Implementation of Traffic Control Devices on Highway Preservation Projects to Enhance Construction Work Zone Safety

Fan ZHANG1, John GAMBATESE2, and Ali MOGHADDAM VAHED3

1 S.M.ASCE, Graduate Student, School of Civil and Construction Engineering, Oregon State University, 101 Kearney Hall, Corvallis, OR 97331-3212; PH (785) 330-3042; email: zhangfan@onid.oregonstate.edu
2 M.ASCE, PE, Professor, School of Civil and Construction Engineering, Oregon State University, 101 Kearney Hall, Corvallis, OR 97331-3212; PH (541) 737-8913; FAX (541) 737-3300; email: john.gambatese@oregonstate.edu
3 Graduate Student, School of Civil and Construction Engineering, Oregon State University, 101 Kearney Hall, Corvallis, OR 97331-3212; PH (541) 602-7298; email: moghadda@onid.oregonstate.edu

ABSTRACT

Highway preservation projects are commonly conducted at night and often require construction workers to work in close proximity to ongoing traffic. This situation creates considerable safety risk for both the workers and passing motorists. It is widely accepted that work zone safety is highly related to vehicle speed, and a lower speed will make the work zone safer. Additionally, vehicle speed and speed variability in work zones is inextricably connected to the work zone design and the selected traffic control devices. Therefore, the type and layout of traffic control devices used in a work zone are important criteria when addressing work zone safety. To provide guidance on how to effectively and efficiently enhance work zone safety, a research study was conducted to investigate the impact of selected traffic control devices within highway preservation project work zones. The researchers implemented multiple traffic control devices on two case study projects and evaluated their impact on vehicle speed, construction productivity, cost, and motorist and worker safety. Interviews were conducted on site to collect worker’s opinions toward traffic control devices implemented each night. Speed data were gathered to evaluate the effectiveness of traffic control devices. A police officer parked on the site was found to effectively reduce traffic speeds and was also highly recommended by interviewees. The research findings also suggest using a combination of temporary reduced speed limit signs, radar speed monitoring display, and PCMS signs on both trailers and rollers.

INTRODUCTION

Freeway pavement preservation projects (e.g., pavement overlays, “chip seal” operations, etc.) typically require construction workers to conduct their work in close proximity to ongoing traffic and often reduce traffic flow to a single lane while work is undertaken in an adjacent lane. During the lane closures, the paving operations place workers on the roadway within a protected work zone. In some places the workers only have a line of cones and a few feet separating them from passing traffic. This situation creates considerable safety risk for both the workers and passing motorists. Inattentive or speeding drivers, careless workers, misplaced cones, and
hazardous roadway conditions can lead to crashes and ultimately work zone injuries and fatalities. The severity of a crash intensifies as the speed of traffic increases. As a result, preservation projects on high-speed roadways present an increased risk of serious and/or fatal injuries to workers, motorists, and their passengers.

Vehicle speed is directly connected to the performance of work zone designs. There is a widely held perception that speed is one of the most significant factors in vehicle-related crashes on roadways (Mahoney et al. 2007). However, safely controlling and reducing vehicle speeds through work zones to reduce the risk can be difficult on high-speed roadways. On such roadways, it has been suggested that reducing traffic speeds to 35 mph would enhance the safety of the workers and traveling public. However, a reduction in speed from 65 mph to 35 mph is significant, and evaluation of the impacts of this differential in speed on interstate highways has been limited. Previous research reveals that work zone speed limit reductions of more than 10 mph show an increase in the number of crashes due to a greater speed differential between vehicles (WSDOT 2009). Additional safety measures in planning, signage, and notification to the driving public are needed to reduce the significant risks to motorists as they navigate through the active work zone and react to the large difference in speed. In addition, large speed reductions during nighttime work—a time when preservation projects are often conducted—can further complicate the jobsite conditions, be difficult to implement, and may increase risks to worker and motorist safety. Practicability is also important when selecting traffic control measures and designing traffic control plans. Cost, ease of implementation, and worker productivity associated with implementation must also be weighed along with safety when considering which measures to implement.

CURRENT PRACTICE AND RESEARCH APPROACH

Research on controlling and reducing speeds on high-speed roadways, and on significant speed reductions, has been conducted but provides limited guidance for practical implementation. In a study of speed reduction measures conducted by Iowa State University on behalf of the Iowa Department of Transportation, the authors state that the most effective speed reduction will probably involve some combination of speed reduction techniques, as opposed to the use of just one type of control measure, although no quantified impact of each independent traffic control measure was provided (Maze et al. 2000). The researchers in Iowa conducted a survey of state transportation agencies and found that only a few agencies even consider reducing speed limits by 20 mph or more. The study also revealed that the use of regulatory speed limit signs and police enforcement is the most common practice for controlling and reducing speeds.

The selection and specification of traffic control measures and the design of construction work zones are addressed and published in the Manual on Uniform Traffic Control Devices (2009) and in state DOT standards such as the Oregon Department of Transportation (ODOT) Traffic Control Plans Design Manual (2011). These design manuals provide guidance to traffic control designers to effectively and safely control traffic and reduce speeds within work zones.
Based on the review of literature and both manuals mentioned above, the researchers and ODOT Technical Advisory Committee for the research study selected the following traffic control devices to include in the study.

- **50 mph speed reduction signs** (Figure 1) – temporary signage used to convey regulatory speed during construction. Figure 1 shows examples of the signs mounted on different kinds of stands depending on the roadway condition.

![50 mph speed reduction signs](image1)

**Figure 1. 50 mph signs on different stands**

- **Portable Changeable Message Sign (PCMS)** – PCMS’s are large lighted signs used to display programmable, dynamic messages that reflect upcoming work zone conditions to be encountered by approaching traffic. PCMS’s can be mounted on either a trailer or work vehicle. Figure 2 (left) shows an example of trailer-mounted PCMS. Figure 2 (right) shows an example of a roller-mounted PCMS.

![PCMS on trailer and roller](image2)

**Figure 2. PCMS on trailer (left) and roller (right)**
- Reducing travel lane width using tubular markers or drums – A narrowing down of the travel lane width. Narrower lanes leave less lateral distance between vehicles in adjacent lanes or between vehicles and shoulder obstructions, requiring more motorist attention and control, and passively influencing motorists to reduce speeds. Figure 3 shows an example of using tubular markers (left) and drums (right) to narrow the travel lane width.

![Figure 3. Reducing lane width using tubular markers (left) or drums (right) on both sides of traveling lane](image)

- Radar speed monitoring display – measures and displays the vehicle speed ("Your speed is XX") along with the posted speed limit. Figure 4 (left) shows an example of using the radar speed monitoring display.

- Police presence and enforcement – Police officers patrolling with active enforcement or parked on-site. Figure 4 (right) shows an example of a police officer parking on-site.

![Figure 4. Radar speed monitoring display (left) and police officer parking on-site (right)](image)
The research approach selected for the study was to implement the selected traffic control devices on current ODOT preservation projects and determine the associated impacts. The researchers selected this experimental approach in order to enable comparison between each traffic control device and comparison with the actual traffic control plan (TCP) designed for the project. In addition, this approach enabled assessments of typical implementation cost, ease of use, and impacts to construction productivity.

CASE STUDY PROJECTS

After selecting traffic control devices to implement, the researchers identified case study projects on which to implement the devices. ODOT desired to focus the research on high-speed, multi-lane, rural/suburban freeways that were undergoing preservation work (re-paving). Two projects were chosen from a list of potential projects during the 2012 construction season: I-84 Fifteen Mile to Celilo, and I-5 Linn County Line to McKenzie River. The I-84 Fifteen Mile to Celilo project was selected because the location of the project and type of work met the research objective and the contractor on the project was interested in and willing to assist with the research. The I-5 Linn County Line to McKenzie River project was chosen because the timing of the project fit well with the study timeline, the location of the project was convenient, the project met the research objectives, and the project site was similar in nature to the I-84 case study project (rural/suburban freeway with two lanes in each direction).

The researchers contacted the contractor to obtain general information about the work plan and paving schedule. Based on the planned paving schedule, the researchers created a research plan to show the traffic control devices to be implemented on each day of paving work. The contractor changed the construction schedule periodically due to various reasons and, as a result, the plan was updated several times. The final research plans for both projects are shown in Table 1. On each work day (work was conducted at night), one or more traffic control devices were implemented as shown in the research plan. The initial TCP was the TCP as designed for the project without the additional traffic control devices selected for the research study. As shown in the research plan, data was collected on one or more nights with just the initial TCP present in order to provide a comparison to current practice.

<table>
<thead>
<tr>
<th>Project and Work Day</th>
<th>Treatments Implemented</th>
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<tbody>
<tr>
<td></td>
<td>Initial TCP</td>
</tr>
<tr>
<td>I-84</td>
<td>Day 1</td>
</tr>
<tr>
<td></td>
<td>Day 2</td>
</tr>
<tr>
<td></td>
<td>Day 3</td>
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RESULTS
The research approach consisted of multiple data collection efforts. Interviews of ODOT and contractor personnel were conducted to collect information related to the time, cost, and resources required to implement the traffic control devices, as well as the limitations and enhancements to implement the devices. Speed data were collected to determine the effectiveness of traffic control devices with regard to impact on the magnitude and variability of vehicle speeds in the work zone. To collect the speed data, sensors were placed at various locations in each travel lane prior to and within the work zone. The results from each of these efforts are summarized below.

Interview results summary
On each project, the researchers conducted interviews of the ODOT project manager and inspector, and the contractor superintendent, traffic control supervisor, work crew members, and asphalt truck drivers to get their opinions on the traffic control device implemented each day. Table 2 provides a summary of the positive and negative attributes for each traffic control device. The information in the table is based on the interview results and researcher observations.

Table 2. Pros and cons of traffic control devices

<table>
<thead>
<tr>
<th>Traffic control device</th>
<th>Positive Attributes</th>
<th>Negative Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 mph signs</td>
<td>• May slow down the traffic.</td>
<td>• Limited effect without law enforcement.</td>
</tr>
<tr>
<td></td>
<td>• Necessary if using law enforcement or a radar speed</td>
<td>• Need to cover existing speed signs.</td>
</tr>
<tr>
<td></td>
<td>monitoring display.</td>
<td>• Need special permission/approval</td>
</tr>
<tr>
<td></td>
<td>• Relatively cheap.</td>
<td></td>
</tr>
<tr>
<td>Method</td>
<td>PROS</td>
<td>CONS</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| PCMS signs on rollers                       | • Highly visible.  
• Make drivers aware of workers on the road.  
• Slows down traffic before the drivers see the paver.  
• After initial installation and programming, require just a few minutes to implement. | • Initial cost is high.  
• Vibration of rollers may damage PCMS signs.  
• Does not benefit workers on the roadway who may be far away from the rollers (e.g., QA/QC personnel). |
| PCMS signs on trailers                      | • Make drivers aware of construction workers ahead.  
• Very large and visible.  
• When located at the beginning of the work zone, will benefit everyone in the work zone, not only the workers who are located around the paver. | • If too many signs at the beginning of the work zone, drivers are distracted.  
• Require a lot of space (need a big shoulder or median)  
• Need to be protected from vehicles using a barricade.  
• Not easy to move.  
• Initial cost is high. |
| Radar speed monitoring display              | • Slows down the traffic.  
• Make drivers think that maybe police officer is somewhere close by.  
• Rental cost is relatively low.  
• Light and easy to move and set up.  
• Small and do not take up a lot of space. | • People tend to slow down before it and then speed up afterwards; works better along with police enforcement.  
• Need to implement together with 50 mph signs.  
• May not be big or bright enough; not very visible depending on location. |
| Tubular markers on both sides of the traveling lane to narrow down the lane width | • Slows down the traffic.  
• Clearly mark the lane, help to direct traffic, provide guidance when there is no fog line.  
• Raise drivers’ attention to the work zone. | • Hit by cars a lot; require more time/personnel to maintain upright and in proper location.  
• Not as visible as drums.  
• Need more time and extra labor to put down and pick up.  
• More tubular markers required for the project. |
| Drums on both sides of the traveling lane to | • Slows down the traffic.  
• Highly visible.  
• Clearly mark the lane, help to direct traffic, provide guidance when there is no fog line. | • Take a long time and three extra laborers to put them out and even more time to pick them up.  
• Cost is high; more drums needed for the project. |
<table>
<thead>
<tr>
<th>Traffic Control Measure</th>
<th>Pro</th>
</tr>
</thead>
</table>
| Narrow down the lane width | - fuzzy line.  
- Raise drivers’ attention to the work zone.  
- Provide a clear path through the work zone.  
- Very shiny; may make drivers confused.  
- When big trucks hit the drums and send them flying, they become a hazard.  
- Asphalt truck drivers feel the spacing is often too narrow to pull into the work area.  |
| Police officer patrolling around the work zone | - Slows down the traffic.  
- Especially effective for truck drivers because they know there are police offices in the work zone through communication over the radio and tickets will affect their jobs.  
- Cost is high; overtime for police officers.  
- Need enough officers to cover extended paving operations.  
- Need extra time to coordinate with State Patrol office.  
- If officers pull over cars in the work zone, may force oncoming vehicles into the closed lane.  |
| Police officer parked at the beginning of the work zone with red/blue lights flashing | - Slows down the traffic and wake up the drivers.  
- Highly visible.  
- Causes drivers to slow down at the beginning of the work zone, benefiting every worker.  
- Especially effective for truck drivers because tickets will affect their jobs.  
- After drivers see police officer, they will lower their temper and tend to hit tubular markers less frequently, lightening the burden on TCS to maintain the markers.  
- Cost is high.  
- Need enough officers so that someone can take this job.  |

As can be seen from the table above, each type of traffic control measure has both positive and negative aspects. The PCMS signs on trailers and rollers provide a relatively low cost means for traffic control and gaining the driver’s attention. PCMS signs on trailers can be placed at the beginning of the work area to alert drivers of not only the work at the paver and grinder, but also alert drivers of the personnel on the ground and the entering/exiting vehicles throughout the work zone. Placing PCMS signs on the rollers provides an additional benefit of the signs staying close to the paver as the paver moves up the roadway. The PCMS signs are relatively easy to implement, readily available, and commonly recognized by motorists.

The radar speed monitoring display also provides a relatively low cost means for traffic control and gaining the driver’s attention. The mobile nature of the display
makes it easy to locate. Placing radar speed displays at the beginning of the work zone and perhaps once or twice within the work zone help to slow down drivers initially and remind them to keep their speeds lower.

Use of the tubular markers and drums on both sides of the travel lane appears to create additional problems and concerns for the passing motorists, asphalt truck drivers, and contractor. The extra cost, especially for a long line of drums, is also an inhibitor to their use. The additional time and effort required to place the second line of markers or drums impacts the contractor’s efficiency. These traffic control measures are therefore not suggested for typical work zones in practice.

The presence of a police officer is appreciated by all of those involved in the paving project and is seen as a benefit to the paving operation. Law enforcement presence is relatively easy to implement, and requires prior communication and coordination between ODOT, the contractor, and law enforcement agency. No additional contractor resources are required. The additional cost and availability of police officers may inhibit their use.

**Speed data results**

The speed data for the two case study projects were summarized and analyzed separately because it was found that the traffic speeds for the two projects were very different. Therefore, the researchers decided that cross project comparisons are not applicable. Table 3 summarizes the mean speed for each day of both projects.

<table>
<thead>
<tr>
<th>Project</th>
<th>Treatment</th>
<th>Mean Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-84</td>
<td>Typical TCP</td>
<td>49.07</td>
</tr>
<tr>
<td></td>
<td>50 mph signs</td>
<td>54.55</td>
</tr>
<tr>
<td></td>
<td>PCMS signs on rollers</td>
<td>50.56</td>
</tr>
<tr>
<td></td>
<td>Police officer patrolling and PCMS</td>
<td>47.19</td>
</tr>
<tr>
<td></td>
<td>Police officer parked and PCMS signs</td>
<td>44.24</td>
</tr>
<tr>
<td></td>
<td>Speed monitor only</td>
<td>49.07</td>
</tr>
<tr>
<td></td>
<td>Tubular markers on both sides and PCMS signs</td>
<td>50.41</td>
</tr>
<tr>
<td></td>
<td>Drums on both sides and PCMS signs</td>
<td>49.03</td>
</tr>
<tr>
<td></td>
<td>PCMS signs and speed monitoring display</td>
<td>48.30</td>
</tr>
<tr>
<td>I-5</td>
<td>Typical TCP</td>
<td>47.40</td>
</tr>
<tr>
<td></td>
<td>50 mph signs</td>
<td>46.03</td>
</tr>
<tr>
<td></td>
<td>PCMS signs on trailer</td>
<td>44.30</td>
</tr>
<tr>
<td></td>
<td>PCMS signs and speed monitoring display</td>
<td>44.39</td>
</tr>
<tr>
<td></td>
<td>Police officer parked only</td>
<td>44.77</td>
</tr>
</tbody>
</table>

The conclusions drawn from the two projects are different. For the I-84 case study project, the most effective treatment is the combination of a police officer parked on-site and PCMS on rollers, followed by the combination of a police officer patrolling and PCMS on rollers. The third most effective treatment is the combination of PCMS on rollers and radar speed monitoring display. For the I-5 project, the effectiveness of the PCMS signs on trailer, the combination of PCMS on trailer and
CONCLUSIONS AND RECOMMENDATIONS

When considering all of the performance criteria and both case study projects, those traffic control measures which performed well were the police officer parked on the site, PCMS signs on trailers and rollers, and the radar speed monitoring display. Each of these traffic control measures performed well when considering ease of implementation, cost, and impact on construction worker productivity. Additionally, when each of these measures was used, the traffic speeds were reduced the greatest amount.

It is important to remember that there is no traffic control device that is a “silver bullet” for work zone safety. The decision regarding whether to use a certain traffic control device or not should be based on the effectiveness of the traffic control device in slowing and controlling traffic, along with consideration of the positives and negatives related to cost, availability, ease of use, application to the particular site, and impact on the work progress. In most cases, a combination of multiple traffic control measures is needed. In all cases, worker and motorist safety should be given highest priority.

In this study, a large amount of data was collected. However, the researchers believe that there are limitations in generalizing the research results beyond the study sample. Additional case studies are needed to provide a higher level of confidence in the statistical comparisons, to confidently suggest recommended practice, and to enable continual improvement of TCP design and construction practices. Further research is currently being undertaken by ODOT to explore how to confidently and effectively control work zone traffic in practice.

REFERENCES


