

Work zone items influencing driver speeds at roadworks: worker, driver and expert perspectives

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Abstract

Roadworks are essential to a safe and efficient road network, yet somewhat paradoxically the necessary work is often associated with increased risk to motorists and workers, as well as with traffic flow disruptions. A major source of increased crash risk at roadwork sites (work zones) is poor speed limit compliance. Speeding in work zones is examined in existing literature to the extent that major issues are known and some effective countermeasures are identified. However, as speeding remains a major problem in work zones, influences on driver behaviour arguably need to be better understood to achieve greater compliance and thus realise further gains in road safety. Current research on safety at Queensland roadwork sites has examined the views of workers, measured work zone speed profiles, and conducted an online survey of drivers (N=410). This paper focuses on survey participants' ratings of 12 specific work zone items (including traffic control measures) in terms of their influence on speed choice. Repeated measures ANOVA revealed statistically significant differences ($p < 0.001$) in the ratings of these items, with the most influential including visible presence of workers, visible police presence, and speed feedback displays. Those rated least influential included 'roadwork speed limits are enforced' and 'reduce speed' signs and increased fines for speeding in work zones. The paper considers the alignment of these findings with those from other sources, including worker interviews and the literature, to provide a consolidated assessment of the influence of work zone items on driver speeds.

Introduction

Vehicles travelling through work zones are hazardous to traffic controllers and others engaged in roadwork. In Australia as elsewhere, unacceptable numbers of workers and road users alike continue to be killed or seriously injured as a direct result of work zone crashes. While it is difficult to quantify these incidents in Australia due to poor data availability and quality, in other highly motorised countries work zone crashes contribute to approximately 2% of work-related fatalities and 2% of road deaths (Pegula, 2004; SWOV, 2010). A recently revised estimate based on New South Wales crash data¹ suggests that more than 22 fatal work zone crashes occur nationally each year, with at least several hundred further crashes resulting in injury to workers or motorists.

Excessive and differential speeds are a major contributing factor in work zone crashes. Despite considerable efforts over many years to improve work zone speed limit compliance, non-compliance remains a typical characteristic of work zone public traffic. Many factors are known to influence driver speed choice in work zones, including driver and vehicle characteristics, safety measures used (or not used), environmental conditions and other work zone characteristics. However, relatively little research has focused on driver perceptions and motivations regarding work zone speed choice. As speeding remains a major problem at

¹ 1.7% of fatal NSW crashes occurred at roadworks/detour/diversion in the 6 years from 2007-2012. Nationally over this period, 1.7% of the average number of fatal crashes annually (n=1281) is 22 crashes.

roadwork sites, influences on driver behaviour arguably need to be better understood to achieve greater compliance and to thus realise further gains in road safety.

Objectives

The current study examines results of a driver survey on the perceived influence of a range of work zone items on speed choice. Of the 12 work zone items included in the relevant survey question, some were deliberate speed reduction measures, some were safety measures not targeting speed reduction specifically, while some were incidental work zone characteristics, including visible worker activity. The responses of drivers were compared with findings reported in the literature, and with the views of workers interviewed and surveyed in previous research. The extent of agreement among these three sources underlies discussion around the influence of different work zone features on speed choice according to multiple perspectives.

Background

Work zone crash risk and prevalence of speeding

Two of the main contributing factors in work zone crashes are excessive and differential speeds. Studies demonstrating the contribution of speeding to work zone crashes are numerous, including those identified in Garber and Patel (1995). Discussing the speed-crash rate relationship more recently, Chen and Tarko (2012) noted that work zone crash rates increase not only with higher speeds but also with greater speed variance. Additionally, as is the case on all roadways, work zone crash severity generally increases with higher speeds. Work zone safety efforts therefore rely largely on encouraging lower speeds to (a) prevent crashes and (b) minimise crash severity. Driver inattention is an important related factor, as failure to notice signs and other traffic controls may lead to noncompliance with the work zone speed limits (Arnold Jr, 2003; Bai & Li, 2011; Debnath, Blackman, & Haworth, 2013).

Research findings vary on the extent to which speeding contributes to work zone crashes, but US studies suggest that speed has historically been a factor in 7-42% of work zone crashes (Brewer, Pesti, & Schneider, 2006; Daniel, Dixon, & Jared, 2000). More recently, Bai and Li (2011) reported that speed contributed to 25% and 16% of fatal and non-fatal work zone injury crashes respectively in Kansas. Comparable data are elusive for Australasia, but according to Allpress and Leland Jr. (2010) excessive speed contributed to 23 fatalities and 413 injuries in 632 reported crashes in New Zealand work zones from 2003-2007.

Low compliance with work zone speed limits, both in Australia and internationally, is well documented in the literature. Recent observation and analysis of vehicle speeds in Queensland work zones (Debnath, Blackman, & Haworth, 2014b) revealed that the majority of vehicles across three sites exceeded posted speed limits by at least 5 km/h. At one of these sites, in the absence of a pilot car which was used intermittently, almost all vehicles (98%) were speeding when entering the activity area, with 31% exceeding the limit by at least 15 km/h (Debnath, Blackman, & Haworth, 2014a). In other Australian research, Haworth et al. (2002) found that more than 70% of trucks and more than 40% of cars exceeded signed speed limits in Victorian work zones. In an earlier Victorian study (VicRoads, 1990) over 60% of drivers exceeded a 60 km/h work zone speed limit, with 10% doing so by more than 15 km/h. Similarly low rates of compliance are consistently reported in other countries, including New Zealand (Allpress & Leland Jr, 2010), the US (Joerger, 2010) and China (Jun, Peng, & Li, 2014), among others. The literature is thus conclusive on the high prevalence of speeding in work zones, as well as on the contribution of this phenomenon to serious and fatal work zone

crashes. However, the factors that influence work zone speed choice are less well understood despite considerable research efforts.

Influences on work zone speed choice

Previous research has considered many potential influences on work zone speed choice, including numerous safety measures, vehicle and driver characteristics, work zone configuration and other conditions. A review of the effectiveness of common work zone speed control measures recently conducted by the current authors (Debnath, Blackman, & Haworth, 2012) looked at four categories of speed reduction measures: informational, physical (including perceptual), enforcement (including perceived) and educational. Of these, enforcement measures, particularly with visible police presence, were deemed most effective in improving work zone speed limit compliance. Huebschman et al. (2003) and Joerger (2010) respectively reported that speed cameras resulted in a 19% and 27% reduction in average work zone speeds. In a survey of Queensland drivers, 85% of participants reported that police presence encourages them to reduce speeds (TMR, 2009). Police presence appeared at least as effective as 'potential to injure a roadworker', indicated by 82% of respondents as a factor that would encourage speed reduction. These results suggest that the perceived risk of attracting a penalty may be just as influential as the potential to cause injury to a worker in encouraging speed limit compliance.

Debnath et al. (2012) found mixed results for physical and informational measures, with their effectiveness often dependent on the type of work zone (long term or temporary/transient, rural or urban, for example) and the specific type of measure (static signage vs. VMS as an informational measure, for example). Speed feedback displays on electronic variable message signs (VMS), which display to drivers their speed on approach, appear relatively effective (compared with static signage) for speed reduction according to some research (Fontaine, Carlson, & Hawkins Jr., 2000; Maze, Kamyab, & Schrock, 2000; Meyer, 2000), particularly when used in conjunction with police presence, but their effects may be spatially and temporally limited (Meyer, 2004). While standard speed limit signs and to a lesser extent advanced warning signs have some effect in reducing speeds, their influence is less than that of visible police presence and speed feedback VMS.

The potential of educational measures was noted, particularly when used to complement other measures, but their actual effectiveness in terms of work zone speed reduction could not be determined due largely to the lack of objective and reliable evaluations. One speed control measure not covered in the above review, and which does not fit neatly in any of the four categories above, is use of a pilot car to escort public traffic through the work area at an appropriate speed. This measure was recently found to be highly effective in controlling work zone speeds (Debnath et al., 2014a). Unfortunately, however, pilot car deployment is only suitable and practical in a limited range of work zone situations.

Some work zone safety research notes the importance of the relationship between driver perceptions and behaviour. In many cases drivers appear relatively unresponsive to reduced speed limits unless they actually perceive a high risk of adverse consequences (collision or penalty for example) and, subsequently, a need to slow down in the work zone (Brewer et al., 2006; Haworth, Symmons, & Mulvihill, 2002). In this sense, warnings and advisory signs may be somewhat unconvincing, particularly for drivers with experience of apparently inactive work zones, if they are ambiguous in terms of identifying specific hazards.

The current authors recently examined the influence of visible work activity on work zone speed choice, through analysis of speed choice in relation to two scenarios which were presented photographically in the online Driver Experience of Roadwork Survey (Blackman, Debnath, & Haworth, 2014). With survey participants unaware of the posted speed limit (60 km/h) in these scenarios, the study found that self-nominated speeds were 22% lower in the scenario with workers present than in the scenario with no visible work activity. This result is consistent with other research cited above, demonstrating that perception of specific hazards motivates speed reduction and compliance more than general hazard warnings and signage.

Method

The current paper draws on results from a specific set of items within the Driver Experience of Roadwork Survey, which was administered online for 17 weeks from 8th October 2013. The survey was designed to investigate factors influencing driver behaviour, including speed choice, in Queensland work zones. This section describes sample recruitment, followed by participant characteristics and the methods of analysis used for the study.

Recruitment

Selection criteria for the survey required that participants were Queensland residents, held a current Queensland driver licence, had driven at least weekly in the last 12 months and had not been employed directly in road construction, maintenance and/or traffic control. Participants were recruited using a range of strategies, including through the Centre for Accident Research and Road Safety's (CARRS-Q) Independent Survey Panel in Road Safety (InSPiRS). At the time of the survey launch the InSPiRS Panel consisted of approximately 850 members of the public who had previously agreed to participate in CARRS-Q research. There were 373 panel members who met the criteria for participation and were subsequently invited to complete the survey. Participants outside of the Panel were recruited through advertising on the CARRS-Q website, group email distribution, radio interviews, newspaper coverage, and snowballing techniques. Mainstream media were alerted to the survey by two media releases on the project prepared by the university's media department.

Participants

A total of 410 participants completed or partially completed the survey, including 99 InSPiRS panel members and 311 members of the general public. Age and/or gender were not reported by 7 participants. Among the remaining 403 participants, 53.8% were males and 46.2% were females. Proportional to Queensland licence holders (TMR, 2013), younger drivers (<25) were somewhat underrepresented in the survey sample (5.7% vs 13.1%), drivers 25 - 59 years slightly overrepresented (71.5% vs 64.2%) and older drivers (60+) represented proportionally (22.8% vs 22.7%). Place of residence (postcode) was provided by 64.3% of participants, by which an approximate estimation of geographic distribution was calculated. Based on this estimation the sample appears roughly representative of the Queensland population according to census data in Australian Statistical Geography Standard (ASGS) categories (Major Cities; Inner Regional; Outer Regional; Remote and Very Remote), though Outer Regional residents appear slightly overrepresented (22.4% vs 14.7%) (ABS, 2013). In terms of income distribution, lower income households (<\$50,000 pa) appear underrepresented compared with the Queensland population (16% vs 42%), while higher income households (≥\$100,000 pa) were overrepresented (47% vs 28%). The survey sample had a lower proportion of single person households than the Queensland population (10.4% vs. 22.8%) and a higher

proportion of 2 person households (47.0% vs. 35.6%), while 3-6 person households were proportionally represented (42.6% vs. 41.6%) (ABS, 2013).

Method of analysis

Analysis focused on survey participants' rating of 12 specific work zone items in terms of their influence on speed choice. Participants answered the survey question ('how likely are the following items to affect your speed at roadworks?') on a five point scale for each item in random order (see Appendix). It should be noted that the question did not seek to determine an influence in any particular direction, although a speed reduction influence was implied by most of the items. The 12 items were selected for inclusion based on their relevance to the local context and the work zone safety literature. As far as items which were specific safety measures, they were deemed to be of local relevance if they had been used in Queensland work zones or if drivers could be expected to be familiar with their use in another context (increased fines and double demerit points during holiday periods, for example).

The 12 items were classified into four categories: Regulatory/enforcement items; Informational items; Visibility/conspicuity items; and Physical items. The categories were selected on the basis of the literature, in which most of these items have previously been discussed in similar groupings (see Debnath et al., 2012 for example). Four of the 12 were Regulatory/enforcement items: reduced speed limits; visible police presence; increased fines for speeding; and double demerit points for speeding. Three items were Informational measures to encourage lower speeds and improve compliance: speed feedback displays (VMS); static 'Reduce Speed' signs; and 'Roadwork Speed Limits are Enforced' signs. Three further items were Physical work zone features; the presence of workers on road; the presence of workers behind barriers; and traffic cones. The remaining two items were Visibility/conspicuity items: flashing amber lights; and high visibility clothing. While one of the 12 items, 'Roadwork Speed Limits are Enforced' signs, is related to enforcement, it is not an enforcement measure as such and was therefore included as an informational item.

After excluding invalid cases from the total 410 survey responses, 389 valid cases were available for analysis. A repeated measures analysis of variance (ANOVA) was used to identify if there was a statistically significant difference in the mean reported likelihood of items to influence drivers' work zone speeds. Post hoc analysis was conducted to determine where the differences lay. A Likert-type scale of 1 (highly unlikely) to 5 (highly likely) was used to derive the mean scores which were then ranked from highest (most likely) to lowest (least likely). Repeated measures ANOVA is sufficiently robust to overcome potential violations of the assumption of normal distribution, as maybe observed in the current data.

Results and discussion

Table 1 summarises the results of the repeated measures ANOVA, which found a statistically significant difference in the rating of the 12 work zone items, $F(11, 378) = 63.76$, $p < 0.001$. Mauchly's test of sphericity was statistically significant ($p < 0.001$), indicating violation of the assumption of sphericity, and the more conservative Greenhouse-Geisser test was therefore used. Post hoc analysis was conducted using a Bonferroni correction to determine the location of significant differences among individual items. Statistically significant differences can be seen between the mean scores of the highest and lowest ranked items and most other items, while among the middle-ranked items (4-8) there were fewer differences.

Of the five items mostly likely to influence work zone speeds, two were Physical items which were not deliberate measures intended to encourage compliance or otherwise improve safety. Of the other three top ranked items, one was a Regulatory/enforcement item, one an Informational item and one a Visibility/conspicuity item. The presence of workers on road was rated most likely of the 12 items to influence driver speeds. The earlier finding in Blackman et al. (2014) that self-nominated speeds were 22% lower in the survey scenario with workers present than in the scenario with no visible work activity supports this current finding. Using these two separate measures in the survey, it appears that drivers may be most likely to slow down in the presence of workers on road, and to slow down by a substantial amount, when compared with their reaction to other items. As a speed reduction of this magnitude is substantial in before and after studies of work zone safety measures (most measures achieve smaller reductions), arguably the ranking of items is reliable in the current analysis. Additionally, even the presence of workers behind barriers was reported to be more likely than several specific speed reduction measures to influence their choice of speed.

Table 1. Likelihood of work zone feature to affect driver speed

Rank	Work zone item	Item category	Mean	SD	No sig diff with rank#
1	Presence of workers on road	Physical	4.59	.62	2
2	Visible police presence	Regulatory/Enforcement	4.51	.87	1
3	Speed feedback displays (VMS)	Informational	4.17	.92	4,5
4	High visibility clothing for workers	Visibility/Conspicuity	4.04	.89	3,5,6,7,8
5	Presence of workers behind barriers	Physical	4.00	.92	3,4,6,7,8,10
6	Reduced speed limits	Regulatory/Enforcement	3.98	.95	4,5,7,8,10
7	Flashing amber lights	Visibility/Conspicuity	3.96	.93	4,5,6,8,10
8	Double demerit points for speeding	Regulatory/Enforcement	3.88	1.2	2,3,6,7,12
9	'Reduce Speed' signs	Informational	3.771	.94	8,10,11
10	Increased fines for speeding in work zones	Regulatory/Enforcement	3.769	1.21	5,6,7,9,11
11	'Roadwork Speed Limits are Enforced' signs	Informational	3.59	1.10	9,10,12
12	Traffic cones	Physical	3.53	.94	11

Items rated on scale of 1 (Highly unlikely) to 5 (Highly likely)

Visible police presence was the second most likely item to influence driver speeds, with a statistically significant difference between this and all other items except the presence of workers on road. With enforcement and perceived enforcement (e.g. visible police presence) deemed in the literature and by workers to be the most effective measure to improve work zone speed limit compliance (Arnold Jr, 2003; Huebschman et al., 2003; Joerger, 2010; Debnath et al., 2013), this finding could arguably be expected. Importantly, however, it suggests that a perceived high risk of penalties is roughly as likely to influence speeds as the presence of workers on road or the 'potential to injure a roadworker' (TMR, 2009). It is worth noting here that police presence is most likely to occur at work zones when workers are also present, so the effect of perceived enforcement, as with the effect of other safety measures, should not be considered in isolation. With the low rating of increased fines and double demerit points for speeding, the perceived risk of apprehension also appears more influential than the threat of higher penalties. This finding is also supported by the literature (Lindly, Noorjahan, & Hill, 2002; Ullman, Carlson, & Trout, 2000) and by workers interviewed as part of the current project (Debnath et al., 2013).

Speed feedback systems have received positive formal evaluations and were noted favourably by some of the workers interviewed in Debnath et al. (2013). However, as noted above, such systems may be most effective when used in conjunction with other measures such as enforcement (Fontaine et al., 2000; Maze et al., 2000) and their effects can be limited both spatially and temporally (Debnath et al., 2012). This was the highest rated item in the Informational category, in which the other two items were traditional static advisory and warning signs as opposed to VMS. Although drivers are able to determine their speed approximately through vehicle instruments, it is possible that an interaction with external technology appeals to drivers such that they are more inclined to comply with speed limits than they would be without the interaction. For instance, drivers may appreciate the opportunity to test their speedometer against the reading of the VMS (which is likely to be perceived as accurate). Noted in the literature, however, is a possible novelty effect associated with this measure (Meyer, 2004), which is currently only deployed at a minority of sites in the study area (hence the 'novelty' effect may be expressed in participant responses).

The relatively low influence of static signage in the current study is unsurprising in light of the literature (Debnath et al., 2012; Haworth et al., 2002). In interviews with roadworkers in Queensland (Debnath et al. 2103), 61% of participants reported that most drivers violate work zone speed limits, after either ignoring or not noticing the speed reduction signage. While various forms of distraction reportedly play a part in drivers' failure to notice signage according to workers, the current study findings suggest that drivers who do notice static signs are only moderately likely at best to respond appropriately. Reduced speed limits in themselves were only moderately likely to influence driver speeds according to survey participants. The implication of this result, confirming the work zone safety literature (Debnath et al., 2012) and the views of workers interviewed (Debnath et al., 2013), is that additional measures are required to encourage compliance. Work zone speed limits are often not deemed credible by drivers, for reasons mentioned above in regard to the influence of workers on road, behind barriers, or the absence of any visible activity.

Increased fines for speeding in work zones were perceived by survey participants to have a low to moderate effect on work zone speed choice. While few studies have attempted to evaluate this speed reduction measure, increased fines for speeding in Texas work zones were found to have little effect on driver speeds (Ullman et al., 2000). The influence of double demerit points for speeding in work zones was rated only slightly higher than that of increased fines. To the knowledge of the authors there are no published evaluations of the effect of double demerit points for speeding in work zones. The lowest rated Informational item was 'Roadwork Speed Limits are Enforced' signs. The low rating of this item – second lowest only to traffic cones – suggests that this threat of enforcement does not convey sufficient perceived risk in the absence of visible police presence. In other words, the message does not appear to be perceived as credible as active work zone speed limit enforcement may be only rarely (if ever) encountered by drivers.

The visibility and conspicuity items (Category 3) (high visibility clothing for workers and flashing amber lights), which were not measures to encourage lower speeds as such, were similarly rated as moderately likely to influence driver speeds in their influence on driver speeds. In a survey of VicRoads staff who worked on roadways, high visibility clothing (safety vests) was reported by more than 90% of participants to improve worker safety greatly (57.5%) or somewhat (34.1%), with a mean rank of effectiveness of 3.9 on a scale of 1 (least effective) to 7 (most effective) (Haworth et al., 2002). While this indicates that safety vests are valued by workers for making them more noticeable, the survey did not specifically

ask participants how high visibility clothing may influence driver speeds. Nonetheless, it is plausible that safety vests contribute somewhat to lower speeds as they may attract attention to workers who would otherwise be unnoticed by motorists in some situations.

Moderately rated in the current survey, flashing lights have been found to be somewhat effective in reducing speeds according to the literature (Arnold Jr, 2003; Li & Bai, 2009), although amber lights alone may be less effective than other colours or combinations of colours (Ullman, 2000). Most of the research evaluating flashing lights considers the use of such devices in combination with other measures such as enforcement, so it is difficult to determine their effects in isolation for comparison with the survey findings. It is likely, however, that drivers may perceive flashing lights as an indication of probable worker activity, which may influence some speed reduction prior to a driver actually seeing workers.

Traffic cones were the lowest rated of all items. There was a statistically significant difference between the mean score for traffic cones and all other items, except 'Roadwork Speed Limits are Enforced' signs. The relatively low influence of traffic cones may be expected as their primary purpose is to provide guidance rather than to draw attention to a specific hazard. They were rated as a moderately effective safety device (mean rating of 4 on a scale of 1 to 5) in the survey of workers by Haworth et al. (2002).

A comparison of the influence of each work zone item according to drivers, workers and the research literature, where applicable, is summarised in Table 2. The sources appear largely in agreement that the most influential of the 12 work zone items are the presence of workers on road, visible police presence and speed feedback displays (workers interviewed by the authors did not comment explicitly on the influence of their presence on driver speeds). Through the driver survey, the current study highlights the importance of drivers perceiving an immediate risk to motivate speed limit compliance, in the form of enforcement, potential collision, or injury. While this point is acknowledged in some of the research literature, it has generally received little emphasis.

Table 2. Effect of work zone feature on driver speed according to information sources

Work zone item	Drivers	Workers	Literature
Presence of workers on road	High	NA	High
Visible police presence	High	High	High
Speed feedback displays (VMS)	Moderate-High	High*	High*
High visibility clothing for workers	Moderate	NA	NA
Presence of workers behind barriers	Moderate	NA	NA
Reduced speed limits	Moderate	Moderate	Moderate*
Flashing amber lights	Moderate	Moderate	Moderate*
Double demerit points for speeding	Moderate	NA	NA
'Reduce Speed' signs	Moderate-Low	Low	Low*
Increased fines for speeding in work zones	Moderate-Low	Moderate-Low	Low
'Roadwork Speed Limits are Enforced' signs	Low	NA	NA
Traffic cones	Low	NA	NA

*most effective when used in conjunction with other measures

Conclusion

The current study compared findings from a driver survey with the published literature and the views of workers on factors influencing speed choice in work zones. The items rated most influential by survey participants were also those found most effective according to the literature and, to a limited extent, workers. The presence of workers and their visibility are key factors in the speed choice of drivers traversing work zones. Although acknowledged in the research literature, this point has arguably been underemphasised and may not be readily recognised by workers themselves. The next key factor according to the current study relates to the perceived risk of speed limit enforcement, with police presence indicated by all sources to be a highly effective speed control measure. Unfortunately, resources constraints severely limit police presence in work zones, while measures such as static warning signs, threats of increased fines and double demerit points have so far had little influence. The research suggests that in order to further improve work zone speed limit compliance it is important that drivers clearly see worker activity as often as possible when passing through work zones.

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Appendix

Screenshot of online survey question and items

1. How likely are the following items to affect your speed at roadworks?

	Highly unlikely	Unlikely	Neutral	Likely	Highly likely
Traffic cones	<input type="radio"/>				
Double demerit points for speeding in roadwork zones	<input type="radio"/>				
'Reduce Speed' signs	<input type="radio"/>				
Increased fines for speeding in roadwork zones	<input type="radio"/>				
Flashing amber lights	<input type="radio"/>				
Presence of workers on road	<input type="radio"/>				
Reduced speed limits	<input type="radio"/>				
'Roadwork Speed Limits are Enforced' signs	<input type="radio"/>				
Presence of workers behind barriers	<input type="radio"/>				
Visible police presence	<input type="radio"/>				
Speed feedback displays (electronic variable message sign)	<input type="radio"/>				
High visibility uniforms for workers	<input type="radio"/>				