Driver Perceptions and Sources of User Dissatisfaction in the Implementation of Variable Speed Limit Systems

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ABSTRACT
This research explores technical innovation and the impact of resistance to innovation in the implementation of an active traffic management system. Technology-driven change initiatives are often difficult to implement and failure rates are high. Lack of success is often linked to failures in understanding the change environment or failure to account for human factors in the implementation of a new technology. This study explores stakeholder perceptions in the implementation of a variable speed limit (VSL) system in St. Louis, Missouri. Survey data from the driving public and law enforcement officials were analyzed during the first two years the VSL system was operational. High levels of dissatisfaction were present in survey results and indicated significant levels of resistance to innovation. Change management theory was used to link sources of dissatisfaction to common resistance factors. This provides an opportunity to develop strategies for the successful implementation of innovative traffic management systems. Decision makers involved with active traffic management will benefit from an understanding of the pervasive nature of resistance to innovation and an awareness of strategies for designing change management processes in innovative traffic systems.

Key Words: variable speed limit system, change management, resistance to innovation, intelligent transportation systems, active traffic management system
INTRODUCTION

This research investigates driver perceptions, sources of user dissatisfaction, and resistance to the implementation of an innovative traffic management system in St. Louis, Missouri. The study is part of a larger evaluation study of the effectiveness of Variable Speed Limit system (VSL), an Intelligent Transportation System (ITS) commissioned by the Missouri Department of Transportation (MoDOT). The benefits of ITS have been quantified in the literature (e.g., 1-4); however, user rejection or dissatisfaction in the deployment of new technology has not been studied. This research addresses this gap in the literature through a study of sample drivers from the Midwestern United States. Change management theory is used to link sources of dissatisfaction to common resistance factors and develop strategies for the successful implementation of innovative traffic management systems. The results from this study will provide transportation managers with an understanding of the nature of resistance to innovation and will provide strategies for designing change management processes into innovative traffic systems.

Overview of Variable Speed Limit Systems

VSL systems are designed to adjust the speed limit along a stretch of roadway as traffic conditions change. Widely employed in Germany, UK, and other parts of the European Union, VSLs have been used in the United States for several years on a limited basis. Multi-year evaluation of the VSL systems in Europe show a marked reduction in the number and severity of crashes (1) and are effective in a variety of roadway conditions ranging from the German autobahn (2) to the intersection of a highway with a secondary road in Finland (5).

Computer models suggest that the VSL system should be effective in reducing congestion in the United States as well (3, 4). Models developed indicate that, when implemented in a work zone, VSL can improve traffic flow (6) and greatly improve the effectiveness of ramp metering (7). However, gaps usually exist between computer predictions and implementation.

A study of a VSL system in a work zone in Michigan indicated only minor impacts on traffic flow, but did show a slightly higher average speed through the work zone when the VSL system was operational (8). It is difficult to generalize from one experiment, but Lyles et al. found that the results of a VSL in a work zone, while positive, were much less than predicted by simulation.

In reviewing the literature on the VSL system, no articles were found that discussed how drivers and other stakeholders felt about the concept or its implementation. Because cultures vary and U.S. drivers may react differently from European drivers, this facet should not be overlooked. Our study addresses this gap in the literature with a U.S. sample of drivers.

VSL System Performance

MoDOT installed a series of networked sensors along the I-270/I-255 corridor to evaluate the traffic conditions as part of the pre-planning efforts for the deployment of a VSL system. These sensors collected traffic variables such as speed, flow and occupancy at 30-second intervals. The data provided by these sensors were used to develop variable speed limit protocols designed to improve traffic safety and throughput. An extensive publicity campaign utilizing press releases, press conferences, updates to MoDOT websites, email updates to local subscribers, Twitter “tweets”, and YouTube videos was initiated prior to installation of the VSL in an attempt to inform people about how variable speed limits worked and the expected benefits (9). These efforts were aimed at the driving public and law enforcement officials in the metropolitan area.
In May 2008, MoDOT initiated signs on roadside shoulders and medians as a first step in implementing the VSL system. These ‘Variable Speed Limit’ signs were installed on the Missouri side of the I-270/I-255 corridor around St. Louis. During recurring and non-recurring congestion, an automated system with manual overrides set speed limits between a low of 40 mph and a high (“normal”) of 60 mph with increments/decrements of 5 mph using the various protocols developed during the pre-planning phase. Speeds were reduced upstream of congestion to regulate traffic and to reduce the speed of incoming traffic. The objectives of the VSL system were to improve traffic flow in order to prevent traffic flow breakdown, thereby reducing congestion and delay, and to improve traffic safety as a result of crashes with queued vehicles. The VSL corridor of operation is shown in Figure 1.

A two year research study (10) evaluated the VSL system performance and its potential benefits to users and MoDOT. The performance evaluation determined the effects of the VSL system on congestion and delay. Changes in travel time, travel time reliability, and capacity, and frequency of crashes were also investigated. The summary of results, categorized into mobility and safety, is presented below.

**Mobility**

The VSL system mobility evaluation used two forms of analysis (uncontrolled and controlled) to best understand the VSL system. Uncontrolled data analysis evaluated data reflecting real-world conditions faced by drivers during weekdays of interest (Tuesdays to Thursdays) irrespective of any incidents or weather conditions. Controlled analysis examined only days without incidents or weather conditions to better understand VSL operations under comparable pre-initiation (referred to as pre-VSL) and post-initiation (referred to as post-VSL) traffic flow conditions. The controlled analysis also provided guidance in refinement of the system. Both the uncontrolled and controlled analyses were carried out for four selected segments during peak periods on I-270.

Segment 1 was I-270 southbound approaching Manchester Road. Uncontrolled analysis indicated a 10% higher average volume in post-VSL conditions compared to pre-VSL conditions, indicating benefits in terms of higher traffic volume. When higher volume was observed during post-VSL conditions, congestion did not worsen. Controlled analysis indicated reduction in traffic congestion, indicating VSL system benefits for segment 1.

Segment 2 was I-270 northbound approaching I-44. Congested traffic conditions were observed during the morning peak period. The data analyzed for uncontrolled analysis found traffic flow to be higher by an average of 9% for post-VSL conditions. Average speed was lower by 4 mph and travel times longer by 13.6%. In addition, travel delay increased slightly but peak period duration remained unchanged. The VSL system, therefore, did not indicate benefits for particular measures of performance as a result of higher volume compared to pre-VSL conditions.

Segment 3 was I-270 eastbound and Segment 4 is I-270 westbound both approaching I-170. From both uncontrolled and controlled analysis, the VSL system was found to be marginally effective in reducing duration of peak periods and improving average speeds.
Effects of the VSL system on safety were evaluated based on crash frequency and crash rates. Assessment included annual and hourly crashes for highways in general and for specific segments. Two different analysis methods, Naïve and the Empirical Bayes (EB), were used to evaluate the effects of the VSL system.

The level of crash reduction varied slightly between the different statistical methods; however, the results consistently indicated the VSL system contributed to crash reduction. The level of crash reduction ranged from 4.5-8% (standard deviation of 3-4%). Based on crash rates, I-270 was the safest major roadway in the St. Louis region (10).

Crash data provided promising results; however, they require validation over the next few years to ensure that long-term benefits are sustainable. Crash reduction resulting from the VSL system was attributed to two major factors:

1. More homogenous traffic speed (i.e., smaller speed variance) reduced the chance of rear-end crashes (66% of the crashes reported on I-270).
2. Reducing the traffic speed (metering traffic flow) upstream of bottlenecks and other incidents improved driver awareness and attention; this may have reduced potential primary and secondary crashes.

Planning and Resistance to Innovation

In the United States, publicly funded transportation management systems such as VSLs are heavily dependent on stakeholders’ acceptance for success. These systems are forms of sociotechnical systems and can be analyzed using system heuristics and guidelines normally used for projects requiring significant stakeholder participation and ‘buy-in’. Sociotechnical systems
are defined as technical systems involving significant social participation, interests, and concerns (11). Stakeholders function as consumers, in this case assigning value to the VSL initiative, similar to that found with the introduction of new products. Value is often based more on perception than fact and a perceived value can adversely bias implementation results (11, 12).

This simplistic model of change does not adequately describe the level of resistance that many individuals experience with change to familiar products and experiences, especially innovative technologies (12-13). Resistance can stem from many sources including a disparity in what constitutes sufficient awareness of the benefits of the proposed change. The form of resistance varies according to the systemic culture and can include the passive form: ‘if you wait it out, it will eventually go away’ (14, 15).

A comprehensive analysis of resistance to innovation may prove useful in identifying potential areas of disconnect. Is it driven by internal or external factors? What are the goals for change and the best methodology for achieving the change? Individuals are far more resistant to change when it involves loss of control over long-standing patterns of behavior. Stakeholders frequently demonstrate resistance to change owing to feelings of uncertainty and threatened self-interests, or different perspectives. These intangibles can be offset by increased stakeholder participation levels in the planning and implementation phases (16, 17). The literature suggests that trust is one of the most critical factors in assuring acceptance of change (17, 18).

Resistance to technological innovation can be mapped to three main consumer reaction types: rejection, postponement and opposition (12). Briefly, rejection posits active resistance driven by consumer attitudes that an innovation will not work. Postponement refers to consumer lags in acceptance based on their desire for an innovation to be more fully tested. Opposition, the strongest form of resistance, is typically rooted in objections based on principles or values. Linkages of these patterns to the VSL implementation in St. Louis will be explored under ‘Discussion of Results’.

RESEARCH METHODS: SURVEY DESIGN

The research design for this study followed a mixed methods approach (19, 20) and builds on the similarities of quantitative and qualitative data analysis. For quantitative analysis, the research design used a formative analysis i.e. perception based quantitative data. The qualitative analysis used an in vivo analysis (e.g., 21) of drivers and law enforcement personnel answers to a reflective question regarding the system.

As part of the study design, stakeholder surveys were conducted to gauge the reaction to the VSL system. Stakeholders were defined for the research as the general public (GP) and law enforcement agency (LE) representatives. Separate surveys were developed for each group. Data regarding stakeholder perceptions of the effectiveness of the VSL system were collected and analyzed over the length of the study to frame the VSL operational results from the perspective of customer satisfaction. Survey questions focused on determining stakeholder opinions of the VSL system’s ability to impact congestion and safety, as well as the effectiveness of the system and the explanation of the system from MoDOT prior to implementation.

A continuous online survey was used to evaluate public perceptions. MoDOT encouraged drivers to complete the survey through press releases, email blasts, and by placing a link to the survey on several MoDOT webpages. The greatest challenge to using online surveys is in getting the general public to participate in terms of a representative sample with respect to the total population demographics or in terms of attitude. Respondents are self-selecting and often motivated to complete surveys because of strong beliefs, either pro or con, regarding an issue.
Sampling approximated area population demographics in terms of gender and income categories. Oversampling occurred with respect to Caucasian respondents when compared to population demographics. Caucasians represent 93% of respondents and comprise 72% of the St. Louis County population. African-Americans were under-sampled (3% response rate; 21% of the St. Louis County population). Limited controls were put in place to prevent respondents from completing the online survey multiple times. Respondents were asked whether they had completed the survey previously. Responses indicating ‘yes’ were not used for this analysis and those who had not used the stated route. The survey also captured the IP address of the respondents and the researchers reviewed these addresses to investigate any suspicious activity. A comment section was also available to capture qualitative assessment and allow the respondents to provide additional information and context not otherwise covered through the survey.

The opinions of 15 law enforcement agencies with enforcement responsibility for the VSL system were gathered through the use of a single-page, double-sided paper survey. During the project design phase, law enforcement personnel requested a paper survey, rather than an online version. Surveys were provided to law enforcement personnel twice during the study period; once at the beginning and again after 18 months. The survey design included a reflective assessment section to maximize the ability of law enforcement officials to provide relevant opinions. As with the online survey, this section allowed the capture of qualitative data. A standard five-point Likert scale (22) was used for both the online public and law enforcement surveys to measure levels of agreement. For this research, 1 = strongly disagree, 2 = slightly disagree, 3 = too soon to tell/no opinion, 4 = slightly agree, and 5 = strongly agree. The two surveys had common questions to provide opportunities for comparison, but also included some questions that were unique to the stakeholder group. For example, law enforcement respondents were asked to provide input regarding the level of enforcement effort required as a result of the VSL system as compared to pre-VSL corridor enforcement patterns. Online survey respondents totaled 1,030; whereas law enforcement respondents totaled 355. Questions were sorted to show comparative attitudes regarding the VSL’s impact on mobility (or congestion), safety, and satisfaction with implementation of the system.

DATA ANALYSIS
Since there was little to no change in opinion over time for both of the groups, the data gathered were combined. Common survey questions (dependent variables) were grouped in three major categories, perceived mobility, perceived safety and satisfaction with implementation of the VSL system (implementation satisfaction). Similar categories were used for both quantitative and qualitative analysis. Details of the analysis are presented in the following sections. The quantitative analysis clearly indicates significant levels of dissatisfaction. Qualitative analysis is used to put dissatisfaction in context and evaluate causality. The results are explained under Discussion of Results.

Quantitative Analysis
The concept of perceived mobility was based on questions regarding relieving congestion, uniformity in speed, as well as stop–and-go traffic conditions. The concept of perceived safety integrates safety in terms of respondents’ impression of reductions in crash frequency, stated compliance with the variable speed limit, and perceived overall improvement in traffic safety. Finally, the concept of implementation satisfaction represents perception in terms of likely
expansion of the system in the future to additional routes in Missouri, respondent opinions on how well the system was implemented on I-270, and subjective ratings on how well the system was explained to the public. For the three dependent variables, the internal reliability was measured using Cronbach’s alpha. The internal reliability was found to be strong for categories perceived mobility (0.88) and safety (0.77), respectively and reasonable (0.62) for perceived satisfaction with implementation of the system.

Table 1 presents the descriptive statistics for the three dependent variables. The mean value of all responses related to mobility was 1.67 (out of 5), indicating a high level of dissatisfaction from both drivers and law enforcement personnel. Similarly, a high level of dissatisfaction was observed for safety. A slightly better level was observed for system implementation.

### Table 1 Means and Standard Deviations for the Perceived Categories

<table>
<thead>
<tr>
<th>Groups</th>
<th>Mobility Mean</th>
<th>Mobility Std. Dev.</th>
<th>Safety Mean</th>
<th>Safety Std. Dev.</th>
<th>Implementation Satisfaction Mean</th>
<th>Implementation Satisfaction Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drivers</td>
<td>1.33</td>
<td>.549 (708)*</td>
<td>1.59</td>
<td>.614 (696)</td>
<td>2.10</td>
<td>.952 (691)</td>
</tr>
<tr>
<td>L. Enforcement</td>
<td>2.95</td>
<td>.816 (182)</td>
<td>2.97</td>
<td>.730 (183)</td>
<td>2.87</td>
<td>.808 (180)</td>
</tr>
<tr>
<td>Total</td>
<td>1.67</td>
<td>.896 (890)</td>
<td>1.88</td>
<td>.850 (879)</td>
<td>2.26</td>
<td>.975 (871)</td>
</tr>
</tbody>
</table>

* indicates the number of participants

### Analysis of Variance: Drivers and Law Enforcement Personnel

For perceived mobility, safety, and implementation satisfaction, the three categories used to measure drivers and law enforcement personnel perception related to the VSL system, results were analyzed using one-way ANOVA, between-group design. Table 2 summarizes the results of the three ANOVA analyses. The results show that the observed effect size was large (>0.14) for perceived impact on mobility and safety and well above mean (0.06) as recommended in the research literature (23). These analyses revealed a significant effect for all three categories with drivers having statistically significant lower means than law enforcement personnel (see also Table 1). That is, drivers perceived a lower impact of VSL system on improving mobility and safety and were less likely than the law enforcement personnel to be satisfied with the implementation of this system.

### Table 2 Analysis of Variance for Drivers and Law Enforcement Personnel Perception of Mobility, Safety and Implementation Satisfaction

<table>
<thead>
<tr>
<th>Variable</th>
<th>df</th>
<th>F</th>
<th>η²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility</td>
<td>1</td>
<td>1011.38*</td>
<td>0.53</td>
<td>0.99</td>
</tr>
<tr>
<td>Within Groups</td>
<td>888</td>
<td>(0.38)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>1</td>
<td>673.04*</td>
<td>0.43</td>
<td>0.99</td>
</tr>
<tr>
<td>Within Groups</td>
<td>877</td>
<td>(0.41)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impl. Satisfaction*</td>
<td>1</td>
<td>98.95*</td>
<td>0.10</td>
<td>0.99</td>
</tr>
<tr>
<td>Within Groups</td>
<td>869</td>
<td>(0.85)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Values in parentheses represent mean square errors.

*p < 0.05
Additional Analysis: Driving Public

As the driving public was significantly less satisfied with the VSL implementation than law enforcement personnel, additional analysis was performed. The three categories – perceived mobility, perceived safety, and perceived implementation satisfaction – were analyzed by age group, gender and income in an attempt to provide robustness and context for the qualitative analysis. To analyze the impact of age, the data collected with the surveys was grouped in four age groups, respectively 25 years and under, ages between 25 and 41 years, ages between 41 and 65 years, and older than 65 years. For perceived safety, the Tukey HSD (Honestly Significant Difference) test showed that the drivers in the age group 25 and younger (N = 62, M = 1.81) rated the VSL system significantly safer than the drivers in the age group 41 to 65 (N = 306, M = 1.55), p < 0.05. Although the analysis did not reveal a reason for this difference, it is possible the use of social media had a stronger impact on younger drivers and provided additional context needed to manage satisfaction levels for this group.

The results by gender and income (less than $40k, $40-60k, $60-90k, $90-120k, and $120k and higher) were also analyzed, but no statistically significant differences were found between the mean values of these groups.

Qualitative Analysis

Review of respondent comments from both the driving public and law enforcement points to significant resistance based on rejection models of innovation (12). Law enforcement respondents frequently remarked that the VSL is not designed for congestion relief, but for efforts surrounding non-recurrent congestion caused by weather, accidents, etc. The general driving consumer complained regularly that the VSL speeds were meaningless and not beneficial as a mechanism for altering behavior or impacting the commuter experience. These comments show a negative bias against the system. An in-vivo analysis of responses allowed mapping of comments to resistance causality. Respondents do not object to the VSL system based on moral or philosophical grounds, but rather on perceptions of low value (discussed further in the next paragraph) and return on investment. Respondents see limited need for the innovation and are dissatisfied with costs occurred in relationship to perceived benefits. Representative comments are presented in Table 3 which divides the comments by mobility, safety, implementation satisfaction, and enforcement.

<table>
<thead>
<tr>
<th>Category</th>
<th>General Public</th>
<th>Law Enforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility</td>
<td>I travel 270 every weekday morning around 645 am and again around 4pm. the variable speed has made zero difference, people still flow at the speed mostly of those around them. Slowing the speed limit had had no effect whatsoever.</td>
<td>Often times I see the suggested speed is 60 or 50 and yet we are bumper-to-bumper going 30 to 30 on I-270.</td>
</tr>
<tr>
<td>Category</td>
<td>General Public</td>
<td>Law Enforcement</td>
</tr>
<tr>
<td>----------</td>
<td>----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td></td>
<td><em>I think the variable message signs have had no impact on my daily commute. There are times that the VMB read 40 mph and everyone is traveling 60+ and other times that they read 60 mph and everyone is at a standstill.</em></td>
<td><em>I travel southbound I-270 during rush hour (PM). Since implementation, the stop and go traffic and overall delay has seemed to diminish.</em></td>
</tr>
<tr>
<td></td>
<td><em>The variable speed limit doesn't seem to make any difference at all - most of the time when the speed is set at 40 the max speed you are able to go is 20mph. This has not changed the gridlock on the roads during rush hour.</em></td>
<td><em>It just didn't work. Good effort, but I don't see anyone abiding by it.</em></td>
</tr>
<tr>
<td>Safety</td>
<td><em>Highways are designed for higher speeds and should remain that way. Also, it seems a bit dangerous when you have one car going 'slower' as the signs indicate, but the rest of the cars are still driving 60 mph, if not more.</em></td>
<td><em>The few accidents I have encountered on our 2 mile stretch of highway reveal to me that the drivers rarely know what the speed limit was according to the variable signage at the time of their impact.</em></td>
</tr>
<tr>
<td></td>
<td><em>The variable speed limits actually make me feel less safe on the road. When I comply with the lower speed limits during rush hour traffic, most other motorists still are going the 60mph limit, if not faster, and end up swerving and rapidly changing lanes to avoid running up on me and other cars going the slower speed limit.</em></td>
<td><em>Most drivers move with the flow of traffic as dictated by volume and conditions and are normally close to the posted speed limit. Problem drivers do not pay any attention to speed limits, whether they are variable or permanent.</em></td>
</tr>
<tr>
<td></td>
<td><em>(The variable speed limits sometimes seem to be more of a problem than a solution to the problem. Often drivers will slam on their brakes immediately when the speed changes causing others behind them to have to do the same. The 40mph speed limit is entirely too slow for highway driving.</em>)</td>
<td><em>(The system has not had the impact it was intended to. Vehicle accidents have not decreased. In fact, in my opinion, I believe I have taken more accident reports on the highway (interstate) than before the VSL was implemented.</em>)</td>
</tr>
<tr>
<td>Implementation Satisfaction</td>
<td><em>This was a completely moronic idea to start with. What an absolute waste of taxpayer money. I'm sure whoever came up with idea received huge bonuses and recognition. And you folks wonder why the taxpayers vote against additional taxes.</em></td>
<td><em>Plain and simple it does not work and wasted money.</em></td>
</tr>
<tr>
<td>Category</td>
<td>General Public</td>
<td>Law Enforcement</td>
</tr>
<tr>
<td>----------</td>
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</tr>
<tr>
<td></td>
<td>First, I view the variable speed limits project as a complete waste of budgetary money that would be put to better use if applied to bridge maintenance or general road repair. Money gripes aside - the variable speed limit signs are completely useless.</td>
<td>They have been a waste of taxpayer dollars. The benefit to cost ratio is very poor.</td>
</tr>
<tr>
<td></td>
<td>Variable speed limits are a bad idea. Somebody sitting at a desk changes the speed limit on a whim, and I'm suddenly a law-breaker? Why don't you change the direction of the lanes while you’re at it?</td>
<td>Variable speed limits on the interstates is one of the most bizarre expenses I have ever seen. I don’t believe the majority of the public see or pay attention to the signs at all.</td>
</tr>
<tr>
<td>Enforcement</td>
<td>They can't be enforced anyway.</td>
<td>Variable Speed Limits are virtually impossible to enforce. They only come into play in a) rush hour or b) incidents of traffic volume due to serious accidents. In neither case is there any practical means for enforcement action.</td>
</tr>
<tr>
<td></td>
<td>Stupidest thing I have ever experienced. Speed limits should remain consistent. Nothing but a revenue generator for the local municipalities. By the way - I have not received a citation from the variable speed limits - yet!</td>
<td>Speed changes during congestion is nearly impossible to enforce without adding to the problem.</td>
</tr>
<tr>
<td></td>
<td>Too many drivers are passing to the right side of ‘slower’ drivers. The variable speed limits need to be better enforced.</td>
<td>Enforcement is not practical nor warranted during circumstances when limits are reduced. Therefore it should be used as an ADVISORY warning and not as an enforcement strategy.</td>
</tr>
<tr>
<td></td>
<td>I agree with the notion that VSL's should help provide a more uniform traffic flow, but not enough enforcement has been taken to ensure that drivers actually slow down to conform to the lower limits. The presence of local police and/or state troopers needs to be more evident during the rush hours to enforce the set limits.</td>
<td>The variable speed limit is not enforceable within current state statutes. Speed limits are set by law, not at the whim of someone in the Traffic Management Center.</td>
</tr>
</tbody>
</table>
DISCUSSION OF RESULTS

High levels of dissatisfaction were clearly present based on survey results and indicated significant levels of resistance to innovation. Lack of success is often linked to failures in understanding the change environment or failure to account for human factors in the implementation of the new technology. Change means different things to different people; this makes the response of the driving public and law enforcement stakeholders difficult to determine. Proper levels of stakeholder participation must be included in change management plans (14, 15, 18, 24). Trust and cohesion issues must be properly managed. During ill-prepared change initiatives leadership teams frequently try to push unwilling users into the change rather than pulling them to the appropriate level with training and ongoing communication patterns (14, 15, 18, 24).

Based on the online survey results, the general public has a high level of dissatisfaction with the system and has serious reservations regarding its effectiveness. The vast majority also feels that it has not increased public safety, reduced stop and go traffic, created a uniform traveling speed, or increased driver compliance with the posted speed limits. An overwhelming majority feels that the VSL system should be eliminated and that it has not been well explained to the public despite high levels of awareness. The stakeholders’ desire to eliminate VSL is also strongly supported by driving public and law enforcement comments.

The question of value was an important issue for respondents. While many respondents did not understand the benefits of VSL, their comments showed a sophisticated understanding of money management including the concept of opportunity costs. Based on their understanding of funding considerations and possible transportation improvements, many people were quite upset that MoDOT had ‘wasted’ millions of dollars on VSL when other desired transportation improvements were not being funded. Even those who accepted the effectiveness of VSL questioned its relative value compared to other transportation needs. The in-vivo analysis clearly indicates the presence of antecedent states most commonly present in resistance to innovation (12). Respondents frequently commented on the mismatch between goals and the implementation of the change process. Many felt that the change environment had been poorly managed and that the technology, as implemented, provided few benefits when compared to the costs. The analysis did not provide insight on differing perceptions between age groups regarding improved safety from the VSL implementation and points the way for future work.

Context from previous innovative projects completed by MoDOT helps to eliminate the alternative hypotheses. The St. Louis area consists of a generally pro-MoDOT population. The same general population expressed high levels of satisfaction with how MoDOT conducted other projects in the same time period. For example, from March 2007 through December 2009, MoDOT oversaw a significant reconstruction of segments of I-64/US-40 in the same area (25) using highly innovative techniques and policies. Respondents were asked to indicate their level of satisfaction (or dissatisfaction) with eight different measures. In general, St. Louis area residents showed extremely high levels of satisfaction with the reconstruction of I-64. In other research, MoDOT commissioned an independent assessment of constituent responses to transportation improvements around the state for fiscal year 2010. Two of these projects were also from the St. Louis area, and the local constituents overwhelmingly (89.2% and 94.9%) thought those projects were the right transportation solution (26).

The results from consumer acceptance surveys on other projects make it unlikely that the negative attitude toward VSL was generated by any ill-will toward MoDOT or toward spending money on highway infrastructure. Stakeholder rejection of change did not result from mistrust
of MoDOT. On the contrary, MoDOT has established a large reserve of local trust, some of which may have been consumed by the VSL experience. The negative feelings measured by this research are based on the perceived failure of VSL and the belief that other transportation needs should have been given priority. Like the general public online survey respondents, law enforcement officers also gave largely negative responses to the survey questions regarding the VSL. The vast majority feels that it should be eliminated and not considered for expansion.

Further insights from the in vivo analysis point to the root cause of the resistance. Stakeholders display little interest in a ‘wait and see’ attitude (27). Perceptions of functional nonperformance of the VSL system have effectively negated opportunities for risk mitigation based on postponement. Resistance was rooted in opposition based on perceptions of ineffectiveness and of high opportunity costs. Ultimately, respondent resistance was based strongly in rejection of the innovation as a viable solution to congestion issues. In contrast to perceptions, the roadway data results (10) show improvements in safety statistics along the corridor, as well as slight improvements in mobility (congestion relief) in some segments of the interstate, although the VSL did not obtain the expected overall improvements in terms of increased mobility. Lack of compliance with posted VSL speeds was identified as an issue preventing maximum benefit from the VSL system. Resistance based on rejection can be overcome through change management policies that include strong connections to consumer learning. Strategies of risk reduction that include additional education of the VSL system and a match of VSL aims to actual roadway results may prove useful along with material that discusses both the financial and non-financial (e.g., time, fuel saved) benefits. Our findings suggest, from an operational and stakeholder acceptance framework, the VSL will increase its benefits by:

1. Improving public understanding through more educational efforts.
2. Improving operations by modifying current settings and examining the results to find the optimal settings.
3. Identifying and evaluating ways to show the value of VSL from an economic perspective.
4. Collaborating with law enforcement to find best ways to encourage respect for speed limits such as automated detection of non-compliant drivers.

It is also possible that future generations will have a different perspective on VSL. Drivers in the age group 25 and younger rated the VSL system significantly safer than the drivers in the age group 41 to 65. Our analysis did not provide any insight into this finding, but we hypothesize that the experience of this generation growing up with sophisticated electronics – i.e., high-definition video games (including realistic and fantasy driving simulations), smart phones, and the internet – may have had an impact. These drivers never knew a world where MapQuest and other electronic driving aids were not available. If this hypothesis is correct, VSL may be much more socially acceptable for future generations.

CONCLUSIONS AND IMPLICATIONS FOR TRANSPORTATION POLICYMAKERS

These results lay the foundation for considering traffic management systems as ‘new products’. As a result, lessons learned from the field of marketing should be useful in combating resistance to innovation on the part of the driving public. Based on the St. Louis experience, the marketing message should stress two points. The first point is the operational capabilities of VSL. The second point is the value of VSL. Some of the negative comments came from people who did not question the effectiveness of VSL, but were upset that ‘millions of dollars’ had been spent on such a ‘trivial’ or ‘unnecessary’ project when there were much more significant traffic needs that
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could have been addressed with those resources. Judging by the St. Louis experience, these two concerns must be addressed before the U.S. driving public will eagerly support VSL projects.

Strategic management of innovation resistance factors is crucial for success in innovative technology initiatives such as the St. Louis metropolitan area variable speed limit system. Trust and cohesion issues must be properly managed through the use of well-planned training or education initiatives (14, 15, 18, 24).

Consumers who fail to see the functional usefulness of a new technology due to inconsistent or incomplete communications regarding the value and functionality of a new system are highly likely to reject it. Managers involved in intelligent transportation systems must consider the perceptions of the user groups in addition to the technical aspects of the transportation management system. Thorough education programs must include attempts to engage the stakeholders in meaningful ways and provide context for approval of the change. While public trust may be a necessary factor for successful change implementation, it is clearly not sufficient in itself.

FUTURE RESEARCH

While beyond the scope of this study, future work should survey European drivers and law enforcement personnel to measure their perceptions of the effectiveness of variable speed limits. These perceptions should be matched to roadway data to determine areas requiring additional consumer education. Statistical analysis such as factor analysis or logit modeling may prove effective in defining key attributes of the change environment between respondent categories. The comparison of cultural dimensions to implementation results would cement the impact of cultural differences and attitudes on technology and innovation in congestion management. A comprehensive textual analysis of the residential and law enforcement comments may also provide new insights and statistical support for the insights gained from the comments as part of this research.

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