to reduce the frequency and severity of crashes caused by sudden changes in speed (by reducing speeds before vehicles reach the back of queue) and by abrupt lane changes (by reducing the speed differential between lanes and thereby removing a driver's incentive to change lanes). The purpose of the weather responsive VAS system is to notify drivers of inclement weather and display advised speeds appropriate for hazardous roadway conditions such as snow or ice on the roadway surface or reduced visibility due to heavy fog or whiteout conditions.

The variable advisory speed system will use smaller, dedicated signs over each travel lane. Example VAS sign messages are shown in Figure 4. The congestion responsive VAS system uses the common traffic sensor network and will turn on when traffic speeds fall below free-flow conditions. The measured average speed is rounded up or down to the nearest 5 mph speed and 5 mph will be added to determine the speed message for the VAS sign. For example, if a segment measures an average speed of 42 mph, the speed is rounded to 40 mph and 5 mph is added, resulting in the upstream VAS sign displaying "ADVISORY SPEED 45". During heavy congestion, a message of "SLOW" will be generated instead of an advisory speed. The message indicates that drivers should slow down and to expect stop-and-go traffic. In these conditions, a queue warning or travel time estimation messages on nearby VMS may accompany the "SLOW" message.

Figure 4. Examples of Proposed Variable Advisory Speed Messages

The weather responsive VAS system will activate during times of adverse weather conditions as detected by Road Weather Information System (RWIS) stations throughout the corridor or manually by an engineer at the nearby traffic management and operations center. Four RWIS stations on Highway 217 provide roadway grip factor, roadway surface classification, and visibility measurements every five minutes. Ideally, if an inclement weather condition is being accurately detected, the system should be activated and messages sent to the signs as quickly as possible. Table 1 below shows the preliminary threshold conditions for grip factor and visibility and the resulting VAS sign message.

Table 1. Preliminary Roadway Weather Conditions and Corresponding VAS Message

Grip Factor **Visibility**	**1.00 to 0.70**	**< 0.70**
> 500’	(Blank)	45 MPH
500’ to 250’	45 MPH	35 MPH
< 250’	35 MPH	“SLOW”

Once a sign is activated, there is a minimum amount of time the sign will stay active before turning off. When advisory speed values change either up or down as conditions improve or worsen, two different minimum time lapses are employed controlling how fast messages can be updated. Changing from a higher to a lower advised speed can occur quicker than transitioning from a lower to a higher advised speed.

In addition to controlling variable speeds, the weather responsive system also generates messages for the arterial and freeway VMS located throughout the Highway 217 corridor. Table 2 shows the corresponding VMS message for different grip factor, visibility, and roadway classifications.

Table 2. Preliminary Roadway Weather Conditions and Corresponding VMS Message

Visibility	Surface Classification \ Grip Factor	1.00 to 0.70	< 0.70
> 500’	Moist or Wet	(Blank)	“Slippery when wet” sign + “USE CAUTION”
	Frosty, Snowy, Icy, or Slushy	(Blank)	“ICE” sign + “USE CAUTION”
500’ to 250’	Moist or Wet	“LOW VISIBILITY”	“Slippery when wet” sign + “USE CAUTION”
	Frosty, Snowy, Icy, or Slushy	“LOW VISIBILITY”	“ICE” sign + “USE CAUTION”
< 250’	Moist or Wet	“LOW VISIBILITY”	“Slippery when wet” sign + “USE CAUTION”
	Frosty, Snowy, Icy, or Slushy	“LOW VISIBILITY”	“ICE” sign + “USE CAUTION”

Multiple Message Conflict and Resolution

With several systems automatically generating messages for VMS and VAS signs, there will be conflicts where multiple messages are needed on a single sign. To manage this, a message queue manager (MQM) was developed. The MQM collects and tracks each message that is requesting display. The manager uses message priority and duration to determine which message should currently be showing on each sign. The highest priority message will be displayed until its duration has expired or a higher priority message is generated. Lower priority messages are stored and displayed when a higher priority message expires. This continues until there are no more messages to display for any given sign.

In general, the highest priority messages for VMS are incident related, followed by queue warnings, adverse weather warnings, and travel time estimations. For the variable advisory speed system, messages priorities are inversely related to speed. Slow advisory speed messages are a higher priority than high speed and blank messages.

SYSTEM DEVELOPMENT

The systems on Highway 217 share much of the physical infrastructure, such as traffic sensors, variable message signs, and communications systems. In addition to each individual traffic management system, there are several common system modules such as the data acquisition module and the message queue manager. Figure 5 shows the relationship between the many components. The software development was managed by ODOT and all components use a common active traffic management (ATM) system architecture. This approach will allow ODOT to use each component on future projects or add new components without significant software modifications.

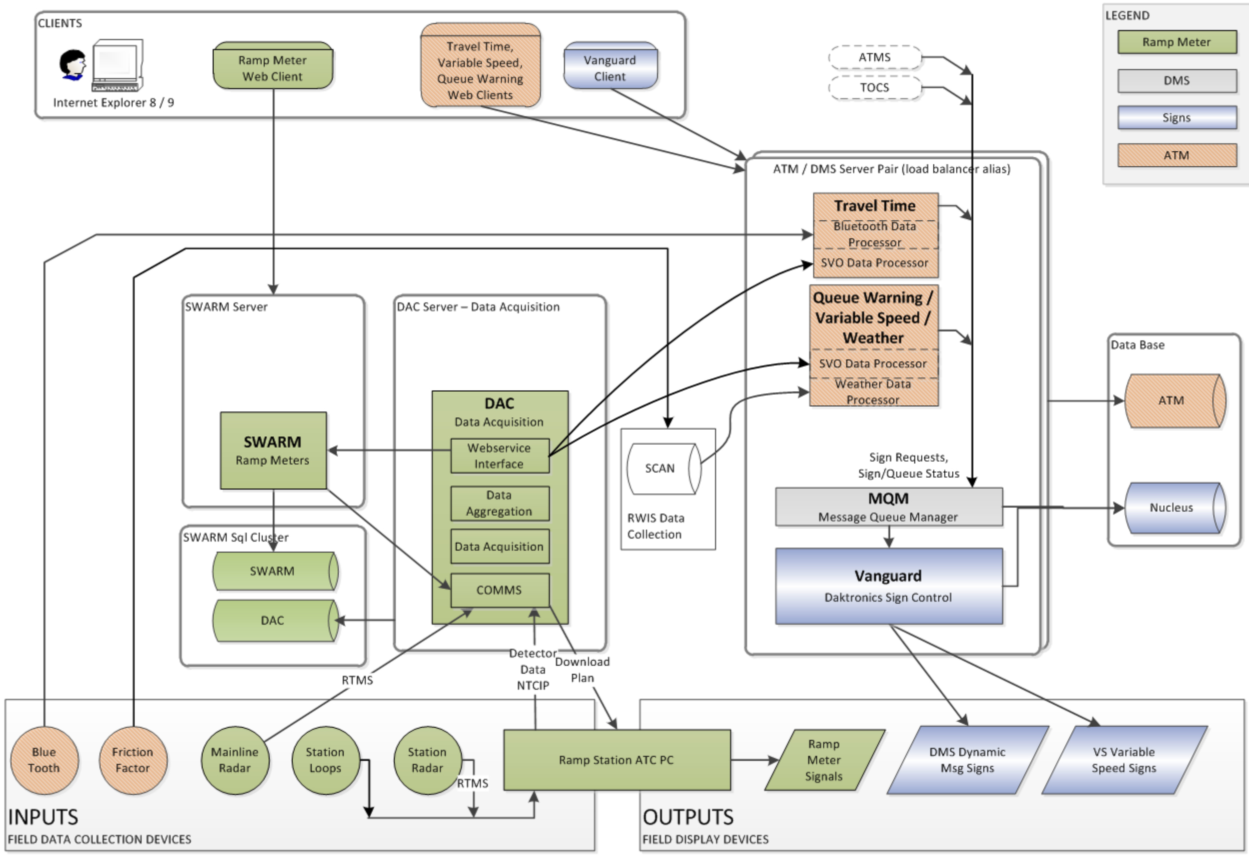

Figure 5. ATM Component Diagram

AUTHORS

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