Assessing the Harmonization Potential of Variable Speed Limit Systems

Williams Ackaah, Gerhard Huber, Klaus Bogenberger, and Robert L. Bertini

Variable speed limit (VSL) control systems have been used as a link control scheme on freeways and urban arterial roads. VSL systems aim to provide advance warning, to harmonize traffic speeds, or to accomplish both. The objective of this paper is to develop methods for assessing the harmonization potential of VSL systems. Two approaches based on the ability of the system to reduce inhomogeneity in the traffic stream and improve the consistency (proper coordination) of the displayed speed limits are presented. Inhomogeneity in the traffic stream was checked by first identifying the traffic state and assessing the ability of the system to reduce the speed differential in the metastable traffic state (i.e., flows > free flow but with speeds > congestion speed). The coefficient of variation was used to quantify the standard deviation of speed. Consistency was assessed by observing the consecutive dynamic changes in the displayed speed limits as drivers traverse the route. This assessment was done by reconstructing the traffic state from loop detector data, generating virtual trajectories based on the reconstruction, and finally tracking the virtual vehicles to reproduce the sequence of speed limits that drivers would have experienced. The methods developed were tested for the VSL system on the Autobahn 99 near Munich, Germany.

Growth in traffic demand has resulted in traffic congestion during certain time periods on most road network categories. Space and financial constraints make it impossible to continually expand the road infrastructure to accommodate the increasing traffic demand. Therefore, a more pragmatic and proactive means of managing the existing infrastructure is required. Variable speed limit (VSL) control systems have been used to improve traffic performance on freeways and urban arterial corridors. The strategy in deploying VSL control systems could vary widely. Most VSL systems are installed to harmonize traffic, to provide warning information for recurrent and nonrecurrent traffic congestion and in work zones, or to accomplish both.

Prevailing traffic speed is a key metric that directly reflects certain aspects of the road, such as traffic performance, road safety, vehicle emissions, and noise pollution (1). Traffic management systems that implement VSL control strategies aim to systematically dampen speeds to stabilize and smooth traffic longitudinally and across lanes, usually according to the prevailing measured traffic flow, speed, or density. Papageorgiu et al. defined speed harmonization or homogenization as the reduction of speed differences between vehicles (longitudinally) and of mean speed differences between lanes (laterally) (2). Harmonization principles used in VSL controls are motivated by the fundamental diagram of the speed–flow curve (3). The highest flow at the point where traffic is nearing breakdown is achieved with the optimal speed that is lower than the free-flow speed. It is therefore possible to increase the operational efficiency of a road by slowing down vehicles in advance before reaching a higher density area. However, the ability of a VSL implementation to increase flow has not been practically proved (2, 4).

High-speed variance is likely to increase the number of crashes (5–7). Therefore, harmonization of traffic that results in low speed differentials has the potential to reduce crashes. This fact has been confirmed as VSL evaluation studies have reported decreases in crash rates after implementation (8–11). Uniform headway distribution and lower speed differences between driving lanes and between consecutive vehicles reduce lane-changing maneuvers, leading to fewer traffic conflicts and thereby preventing crashes. Smoothing traffic flow also decreases noise pollution and reduces environmental pollution (12).

Simulation studies have been used to assess the harmonization potential of VSL systems (13, 14). Other works—for example, Lucky (3), Weikl et al. (4), Kwon et al. (15), the U.K. Highway Agency (16), and van den Hoogen and Smulders (17)—have compared traffic flow variables such as headway and lane distribution in before-and-after implementation studies or compared the test site with a control site for this same purpose. Vukanovic measured harmonization on the basis of the relationship between the displayed (variable speed) and measured speeds (18). If the traffic flow exceeds free flow but the speeds are still higher than the minimum speed and if the driven speed does not deviate significantly from the control speed, the system is assumed to have smoothed traffic. This allowable deviation was defined with a measure of range and bias or offset, which was 20 and 5 km/h, respectively. That is, a harmonization benefit should be expected if speeds fall within ±25 km/h from the displayed speed limit. According to Vukanovic, this approach was adopted because, at the time, the researcher had no access to speed deviation data (18). Some studies since then have compared the standard deviation of speeds before and after installation of VSL systems to assess harmonization (13, 19). The question then arises: Should, for instance, standard deviations of speeds of 8.5 and 9.0 km/h for two data sets with mean speeds of 65 and 110 km/h, respectively, be compared on the basis of their nominal values, considering that the means about which they occur are different from each other?

This study proposes two methods for assessing harmonization. The first is an extension of the traditional method of using speed deviation data to assess inhomogeneity in the traffic stream. However, the inhomogeneity assessment is done in uncongested situations where high flows occur. The reason is that the application of a VSL...
system to resolve inhomogeneity is useful only under such circumstances. The second approach uses straightforward measurement by checking the systematic consecutive variation of the displayed speed limits (consistency).

METHODS FOR EVALUATION

Shock waves, which may lead to congestion and crashes, are caused by severe inhomogeneities of the traffic stream that exist when the traffic flow approaches capacity (20). Smulders named examples of these inhomogeneities as speed differences between consecutive vehicles in one lane, speed differences that exist across lanes, and flow differences across lanes (20). Harmonization methods aim to eliminate or reduce these inhomogeneities in the traffic stream by applying speed limits to suppress shock waves. However, applying harmonization strategies may not be useful under all traffic conditions. Kerner observed three states of traffic flow, namely, stable, metastable, and unstable traffic states (21). In the stable state, any disturbance can be resolved without the need of an intervention. In unstable traffic, small disturbances usually result in the inducement of shock waves. According to Kerner, when the number of vehicles on a road is high and the speed of the traffic stream is also significant (i.e., the metastable traffic state), small disturbances usually will be resolved while large disturbances will lead to shock waves (21). Thus, if speed limits are intended to dissolve shock waves, the traffic flow must be in the metastable state because in the stable state, there is not much to control, and in the unstable state, drivers are already unable to move at their desired speed (22).

Algorithms for deploying harmonization strategies of VSL systems may implement reactive strategies, proactive strategies, or both. Harmonization of traffic speeds can be activated if congestion is detected. There are times of the day when VSL may be activated in anticipation of congestion. Successively lower speeds (over some distance) may be displayed to gradually reduce speeds over multiple upstream gantries as drivers need time to react before they reach a bottleneck; that is, the ability of the system to convey a coherent picture of the overall traffic situation and prepare drivers progressively for downstream bottlenecks is very important and could influence the ability of the system to reduce inhomogeneities. Therefore, consistency could be used as a measure to assess harmonization. Proper coordination of speeds along a link should dampen sudden speed drops and frequent acceleration and deceleration and thereby smooth traffic.

From the foregoing, two methods for assessing harmonization based on the ability of the system to reduce an inhomogeneity (speed differential) and the systematic changes of the displayed speed limits (consistency) are discussed. The ability of the system to minimize speed variance is assessed by identifying the metastable traffic state and assessing the variation in traffic speeds in that region with the use of the coefficient of variation (CV). Consistency evaluation is realized by reconstructing the traffic state and generating virtual trajectories based on the reconstruction. Next, these trajectories are followed to reproduce the sequence of displayed speed limits drivers would have experienced. Doing so allows direct analysis of whether the order of speed limits encountered is consistent. Details of these methods and results are presented in the subsequent sections.

Assessing Inhomogeneity in the Traffic Stream

Identification of Traffic State

As mentioned, harmonization of traffic speeds may be advantageous only in a metastable traffic state. This state occurs when traffic flow exceeds free flow ($q_{\text{min}}$), but the speeds are still higher than in the congested state (18). Recommended values for $q_{\text{min}}$ and the minimum speed ($u_{\text{min}}$), above which harmonization benefit could be expected, are 600 vehicles/h/lane and 60 km/h, respectively (18, 23, 24). A sensitivity analysis could also be done to select the optimal values for these thresholds.

Because traffic variables (e.g., speed and flow) are available only at specific locations and for specific times, an estimation of these parameters for all locations along the freeway [ground truth (GT)] during the considered time period is required. The adaptive smoothing method developed by Treiber and Helbing—which takes the characteristic propagation velocity observed in free and congested traffic into account—was used for the GT generation (25). Figures 1 and 2 show an example of the reconstructed speed and flow fields, respectively. Superimposing the GT speeds and flows allows the...
different traffic states to be identified. Spatiotemporal regions with traffic flow exceeding $q_{\text{min}}$ and speeds greater than $u_{\text{min}}$ constitute the metastable traffic state. Regions with speeds less than $u_{\text{min}}$ represent an unstable traffic state while regions with flows below $q_{\text{min}}$ constitute a stable traffic state. The green, yellow, and red regions in Figure 3 represent stable, metastable, and unstable traffic states for the traffic situation shown in Figures 1 and 2.

Quantifying Speed Differentials

Once the traffic state has been determined, the ability of the system to reduce inhomogeneities in the metastable traffic state is evaluated. The standard deviation (SD) of speeds, which is also collected by the dual inductive loop detectors, is used for this purpose. The SD measures the spread of the speed data from the mean. However, knowing the SD alone gives little information about the relative variability since it is based on the sampled data and, as such, must be understood in the context of the mean about which they occur. To make comparing data sets gathered from different detector stations meaningful, the CV is used. The CV is the ratio of the SD to the mean, that is,

$$\text{CV} = \frac{\text{standard deviation}}{\text{mean}}$$

The CV is a standardized measure of dispersion and helps to determine the relative magnitude of variability in the traffic stream. A small CV indicates low speed differential and thus is used as an indicator for smoothed traffic.

Evaluating Consistency

Generation of Virtual Trajectories and VSL Data

The generation of virtual trajectories makes it possible to determine the speed limits drivers encounter as they traverse the route. The GT speed has been reconstructed according to Treiber and Helbing (25). Applying the adaptive smoothing method results in a high-resolution
grid-based speed function. The high-resolution grid is to ensure a good approximation of the real traffic situation. The filtered speed-based trajectory method, proposed by van Lint (26) and modified by Huber et al. (27), has been used for the trajectory generation. Many trajectories are generated to cover the whole road segment throughout the considered time period. These trajectories are generated at a specified time interval.

Considering the generated trajectories individually, the times at which a virtual vehicle passes a particular gantry is noticed. Figure 4a shows a speed profile of a trajectory generated on the basis of the GT speeds at a starting time of 17:00 hours on Autobahn 99 (A 99), near Munich, Germany, for July 9, 2012. As can be observed from the figure, the gantry locations (dashed vertical lines) and the times at which a vehicle passes can be determined. The observed time is then used to obtain the speed limits displayed by the system at the time a gantry is passed. Figure 4b illustrates the superimposition of all generated trajectories on the displayed speed limits (shown by the colors in the background) between 13:00 and 20:00 hours. In congested situations (speeds < 60 km/h) and in free-flowing conditions (speeds > 120 km/h), the VSL system at the study location does not display any speed limit. However, the message “Congestion” is displayed. Congested traffic is represented by a speed value of

FIGURE 4  Trajectory generation: (a) speed profile generated on basis of GT speeds and (b) determination of speed limits encountered by drivers.
30 km/h, while freely flowing traffic is represented by a speed of 130 km/h.

**Possible Scenarios Encountered by Drivers**

The scenarios described below have been identified as possible sequences of speed limit signs that vehicles using the freeway with a VSL facility can experience. Examples for each of the scenarios based on simulated trajectories on the A 99 in Germany are illustrated in Figure 5. The assessment of the consistency of the system is based on these scenarios.

**Scenario T.1. Gradual Speed Drop**  Gradual speed reduction is a very important component of VSL systems. Systematically reducing traffic speeds ensures a smooth transition from high speeds to lower speeds. This approach ultimately prevents surprises that are likely to be encountered by a driver. The variable message signs at the study location display speed limits in multiples of 20 km/h. A one-step decrement (as shown in Figure 5a) from one gantry to the next is considered appropriate and ensures a gradual transition from one speed class to the other.

**Scenario T.2. High Speed Drop** Problems in adapting to a newly displayed speed limit will arise if the decrement is drastic. Specifically, changing a speed limit by more than one step (e.g., from 120 to 80 km/h) may cause speed adaptation issues and rapid decelerations. Therefore, if the displayed speed limit was to be reduced from, say, 120 to 80 km/h, then there should be a middle gantry to display 100 km/h to provide a gradual transition. A high speed drop defined as a drop of more than one step is considered inappropriate. Figure 5b shows an example of a high speed drop.

**Scenario T.3. Constant Speed at Consecutive Gantries**  The speed limit displayed at the immediately passed upstream gantry may be maintained at the next downstream gantry if the traffic environment remains unchanged (see Figure 5c). Constant speed at consecutive gantries may also be to control speeds in anticipation of a traffic breakdown. Maintaining a constant speed at successive gantries does not cause any adverse effect on stability and is considered appropriate.
Scenario T.4. Speed Increase  A speed increase is not expected to follow the same pattern at which speed was decreased. While a gradual speed decrease upstream of a bottleneck may be applied to ensure a gradual reduction of vehicle speeds, increasing speeds downstream of a bottleneck may be used to urge drivers to accelerate to increase the discharge rate at a bottleneck. Therefore, a speed increase (whether gradual or rapid) is not considered as undesirable for the system. An example of a rapid speed increase is shown in Figure 5d.

Scenario T.5. Roller Coaster Pattern  The traffic state experienced on a road segment can change over a short time interval as in stop-and-go traffic. Stability in a VSL system is necessary to prevent speed limits from being displayed for very short durations. Requiring drivers to accelerate and then to decelerate over a short period does not bring any benefit to the system. However, this situation is looked at differently from one in which drivers are required to slow down even for a short time because of an incident in a section of the road. The latter may have consequences on safety. A “roller coaster” pattern is therefore defined as one in which speed increases last for short times or distances (i.e., if the distance between the last speed increase and first speed decrease is less than 3,500 m). Drivers require time to react to incidents and speed limits displayed ahead of them. However, posting messages too far upstream of an incident is also not beneficial as drivers might tend to forget about the warning (28). The distance of 3,500 m is chosen according to the authors’ engineering judgment and the highest recommended distance within which drivers are able to recall a displayed advance warning on a freeway (28). The roller coaster pattern is considered detrimental to the system. An example of a roller coaster pattern is shown in Figure 5e.

Aggregating Consistency

The idea of the consistency assessment is to observe changes in the displayed speed limits as one travels along the freeway corridor. As a vehicle trajectory is followed, a check is made as to whether the scenarios described above were encountered along the route. The algorithm first assigns the consecutive variations in the speed limits to one of the scenario types T.1 to T.4, as in Equation Box 1. The 20 km/h in the algorithm represents a gradual speed drop at the point where the traffic state experienced upstream of a bottleneck changes over a short time interval. The distance of 3,500 m is chosen according to the authors’ engineering judgment and the highest recommended distance within which drivers are able to recall a displayed advance warning on a freeway (28). The roller coaster pattern is considered detrimental to the system. An example of a roller coaster pattern is shown in Figure 5e.

EQUATION BOX 1 Algorithm for Assignment of Scenario Types T.1 to T.4

\[
\text{Initialization: } i = 1; \text{sc}_\text{type} = \text{scenario type}; \\
\text{VSL}_{(\text{end} - i)} = \text{next to last VSL}; \\
\text{Step 1} \quad \text{for } (i \leq \text{VSL}_{(\text{end} - i)}) \quad \text{Do } \ldots \\
\text{Step 2} \quad \text{if } \text{VSL}_{(i)} - \text{VSL}_{(i+1)} = 20; \text{sc}_\text{type} = T.1 \\
\text{Step 3} \quad \text{else if } \text{VSL}_{(i)} - \text{VSL}_{(i+1)} > 0; \text{sc}_\text{type} = T.2 \\
\text{Step 4} \quad \text{else if } \text{VSL}_{(i)} - \text{VSL}_{(i+1)} = 0; \text{sc}_\text{type} = T.3 \\
\text{Step 5} \quad \text{else if } \text{VSL}_{(i)} - \text{VSL}_{(i+1)} < 0; \text{sc}_\text{type} = T.4; \\
\text{Step 6} \quad i = i + 1 \\
\text{Step 7} \quad \text{end if} \\
\text{Step 8} \quad \text{end for}
\]

where

\[
Id_i(b) = \begin{cases} 
1 & \text{if } b \in A \\
0 & \text{else}
\end{cases}
\]

The SCR and the FCR are estimated by calculating the percentages of SC and FC scenarios over all scenarios, respectively. At the times

EQUATION BOX 2 Algorithm for Assignment of Scenario Type T.5

\[
\text{Initialization: } i = 1; \text{sc}_\text{type} = \text{scenario type}; \\
\text{VSL}_{\text{pos}} = \text{VSL exit position} \\
\text{Step 1} \quad \text{for } (i \leq \text{sc}_\text{type}_{(\text{end})}) \quad \text{Do } \ldots \\
\text{Step 2} \quad \text{if } \text{sc}_\text{type}_{(i)} = T.4 \\
\text{Step 3} \quad j = i + 1 \\
\text{Step 4} \quad \text{for } (j \leq \text{sc}_\text{type}_{(\text{end})}) \quad \text{Do } \ldots \\
\text{Step 5} \quad \text{if } \text{sc}_\text{type}_{(j)} = T.4 \\
\text{Step 6} \quad \text{break (exit the loop)} \\
\text{Step 7} \quad \text{else if } \text{sc}_\text{type}_{(j)} = T.1 \text{ or T.2} \ldots \\
\text{Step 8} \quad \text{VSL}_{\text{pos}} - \text{VSL}_{\text{pos}} < 3,500 \ldots \\
\text{Step 9} \quad \text{sc}_\text{type}_{(j)} = T.5; \\
\text{Step 10} \quad \text{break (exit the loop)} \\
\text{Step 11} \quad \text{end if} \\
\text{Step 12} \quad \text{end for} \\
\text{Step 13} \quad i = i + 1 \\
\text{Step 14} \quad \text{end if} \\
\text{Step 15} \quad \text{end for}
\]
when freely flowing conditions prevail along the entire freeway corridor, the VSL is inactive (no speed information is displayed). Applying the method described above under this condition will always assign Scenario Type T.3, which belongs to the set SC for all observations, although, in reality, traffic was not harmonized. Therefore, trajectories that did not encounter any displayed VSL along their entire lengths are excluded from the analysis. Doing so ensures that the method focuses on assessing the system’s consistency only during relevant periods.

**CASE STUDY**

**Study Location and Data**

The study location (between the points marked “A” and “B” in Figure 6a) is primarily a three-lane southbound freeway (A 99) near Munich, with temporary hard shoulder running during peak periods. The corridor is equipped with a VSL system with dual inductive loop detectors that collect information on vehicle speed, flow, and occupancy. These data are aggregated at a 1-min resolution. Data on displayed speed limits, messages displayed to drivers, as well as information on hard shoulder lane usage are also logged. Data for the 4-month period from April to July 2012 were available for the study. Also available were data for 41 days (October 15 to 25 and November 1 to 30, 2003). Although the 2003 data are fairly dated relative to the 2012 data, and traffic characteristics might have changed, there is a motivation for their inclusion in the study. The advantage with the 2003 data is that on October 25 and November 1 to 10, 2003, the VSL system was not operating although traffic data were available. However, data for an “off” case is not available for 2012. The 2003 data made it possible to test the developed method for the “on” and “off” cases for 2003, which could not have been possible with the 2012 data. Also, whereas the 2012 data covered approximately 34 km with 25 detector stations, the 2003 data covered 16 km with 14 detector stations (Detector Numbers 060 to 235) in the southbound direction studied, as shown in Figure 6b.

**Evaluating Speed Variance in Synchronized Traffic**

For the “off” case, all available information was analyzed as it consisted of only 11 days of data. Moreover, data for 3 days for each of the 4 months in 2012 were randomly chosen and analyzed in detail. Twelve days of data were also randomly selected for 2003 when the VSL system was in operation. To convert the traffic stream composed of different vehicle types into an equivalent traffic stream, trucks and buses were converted into their passenger car equivalent or passenger car unit by multiplying by a factor of 3. The aggregated standard deviation speeds for all lanes were used. In this way, speed deviation across lanes (lateral speed harmonization) was measured. Traffic flows were averaged over all lanes (taking into account when the hard shoulder lane was either opened or closed) to obtain the flow per lane. The GT for flow and speed data was reconstructed as in Figures 1 and 2. Values for $q_{max}$ and $u_{max}$ of 600 vehicles/h/lane and 60 km/h, respectively, were used to identify the metastable traffic state regions. A sensitivity analysis was carried out on the flow threshold used in identifying the traffic state. Values experimented with included 800, 1,000, and 1,200 vehicles/h/lane. It was observed that the CV shrinks across the board as the traffic flow increases. The result of the sensitivity analysis is not presented in this paper. The CVs at detector stations in the metastable traffic state regions were analyzed and are presented in Table 1. Finally, Welch’s $t$-test was performed in MATLAB to test the significance of any observed changes in the CV at the 95% confidence level.

From the analysis, there was no statistically significant difference ($p = .231$) between the periods when the VSL system was “on” and when it was “off” in 2003; that is, the system had not substantially reduced speed deviations. Nissan noticed that the success of dynamic motorway traffic management depends to a large extent on how the drivers respond to the displayed VSL and their interaction with other vehicles (13). Failure of a system to effectively manage traffic may be the result of a high noncompliance rate. Riggins et al. studied the driver compliance level at the test location (A 99) (29). The study compared the displayed VSL with the GT speed measured by loop detectors. It was established that approximately 58% of the traffic on the corridor was moving above the displayed speed limits while the system was active. The high level of noncompliance with the displayed speed limits may partly explain why no significant difference was found between the “on” and “off” cases in 2003. Conversely, the study found a significant difference ($p < .001$) in the 2003 and 2012 results when the VSL system was on. There was also a marked difference ($p < .001$) in the “on” case in 2012 and the “off” case in 2003. However, this result cannot be attributed to the system as it might be the result of changes in the traffic characteristics resulting from the time difference or the result of recalibration or change in the implemented harmonization algorithm.

**Consistency Assessment**

Consistency was checked for 12 days for the 2012 data. The results of the case study are as presented in Table 2. From the evaluation, SCRs ranged from 90.1% to 100.0% with an average of 93.8%, which can be said to be good practically. However, the performance of the system can still be improved to ensure smooth harmonization at all times. Figure 7 shows the distribution of the scenario types encountered by drivers as they traverse the corridor. A total of 79% of all scenario types involved constant speed limits at consecutive gantries, gradual speed drops constituted 8%, and speed increments made up 7%. The roller coaster pattern wastes fuel, pollutes the environment, and is seen as an indicator of unsafe driving. Driving at a steady speed under such circumstances should be the aim. Rapid speed drops may also result in rear-end collisions when witnessed at the tail of queues.

**Speed Variance Versus Consistency**

A higher rate of successful consistency should imply a stronger harmonization. Therefore, the results from the speed differential and consistency analysis for the 2012 data were compared. From the assessment, no statistically valid relationship was established between the two methods. This finding may also be attributed to the level of driver compliance. A higher rate of successful consistency should result in a lower speed standard deviation if speed limits are obeyed. Data from other sites need to be analyzed to verify the relationship between the two methods.
FIGURE 6  Study location, A 99 near Munich: (a) site map and (b) schematic diagram.
In this paper, two methods for evaluating harmonization capabilities of VSL systems have been proposed. The methods were derived from the ability of the system to reduce the speed differential and the consistency in the displayed speed limits. Speed variance was evaluated by identifying metastable traffic conditions and determining whether the system has been able to minimize it. The deviation in speeds was measured with the coefficient of variation. Consistency was analyzed by tracking vehicles and observing the variations in the displayed speed limits as drivers traverse a route. This assessment was made possible by first reconstructing the traffic state and generating virtual trajectories. The paper categorized the various scenarios encountered by drivers and finally checked for consistency on the basis of successful and failed consistency rates.

The developed methods were applied to evaluate the VSL system on the A 99 near Munich. From the assessment, no statistically valid relationship was found between the two approaches. In future, data from other sites will be analyzed to confirm this result.

The speed differential method could be used to assess lateral speed harmonization. However, the consistency approach can be used to measure longitudinal speed harmonization. The consistency approach could also be used as a quick check in determining the potential of VSL systems to harmonize traffic flows, particularly in new installations.

**TABLE 1** Results of Coefficient of Variation

<table>
<thead>
<tr>
<th>Date in 2012</th>
<th>CV On</th>
<th>Date in 2003</th>
<th>CV On</th>
<th>Date in 2003</th>
<th>CV Off</th>
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<td>April 1</td>
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<td>Oct. 15</td>
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<td>Oct. 17</td>
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</tr>
<tr>
<td>May 22</td>
<td>9.7</td>
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</tr>
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Note: na = not applicable.

**TABLE 2** Rates of Successful Consistency on A 99 near Munich

<table>
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<th>Successful Consistency Rate (%)</th>
<th>Date in 2012</th>
<th>Successful Consistency Rate (%)</th>
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<tr>
<td>April 1</td>
<td>100.0</td>
<td>June 11</td>
<td>92.8</td>
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**REFERENCES**


The Standing Committee on Freeway Operations peer-reviewed this paper.