

*This is an Accepted Manuscript of the following article:
Steinbakk, R. T., Ulleberg, P., Sagberg, F., Fostervold, K. I.
Effects of roadwork characteristics and drivers' individual
differences on speed preferences in a rural work zone.
Accident Analysis and Prevention. 132 (105263), 2019 ISSN
The article has been published in final form by Elsevier at
<http://dx.doi.org/10.1016/j.aap.2019.105263> © 2019.
This manuscript version is made available under the
CC-BY-NC-ND 4.0 license
<http://creativecommons.org/licenses/by-nc-nd/4.0/>
It is recommended to use the published version for citation.*

Title: Effects of roadwork characteristics and drivers' individual differences on speed preferences in a rural work zone

Authors:

Renata Torquato Steinbakk*

Department of Psychology, University of Oslo, Forskningsveien 3A, 0373, Oslo, Norway

Norwegian Public Roads Administration, Brynsengfaret 6A, 0667, Oslo, Norway

renata.steinbakk@vegvesen.no

Pål Ulleberg

Department of Psychology, University of Oslo, Forskningsveien 3A, 0373, Oslo, Norway

pal.ulleberg@psykologi.uio.no

Fridulv Sagberg

Institute of Transport Economics, Oslo, Norway, Gaustadalléen 21, 0349, Oslo, Norway

fs@toi.no

Knut Inge Fostervold

Department of Psychology, University of Oslo, Forskningsveien 3A, 0373, Oslo, Norway

k.i.fostervold@psykologi.uio.no

*Corresponding author:

Norwegian Public Roads Administration

Brynsengfaret 6A, 0667

Oslo, Norway

Phone: +47 48281647

Highlights

- Drivers had a high variation on speed preference in a work zone.
- Preferred speeds increased with age, higher scores in normlessness trait and self-assessment of driving skills.
- Higher speeds were preferred in work zones' areas with clear centre road marking, while lower speeds were preferred when road delineator and roadside barriers were present.
- Work zones should provide enough situational cues to the drivers to indicate the desired behaviour in order to lessen the impact of the driver's personality on speed preference.

Title: Effects of roadwork characteristics and drivers' individual differences on speed preferences in a rural work zone

Abstract:

Work zone safety from a psychological perspective has received little attention in scientific literature. Therefore, the present study aims to explore the influence of roadwork characteristics and drivers' individual differences in terms of personality traits and self-assessment of driving skills on speed preferences in a rural work zone. Eight hundred forty-five Norwegian drivers stated their preferred speed for ten pictures of a rural work zone with a 50 km/h reduced speed limit without knowing the speed limit. The results showed that the preferred speeds were greater than the actual reduced speed limit for all pictures. The standard deviations were quite high (from 11 to 14 km/h), indicating that drivers have a rather high variation in preferred speeds. A multilevel model was used to analyse the effects of the variables on speed preference. The results indicated that preferred speeds increased with age, higher scores on the normlessness scale, and higher self-assessment of own driving skills. As for the roadwork characteristics, speed increased with the presence of road markings by 11 km/h, while it decreased by 9 km/h with the presence of road delineators and by 5 km/h with barriers. Implications for respect for the reduced speed limits in work zones were discussed, and recommendations of other countermeasures were presented.

Keywords: Roadwork, speed preferences, self-assessment of driving skills, personality traits

1. Introduction

Speed is an important risk factor when it comes to traffic safety. It is well established in the literature that high speed increases the probability of a crash and intensifies injury severity (Aarts & van Schagen, 2006; Elander, West & French, 1993; Elvik, 2013). The same issue applies to safety in work zones, in which a high number of speed violations and wide speed variance represent the main risk factors (Advanced Research on Road Work Zone Safety Standards in Europe Consortium [ARROWS], 1998; Akepati & Dissanayake, 2011; Bai, Finger & Li, 2010; Silverstein, Schorr & Hamdar, 2014). Crash severity in work zones was also found to be higher compared to other roads (Høye et al., 2015; Qi et al., 2013; Wang et al., 1996). Since high speeds are a considerable issue concerning work zone safety, it is valuable to obtain a deeper understanding of how different factors may affect driving speed.

1.1. *Speed choice and speed limit credibility in work zones*

Drivers' speed choice is not always an objective rational decision. As pointed out by Elvik (2010), drivers tend to ignore the environmental impacts of speed, perceive incorrectly the relationship between speed and travel time, and underestimate the increase in risks associated with increased speeds. Elvik furthermore argued that if posted speed limits did not exist, mean

speeds would be higher due to the wide spectrum of drivers' speed preferences. According to him, the lack of objective rationality in drivers' speed choices is a strong argument for the use of posted speed limits to guide and regulate this choice. Posted speed limits are thus an important traffic safety measure, as they stipulate the highest safe speed for a road section for all drivers, independently of their speed preferences.

However, disregard for traffic signs, particularly speed limits signs, was a risk behaviour found to be associated with severe crashes in work zones (Li & Bai, 2009). Several studies on speed choice in work zones demonstrated that most drivers **drove at** speeds over the posted speed limits (e.g. Bai et al., 2010; Debnath, Blackman & Haworth, 2014; Debnath, Blackman & Haworth, 2015; Domenichini et al., 2017; Finley, Jenkins & McAvoy, 2015; Ullman & Brewer, 2014; Rahman et al., 2017). One explanation of why speed limit compliance is so low in work zones is that drivers only adapt their speed when they see a reason for it. Summala and Hietamäki (1984) argued that sign compliance is a matter of motivation, with drivers relying more often on their own experience, expectations, and context than on traffic signs when adapting their driving behaviours. This assumption is supported by many studies, which have demonstrated that drivers were more compliant with posted speed limits near work activity areas at which roadworkers, machinery and work activity are often present (Benekohal, Wang, Orloski & Kastel, 1992; Benekohal & Wang, 1994; Debnath et al., 2014; Finley et al., 2015; Paolo & Sar, 2012). Additionally, the reduced speed limits in short-term work zones seem to be more effective compared to speed limits in long-term work zones (Hou, Edara & Sun, 2011). The authors suggested that since short-term work zones are shorter in duration, drivers are more likely to see roadworkers present at the area and are therefore more motivated to comply with the posted speed limits. Yet, it is necessary to mention that even though speed reductions were more often observed in situations in which the speed limits were more credible (i.e., near roadwork activity), an increase in speed variance was nevertheless also observed (Debnath et al., 2014; Finley et al., 2015), which may be due to drivers' different reactions to traffic signs and work zone elements. One example of how drivers react differently in the same situation can be seen in a field study conducted by Benekohal et al. (1992) in which the speed profile patterns of drivers in one work zone were observed. The results showed that about 26% of drivers reduced their speeds after passing the first speed limit sign but increased their speeds before reaching the work activity area, then again slowed down when arriving at the work activity area. Eleven percent of all drivers travelled faster than the posted speed limit when passing the first sign but slowed down when arriving at the work activity area. Only 12% reduced their speeds after passing the first signs and kept their speeds until they had passed the

entire work area. These findings also indicate that even though most drivers decreased their speed, their speeds were still higher than the posted speed limit (about 70% of car and 55% of truck drivers). Paolo and Sar (2012) also found that speeds at the beginning of a work zone were higher than the posted speed limit and that nearly 80% of all drivers drove above this limit. Further analysis of the data from Benekohal et al. (1992) showed that the speed of a vehicle throughout the work zone was related to its initial speed; that is, drivers with higher initial speeds had higher speeds throughout the work zone compared to drivers with lower initial speeds (Benekohal & Wang, 1994). Those results support the assumption that drivers react differently to the roadwork environment and reduced speed limits, but do not provide suggestions as to why this variation occurs. One approach to addressing the variance between drivers' preferred speeds in work zones is to investigate their personal characteristics and how these might affect their speed choice.

Näätänen and Summala (1974) argued that drivers enter traffic with different types of motivations, which are influenced, among other things, by drivers' personalities and transient motivations (i.e., states of mind). Even though personality traits were found to be weak predictors of accidents (Wählberg, Barraclough & Freeman, 2017), it is assumed that the willingness to commit driving violations might be explicable in terms of personality (Elander et al., 1993). Furthermore, Ulleberg and Rundmo (2003) noted that personality traits can help predict risky driver behaviour according a more global perspective and lead to inferences of the motivations underlying behaviours. Several studies have addressed the association between personality and driving behaviours. For instance, personality traits such as sensation-seeking and impulsivity were found to be correlated positively with overall traffic violations (Constantinou et al., 2011). Personality traits have moreover been shown to influence how drivers react to different traffic situations. The study conducted by Goldenbeld and van Schagen (2007) found that drivers scoring high on the trait sensation-seeking were less influenced by road characteristics and had higher preferred speeds for rural roads compared to other drivers. Using a video experiment, Steinbakk et al. (2019) found that drivers scoring high on normlessness tended to prefer higher speed in work zones, but that this effect was dependent upon the presence of roadwork activity. These results point to the fact that the relationship between personality traits and behaviour may be dependent of the situation strength, that is, whether the context provides enough of the clues and opportunities that would limit or enhance the possibility of a trait being expressed in behaviour (for a deeper discussion on the person-situation debate, see Judge & Zapata, 2015).

Another interesting factor to explain drivers' speeds is how they evaluate their driving skills. Drivers who have unrealistic beliefs about their driving skills may perceive the situation to be less dangerous and drive in a riskier manner (Martinussen, Møller & Prato, 2014). Goldenbeld and van Schagen (2007) found large differences between what drivers stated as preferred speeds and what they perceived as safe speeds for several road scenes. Preferred speeds were overall higher compared to the speed that was perceived as safe. One hypothesis is that drivers might assess their driving skills favourably, thinking that they can drive faster than the speed they otherwise consider safe. These results could explain the findings of Benekohal, Orloski, and Hashmi (1993), who showed that most drivers who knew they were speeding over the limit at the work zone (94% of drivers who were interviewed) reported feeling that their speed was safe enough for the road conditions. Other studies have demonstrated that drivers who had more driving experience tended to evaluate their own driving abilities more positively (Tronsmoen, 2008), and drivers who rated their driving skills as high, or perceived themselves as more skilful than the average driver, had a greater tendency to engage in more risky behaviour (Horswill, Waylen & Tofield, 2004; Martinussen et al., 2014). Thus, self-assessment of driving skills may provide helpful information with which to understand speed preferences in work zones.

Considering the studies presented here, the present study aimed to explore the effects of road characteristics and drivers' individual differences, in terms of specific personality traits and self-assessment of driving skills, on speed preferences in a rural work zone. We hypothesised that drivers with high evaluations of their driving skills, drivers who have lower barriers against socially unapproved behaviour (trait normlessness), drivers who lack the ability to remain focused on a task (trait perseverance), and drivers who often tend to display impulsive **behaviours influenced by negative emotions such as distress** (trait negative urgency) would prefer higher speeds. As for the effects of road characteristics, we predicted that situations that presented clearer and adequate indications of what behaviour is expected or appropriate would influence the effects of personality traits on speed preferences (see also Judge & Zapata, 2015). Another interesting question was how much personality trait variables contribute to explaining preferred speeds when the road characteristics were controlled for.

2. Method

2.1. Participants and procedure

Participants were randomly drawn from an existing panel of the independent survey bureau *Respons Analyse* and invited by e-mail to participate. In total, 845 Norwegian drivers

responded to an online questionnaire. First, the informed consent was presented. Participants were informed that participation was anonymous and that the data could not be retraceable to the individual. After agreeing to participate, participants completed the questionnaire. Of the respondents, 57% were male and 43% female. Their mean age was 51.47 (SD = 15.79), ranging from 18 to 91 years old, with an average of 32 years (SD = 15.30) of holding a driver's licence. A plurality of participants had driven through a work zone one to three times in the past month (29%), followed by one to two days weekly (23%) and five to seven days weekly (20%).

2.2. Materials and design

Ten pictures of a real work zone were used. The road scenes were extracted from a video of one rural work zone in Norway. The video was taken from the perspective of the driver of a moving car. The screenshots were captured directly after passing a 50 km/h reduced speed limit sign; however, the participants did not receive any information about the current speed limit. Figure 1 displays examples of the road scenes used in the study.

A within-subjects design was used, in which all pictures were presented to all participants. The pictures were presented in a randomised order to rule out order effects. Participants received instructions to state at what speed they would prefer to drive through the depicted road section.

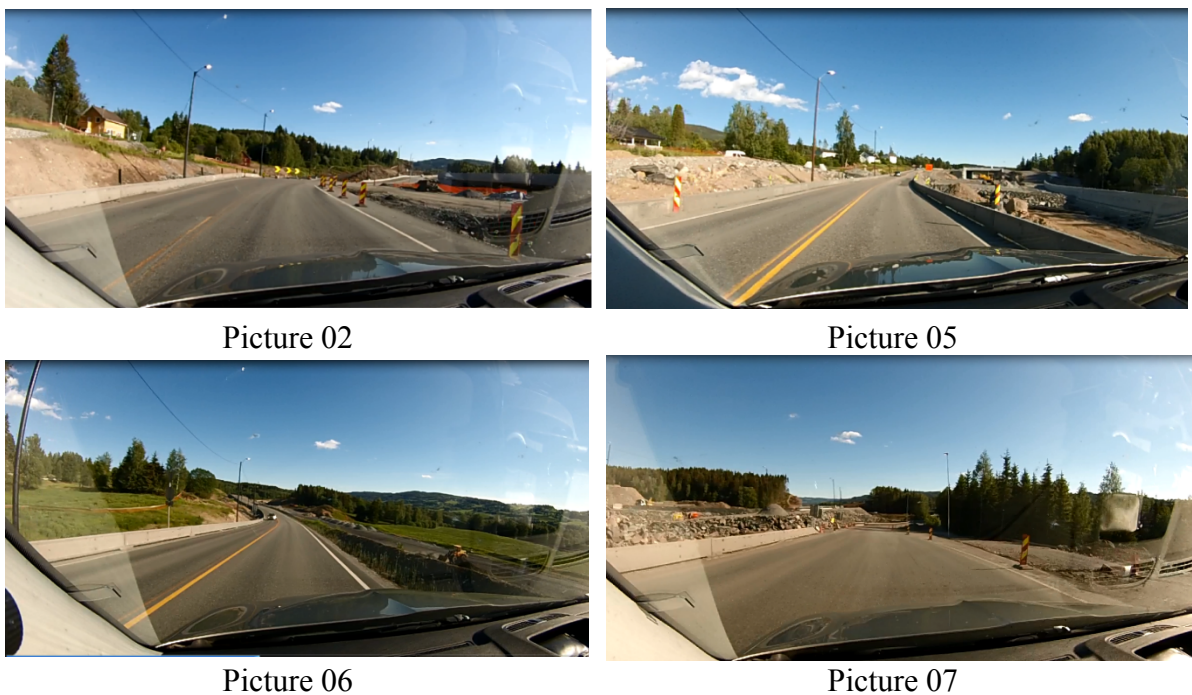


Fig 1. Example of pictures used in the study. Speed limits were reduced to 50 km/h for all depicted road sections.

2.3. Measures

2.3.1. Dependent variable

Participants were instructed to state at what speed, in kilometres per hour, they would prefer to drive if they were driving on the road section displayed in each picture. The mean scores of preferred speeds were the dependent variable.

2.3.2. Roadwork characteristics and drivers' individual differences

The roadwork characteristics depicted on the pictures that were analysed were (1) curve: yes/no; (2) barriers (guardrail or jersey barriers) on same side: yes/no; (3) centre road marking: yes/no; and (4) road delineators (**vertical panel** or chevron signs): yes/no. The coding used for each picture is provided in the appendix.

Three personality traits were selected which were found in a previous study to have a significant effect on preferred speeds in work zones (Steinbakk et al., 2019). The first trait was *perseverance* (see Whiteside & Lynam, 2001), which refers to the “individual’s ability to remain focused on a task that may be boring or difficult” (p. 685). The second trait was *negative urgency*, referring to the “tendency to commit rash or regrettable actions as a result of intense negative affect” (Whiteside & Lynam, 2001, p. 677). Those traits comprised four items each and were measured on a four-point scale ranging from “*strongly disagree*” to “*strongly agree*”. The third trait was *normlessness*, from Kohn and Schooler (1983), which refers to the “individual’s belief that it is acceptable to do whatever [one] can get away with” (p. 87). This trait consisted of four items measured on a five-point scale ranging from “*strongly disagree*” to “*strongly agree*”.

The self-assessment of driving ability was measured using the questionnaire developed by Tronsmoen (2008) for the Norwegian context. The instrument comprised 22 items. Participants needed to indicate to what degree they agree with the statements, on a five-point scale from “*very untrue*” to “*very true*”. A high score on the scale indicated a more confident evaluation of the participant’s own driving skills, while low scores indicated an average to **lower** confidence in driving skills.

2.3.3. Demographic variables

The demographic variables collected were gender, age, number of years holding a driver’s licence, and frequency of driving through work zones (exposure).

2.4. Statistical analysis

To test whether variation in preferred speed could be explained by the proposed predictors, multilevel modelling (MLM) was employed. Multilevel modelling is advantageous with the kind of data used in the present study since each participant rated preferred speed based on 10 pictures. The repeated measurements are thus nested within participants, meaning that the assumption of independence of residuals can be violated. Multilevel modelling takes this kind of dependency into account by specifying that each of the repeated measurements (level 1) are nested within individuals (level 2) (see Hox, 2010). Ignoring such effects gives biased estimates of standard error, which could lead to incorrect inferences about the statistical significance of the effects of the predictors. Data were analysed using IBM SPSS, Version 25.0. Preferred speed was the outcome variable, and random intercepts for each participant were included in the multilevel model. Only fixed effects of the predictors were estimated.

3. Results

3.1. Credibility of speed limits: means of preferred speeds and standard deviations for all scenes

The mean preferred speed for each picture is presented in Table 1. The mean preferred speed for all road scenes was 63.98 km/h (SD = 9.35 km/h). One-sample *t* tests were performed to analyse the level of credibility of a 50 km/h speed limit for all road scenes. Credibility of speed limit was operationalised corresponding to the definition proposed by Goldenbeld and van Schagen (2007), that is, as the difference between the preferred speed limit and the actual speed limit, where the larger the difference, the lower the credibility. The results of the one-sample *t* tests showed that drivers' preferred speeds differed significantly from the actual speed limit (50 km/h) for all road pictures. The level of credibility of the speed limit varied between the pictures, with the lowest credibility for picture 6 (difference of 27 km/h) and the highest credibility for picture 7 (difference of 3 km/h) (see Figure 1).

A one-way repeated measure ANOVA was conducted on speed preferences for all pictures. There was a significant effect of picture on speed preferences ($F(9, 819) = 449.65$, $p < 0.001$, $Eta^2 = 0.83$), indicating that the differences between the speed at which drivers would prefer to drive in different work zone sections were quite large, even though all scenarios had 50 km/h speed limits. The standard deviations were also large, with the highest standard deviation at 13.6 km/h and the lowest at 10.6 km/h.

Table 1. The mean and standard deviations (SD) of preferred speeds for all pictures

Picture	Preferred speed (km/h)	
	Mean	S.D.
1	67.05	11.42
2	53.93	12.82
3	68.60	12.89
4	61.81	11.98
5	57.51	12.33
6	76.60	10.55
7	52.99	12.96
8	70.85	12.94
9	60.62	13.56
10	70.12	12.57

Note. All differences between preferred speed and posted speed limit were found to be statistically significant at the 0.001 level using one-sample *t* test.

3.2. The relationship between drivers' characteristics and preferred speeds

Correlations between drivers' characteristics, personality traits, self-assessment of driving skills, and mean scores for preferred speeds are presented in Table 2. The table also displays α values (internal consistency) for the measures of individual characteristics, varying from 0.51 for normlessness to 0.92 for skill assessment. For preferred speeds, the results showed significant relationships with all variables except work zone exposure and the trait negative urgency. Age had the strongest relationship with mean preferred speeds, where the older the driver, the higher the mean preferred speeds. Results also indicated that drivers who scored higher on normlessness, as well as drivers who had higher self-assessment of their driving skills, preferred higher speeds. High assessment of driving skills was negatively related to gender, with male drivers having a more positive assessment of their driving skills.

Table 2. Pearson product-moment correlations between drivers' characteristics and preferred speeds (N = 845).

	1	2	3	4	5	6	7	α
1. Gender ¹	-							-
2. Age	-0.15**							-
3. Work zone exposure ²	0.14**	0						-
4. Assessment of skills	-0.30**	0.02	-0.08*					0.92
5. Perseverance	-0.07*	-0.10**	-0.03	-0.09*				0.58

6. Normlessness	-0.12**	-0.14**	-0.07*	0.22**	-0.04			0.51
7. Negative Urgency	-0.07*	0.16**	0	-0.15**	0.12**	0.12**		0.76
8. Mean preferred speeds	-0.10**	0.19**	-0.02	0.13**	-0.007*	0.16**	0.27	-

Note. The values were **1: gender**, 1 = male and 2 = female; **2: work zone exposure**, 1 = more than one time weekly and 2 = less than three times monthly; * $p < 0.05$; ** $p < 0.001$.

3.3. Effect of roadwork, drivers' characteristics and self-assessment of driving skills on preferred speeds

First, road characteristics were entered in the multilevel analysis presented in Table 3. The four road characteristics explained 19% of the variance in speed preferences. The presence of centre road marking gave the strongest influence upon preferred speed by on average increasing preferred speed by almost 11 km/h. Having road delineators present on the side of the road, however, led to a relatively large reduction of speed – on average 8.6 km/h. Likewise, the presence of barriers (guardrails or jersey barriers) on the side of the driving direction was estimated to lead to a reduction of speed of 5.1 km/h. The presence of an approaching curve led to an unexpected increase in preferred driving speeds, but only a small increase of 0.85 km/h.

Adding drivers' characteristics to the model increased the amount of explained variance by 4%. Normlessness was significantly related to preferred speed: The higher the normlessness score, the higher the preferred speed. The estimated effect suggested that the difference between drivers at each end of the normlessness scale was almost 10 km/h in preferred speed. Self-assessed driving skills was also related to preferred speed in the expected direction: The more confident the driver was in their own skills, the higher the level of preferred speed. The difference between driver scoring at each end of the skill assessment scale was about 6 km/h.

Preferred speed was found to increase significantly with driver age. This effect of age was rather small: The difference in preferred speed between, for example, a 30-year old driver and a 40-year old driver was estimated to be 1 km/h. Gender, negative urgency, and perseverance were not found to be significantly related to preferred speed.

Table 3. Multilevel analysis estimating the influence of roadwork characteristics and drivers' characteristics on preferred speed in roadwork areas. Unstandardised regression coefficients.

Predictor variable	Regression coefficient (SE)	<i>p</i> value	95% CI
Intercept	48.64 (3.56)	< 0.001	[41.64, 55.63]
<i>Model 1: roadwork characteristics</i>			
Curve ^a	0.85 (0.22)	< 0.001	[0.40, 1.29]
Barriers same lane ^a	-5.14 (0.26)	< 0.001	[-5.66, -4.62]
Centre road marking ^a	10.89 (0.26)	< 0.001	[10.37, 11.41]
Road delineators	-8.63 (0.22)	< 0.001	[-9.06, -8.19]
<i>R</i> ² by model 1	0.19		
<i>Model 2: Driver characteristics</i>			
Gender ^b	-0.57 (0.67)	0.394	[-1.90, 0.74]
Age	0.10 (0.02)	< 0.001	[0.06, 0.14]
Normlessness	2.37 (0.49)	< 0.001	[1.40, 3.34]
Perseverance	-0.74 (0.61)	0.225	[-1.95, 0.45]
Negative Urgency	0.09 (0.52)	0.856	[-0.92, 1.11]
Mean assessment skills	1.57 (0.60)	0.009	[0.39, 2.75]
ΔR^2 by model 2	0.04		
<i>R</i> ² by model 12	0.23		

Note. Multilevel analysis with fixed effects of predictors from Model 2 presented, including a random intercept for participants. Covariance matrix of within-subject measurements was variance components. Ten repeated measurements (level 1) nested within each participant (level 2). *N* level 1 = 8450, *N* level 2 = 845. *R*² = 0.23.

^a 0 = not present, 1 = present. ^b 0 = male, 1 = female

4. Discussion

The present study aimed to explore the effects of road characteristics and drivers' individual differences, in terms of specific personality traits and self-assessment of driving skills, on speed preferences at a rural work zone. The high variation in preferred speeds among the pictures shows that different road sections are evaluated by various means, even though they all have the identical 50 km/h posted speed limit. The drivers in this study were not aware of the posted speed limit and stated their mean preferred speeds for all road scenes as being 64 km/h. The discrepancies between the preferred speeds and actual posted speed limits indicate that the situations do not always provide the drivers with the necessary cues to understand what the appropriate behaviour is. Since participants did not know the speed limits, we could speculate that preferred speed would probably be closer to the limit if they had knowledge of this limit. However, since wide speed variance is a common risk factor in work zone (e.g., ARROWS, 1998) this information is not guaranteed to diminish speed preference heterogeneity among drivers in this study. In real traffic, some drivers will choose to comply with the speed limit

signs, while others will think that the value of the speed limit is too low and decide themselves the speed at which to drive. Variable speeds limits are supposed to have better effects on speed compliance, since they can be adjusted according to the road situation. In a simulator study, van Nes, Brandenburg, and Twisk (2010) found that the dynamic speed limits were perceived as more credible (compared to static speed limits) for some situations. Even though many positive aspects are associated with changing the value of the speed limits according to real-time changes in road conditions, it is also a point of concern whether drivers will be aware of the speed limit changes as they occur. Several studies have found that changes in traffic signs are often not perceived, especially if drivers are not looking for such a change, if they are familiar with the route, or if the changes are small (Harms & Brookhuis, 2016; Martens & Fox, 2007). Thus, the use of dynamic speed limits in work zones should be carefully investigated. As noted by Harms and Brookhuis (2016), even though the consequences of missing a change in increase of speed limit from 50 to 70 km/h may be small, missing a change from 70 to 50 km/h turns drivers into serious speed offenders by negligence alone. Another important question is whether a single speed limit value would be credible for all drivers. While studies indicate that it is impossible to have one speed limit that is equally credible for all drivers (Goldenbeld & van Schagen, 2007; Lee et al., 2017), it is reasonable to assume that a speed limit credible to *most* drivers could increase speed compliance and diminish mean speeds and speed variance in work zones. The results found by Debnath et al. (2014) could support this assumption. They found that speed behaviour in work zones was significantly influenced by the speeding characteristics of surrounding traffic where drivers were more likely to speed when other vehicles were also speeding. For this reason, making the speed limit more credible for most drivers has a potential to increase overall safety in work zones. An indication of what speed limit would be more credible can be achieved by checking speeds at the early stages of the work and adjusting the speed limit closer to the mean speeds. If the risk analysis suggests that a reduced speed limit is the best limit for safety reasons, countermeasures that enhance situational cues of a work zone should be used in addition to the speed limits.

Results from the multilevel analysis show that roadwork characteristics explained nearly 20% of the variance in speed preferences, where road delineators and barriers gave the strongest large reduction of speed preference. Vertical delineators or barriers are countermeasures that act as perceptual measures, while cones passing through the drivers' peripheral vision may lead to an illusion of increased speeds. A field study by Allpress and Leland Jr. (2010) tested for the effects of both uneven and even cone arrangements at a work zone. They found that the speeds decreased in both conditions, with a greater reduction when the cones were arranged in a

random spacing. This effect was also maintained into the work activity area (without any cones), indicating that the cone arrangements had generalising effects on speeds. Since delineators are easily implemented and removed, they can be used at the beginning of work areas, with better effects when they are arranged in an uneven manner. Barriers separate physically the traffic lane from the work site, and at a road where they were present, a 5 km/h decrease in preferred speeds was observed. Delineators and barriers provide situation cues that indicate to drivers that the road is not in a normal state and that speed adjustment is necessary. Our results also indicated that for roads in the worst conditions (in terms of worn out or non-existence centre road markings), drivers preferred lower speeds. The presence of centre road marking gave the strongest influence in preferred speeds, with an increase of almost 11 km/h. At places with apparently better road conditions, or at places in which the environmental cues are inconspicuous, other perceptual measures (such as delineators) should be used together with reduced speed limits to achieve better compliance. We should add that, even though the presence of centre road marking led to an increase in preferable speeds, we do not have enough data to recommend its removal from work zones. Moreover, De Waard, Steyvers, and Brookhuis (2003) found that participants drove at a more central position on non-delineated roads, while with a centre line they drove more towards roads' shoulder. Road marking in a work zone may provide guidance to drivers on lane position; however, apparent new road marking in work zones may indicate to drivers that the road is in good condition; thus, other countermeasures that increase the situational cues for the "work zone situation" should be considered. Our results surprisingly showed that the presence of a curve led to an increase in preferred speeds, which is contrary to previous studies (e.g., Goldenbeld & Van Schagen, 2007). However, this increase was rather small (1 km/h), and an explanation may be that the curves depicted in the scenes used in this study did not seem very sharp. Summarising the effects of roadwork characteristics, we can conclude that strong environmental cues that clearly indicate that the area was a work zone (e.g., presence of delineator, barriers, and weak road markings), influenced the preferred speeds to be lower.

Our results showed that the variables encompassing drivers' characteristics only added 4% to the amount of explained variance in the model. We can argue that the traffic environment is a place that constrains to some extent the expression of individual differences, since there are rules and regulations that all drivers must follow. Thus, driving could be regarded a "strong situation" (see Judge & Zapata, 2015), which could explain why we found that driver's characteristics only explained a small amount of explained variance. Moreover, driving abilities are to some degree equivalent, since all drivers are required to pass a driving test to be allowed

to drive. In this sense, drivers should present low variance in behaviour (in the present case, low variance in speed preferences) across various personality traits, which was not the case in the present study. Older and male drivers tended to prefer higher speeds; however, only age was a significant predictor for speed preference. These results are supported by studies that demonstrated that middle-aged drivers and males are more often involved in fatal crashes in work zones (Norwegian Public Roads Administration, 2011). The trait normlessness was the only personality trait that was significantly related to preferred speed, where drivers scoring higher in the trait preferred higher speeds. High normlessness scores were found previously to be associated with more positive attitudes towards speeding, which in turn was related to higher preferred speeds in work zones (Steinbakk et al., 2019). Normlessness was also found to be positively correlated with speeding, risk taking in traffic, accidents, and near-accidents (e.g., Iversen & Rundmo, 2002; Machin & Sankey, 2008; Steinbakk et al., 2019; Ulleberg & Rundmo, 2003; Yang et al., 2013). Individuals scoring high on this trait are supposed not to care much about violating the rules if it functions as a way to satisfy their motives or achieve their goals. Providing visible and unambiguous situational cues in the work zone has the potential to prevent an eventual manifestation of this personality trait. As demonstrated by Steinbakk et al. (2019), when there was visible roadwork activity, individuals scoring high in this trait preferred lower speeds. Another interesting result was that drivers scoring high in the normlessness trait also tended to assess their skills more favourably. Summala (1988) argued that, even though the driver is motivated to escape or avoid the experience of risk, they often use the road to satisfy their motives of mobility. According to him, the adaptation to risk is largely a function of increasing self-confidence, because drivers' feelings of uncertainty (that would have inhibitory effects) diminish as the confidence in their control skills increases, which tends to eliminate conscious attention to safe driving practices. Indeed, Horswill et al. (2004) found that drivers who considered themselves more skilful reported faster driving speeds and tended to also consider themselves more skilful at hazard perception. Drivers scoring high in normlessness and assessing their driving skills as high may think that they are entitled to choose whatever speed they find acceptable. Providing reasons for the speed limit (e.g., using other perceptual or barriers countermeasures) may influence their perception and thus their speeds. The situational cues should provide guidance as to what kind appropriate behavioural responses are correct for a specific situation (see Judge & Zapata, 2015). Traffic safety campaigns can also focus on human limitations of perception and give drivers some tools for a "reality check".

The present study has some limitations that should be noted. An important issue is related to external validity. Pictures provide limited information compared to actual driving and

may not yield comprehensive results of drivers' speed choices in real life. Debnath, Blackman, and Haworth (2015) found that asking drivers about their self-nominated speeds did not necessarily produce answers that were the same as the speeds they would drive in a work zone. However, as they pointed out, asking drivers about their speeds can still be helpful for understanding how their individual differences may affect their actual speeds in real traffic. The advantage in using an online questionnaire and pictures to investigate speed preferences is that these permit the researchers to collect data that otherwise would be impossible or difficult to collect in the field. Since the results of the present study corroborate results from field studies in work zones, we can assume that they are rather valid. A deeper discussion on external validity of studies using photographs is provided by Goldenbeld and van Schagen (2007) and by Steinbakk et al. (2017; 2019). Further studies could combine different methods, such as observation or use of simulators, to validate the use of pictures to assess drivers' speed choices in different traffic situations.

Methods using self-reports on preferred speeds should always be critically analysed. For instance, participants may be prone to list a lower preferable speed than the speed they would choose in real life. Still, we could show that preferable speeds were highly different among drivers and among road scenes, which is also corroborated by numerous field studies. Another issue concerns the self-assessment of driving skills. There is evidence that the association between assessment of driving skills and actual driving skills is not always accurate. For instance, Martinussen et al. (2017) found that more experienced drivers were most inaccurate in their self-assessments of hazard prediction, hazard detection, and overtaking skills when driving in a simulator. Nonetheless, it is interesting to investigate drivers' own self-assessment of driving skills, whether accurate or not, since it can help to understand speed preferences in work zones.

Another limitation that should be acknowledged is that this study only examined one work zone with a limited number of road characteristics. This also may limit the generalisability of the results to situations in other work zones. For this reason, other types of work zones and different traffic and weather conditions (such as night-time, rainy weather, etc.) should be further explored. It would be also valuable to investigate additional roadwork countermeasures and how they could influence each other.

The low percentages with which the variables analysed in this study explain variance in speed preferences suggest that other variables should be further investigated to increase the understandings of drivers' behaviour in work zones. A suggestion for future research is to investigate other variables such as social pressure and subjective risk of police control. It is

nevertheless worth mentioning that it is not unusual within traffic safety research to find low amounts of explained variance, especially when general measures (such as personality traits) are used to predict highly specific measures (such as speed in a work zone).

5. Practical implications and conclusions

Based on the results presented here, we can assume that posted reduced speed limits in work zones may not alone be the best way to increase safety in work zones, especially if the road appears to be in a good condition and no further countermeasures are used. However, reduced speed limits could contribute to increased speed violations, especially at roads perceived to be in better condition (e.g., with centre road markings). At those places, other traffic countermeasures are necessary to justify the speed limit reduction and increase the situational cues that indicate the appropriate behaviour (i.e., slow down). In this study, the presence of road delineators contributed to a reduction of nearly 9 km/h in speed preferences. We can also argue that perceptual countermeasures, beyond increasing speed perception, are objects that can be run over and potentially damage ones' vehicle. This would provide a motivation to drivers to slow down and be more careful when driving in those areas.

Work zones are often a complex traffic environment, in which the safety of both roadworkers and road users should be part of a risk assessment. Road authorities should bear in mind that posted reduced speed limits should be used with caution. If the environment does not provide enough cues to support this limit, they may not appear credible to all drivers and could intensify speed variation and increase crash risks. Other measures should be used in strategic locations at the work zone, especially in locations in which the road appears to be in good condition, to provide enough situational cues to encourage most drivers to slow down.

The results of our study point to the fact that cues in the environment are a substantial factor in providing drivers a reason for the reduced posted speed limit and important to understand their speed preferences and speed limit credibility in work zones.

Acknowledgments

The authors are grateful to Norwegian Public Roads Administration for funding the study. We are also grateful to Morten Hafting for the work zone video.





References


- Aarts, L., & Van Schagen, I. (2006). Driving speed and the risk of road crashes: A review. *Accident Analysis & Prevention*, 38(2), 215-224.
- Advanced Research on Road Work Zone Safety Standards in Europe Consortium. (1998). *Road Work Zone Safety Practical Handbook. Final Report for Publication*, 1-87 National Technical University Athens.
- Ahie, L. M., Charlton, S. G., & Starkey, N. J. (2015). The role of preference in speed choice. *Transportation Research Part F: Traffic Psychology and Behaviour*, 30, 66-73.
- Akepati, S., & Dissanayake, S. (2011). Characteristics and Contributory Factors of Work Zone Crashes. In *90th Transportation Research Board Annual Meeting*, 11-3769, Washington DC: Transportation Research Board.
- Bai, Y., Finger, K., & Li, Y. (2010). Analyzing motorists' responses to temporary signage in highway work zones. *Safety science*, 48(2), 215-221.
- Benekohal, R. R. F., & Wang, L. (1994). Relationship between initial speed and speed inside a highway work zone. *Transportation Research Record*, (1442).
- Benekohal, R. F., Orloski, R. L., & Hashmi, A. M. (1993). Drivers' opinions on work zone traffic control. *Transportation quarterly*, 47(1) 19-38.
- Benekohal, R. F., Wang, L., Orloski, R., & Kastel, L. M. (1992). Speed-reduction patterns of vehicles in a highway construction zone. *Transportation Research Record*, (1352).
- Blackman, R. A., Debnath, A. K., & Haworth, N. L. (2014). Influence of visible work activity on drivers' speed choice at roadworks. In *Proceedings of the 2nd Occupational Safety in Transport Conference, CARRS-Q, Queensland University of Technology*, 1-10. Accessed from: <http://eprints.qut.edu.au/76277/>.
- Constantinou, E., Panayiotou, G., Konstantinou, N., Loutsiou-Ladd, A., & Kapardis, A. (2011). Risky and aggressive driving in young adults: Personality matters. *Accident Analysis & Prevention*, 43(4), 1323-1331.
- Debnath, A. K., Backman, R., & Haworth, N. (2014). A Tobit model for analysing speed limit compliance in work zones. *Safety Science*, 70, 367-377.
- Debnath, A. K., Backman, R., & Haworth, N. (2015). A comparison of self-nominated and actual speeds in work zones. *Transportation research part F: traffic psychology and behaviour*, 35, 213-222.
- Domenichini, L., La Torre, F., Branzi, V., & Nocentini, A. (2017). Speed behaviour in work zone crossovers. A driving simulator study. *Accident Analysis & Prevention*, 98, 10-24.
- Elander, J., West, R., & French, D. (1993). Behavioral correlates of individual differences in road-traffic crash risk: An examination of methods and findings. *Psychological bulletin*, 113(2), 279.
- Elvik, R. (2010). A restatement of the case for speed limits. *Transport Policy* 17, 196–204.
- Elvik, R. (2013). A re-parameterisation of the Power Model of the relationship between the speed of traffic and the number of accident victims. *Accident Analysis & Prevention*, 50, 854–860.
- Finley, M. D., Jenkins, J., & McAvoy, D. S. (2015). Motorists' Speed Response to Non-Variable and Variable Work Zone Speed Limits and Other Work Zone Conditions. In *Transportation Research Board 94th Annual Meeting* (No. 15-3214).
- Goldenbeld, C., & van Schagen, I. (2007). The credibility of speed limits on 80 km/h rural roads: The effects of road and person(ality) characteristics. *Accident Analysis & Prevention*, 39, 1121-1130.
- Horswill, M. A.; Waylen, A. E.; & M. I. Tofield. (2004). Drivers ratings of different components of their own driving skill: A greater illusion of superiority for skills that relate to accident involvement. *Journal of Applied Social Psychology*, 34, 177-195.

- Hou, Y., Edara, P., & Sun, C. (2013). Speed limit effectiveness in short-term rural interstate work zones. *Transportation Letters: The International Journal of Transportation Research*, 5.
- Hox, J. J. (2010). *Multilevel analysis. Techniques and applications*. 2. Ed. Routledge, New York.
- Høye, A., Phillips, R., & Hesjevoll, I. S. (2015). *Evaluering av E18 Gulli-Langåker: Trafikantenes sikkerhet i anleggsperioden* [Evaluation of E18 Gulli-Langåker: Road safety during the construction period]. TØI report 1445. Oslo, Norway: Institute of Transport Economics.
- Kohn, M. L., & Schooler, C. (1983). *Work and personality: An inquiry into the impact of social stratification*. New Jersey: Ablex Publishing Corporation.
- Lee, Y. M., Chong, S. Y., Goonting, K., & Sheppard, E. (2017). The effect of speed limit credibility on drivers' speed choice. *Transportation research part F: traffic psychology and behaviour*, 45, 43-53.
- Li, Y., & Bai, Y. (2009). Highway work zone risk factors and their impact on crash severity. *Journal of Transportation engineering*, 135(10), 694-701.
- Loo, R. (1979). Role of primary personality factors in the perception of traffic signs and driver violations and accidents. *Accident Analysis and Prevention*, 11, 125-127.
- Martinussen, L. M; Møller, M.; & Prato, C. G. (2014). Assessing the relationship between the Driver Behavior Questionnaire and the Driver Skill Inventory: Revealing sub-groups of drivers. *Transportation research part F: traffic psychology and behaviour*, 26, 82-91.
- Martinussen, L. M; Møller, M.; & Prato, C. G. (2017). Accuracy of young male drivers' self-assessments of driving skill. *Transportation research part F: traffic psychology and behaviour*, 46, 228-235.
- Näätänen, R., & Summala, H. (1974). A model for the role of motivational factors in drivers' decision-making. *Accident Analysis and Prevention*, 6(3), 243-261.
- Paolo, P., & Sar, D. (2012). Driving speed behaviour approaching road work zones on two-lane rural roads. *Procedia-Social and Behavioral Sciences*, 53, 672-681.
- Qi, Y., Srinivasan, R., Teng, H., & Baker, R. (2013). Analysis of the frequency and severity of rear-end crashes in work zones. *Traffic injury prevention*, 14(1), 61-72.
- Rahman, M., Strawderman, L., Garrison, T., Eakin, D., Williams, C. C. (2017). Work zone sign design for increased driver compliance and worker safety. *Accident Analysis & Prevention*, 106, 67-75.
- Silverstein, C., Schorr, J., & Hamdar, S. H. (2014). Work Zones vs. Non-Work Zones: Risk factors leading to Rear-End and Sideswipe Collisions. In. *Transportation Research Board 93rd Annual Meeting*. Washington DC: Transportation Research Board.
- Steinbakk, R. T., Ulleberg, P., Sagberg, F., & Fostervold, K. I. (2017). Analysing the influence of visible roadwork activity on drivers' speed choice at work zones using a video-based experiment. *Transportation research part F: traffic psychology and behaviour*, 44, 53-62.
- Steinbakk, R. T., Ulleberg, P., Sagberg, F., & Fostervold, K. I. (2019). Speed preferences in work zones: Does the presence of roadwork activity moderate the influence of personality traits? *Transportation research part F: traffic psychology and behaviour*, 62, 390-405.
- Summala, H. (1988). Risk control is not risk adjustment: The zero-risk theory of driver behaviour and its implications. *Ergonomics*, 31(4), 491-506.
- Summala, H., & Hietamäki, J. (1984). Drivers' immediate responses to traffic signs. *Ergonomics*, 27(2), 205-216.
- Tronsmoen, T. (2008). Associations between self-assessment of driving ability, driver training and crash involvement among young drivers. *Transportation research part F: traffic psychology and behaviour*, 11, 334-346.

- Ulleberg, P., & Rundmo, T. (2003). Personality, attitudes and risk perception as predictors of risky driving behaviour among young drivers. *Safety Science*, 41(5), 427-443.
- Ullman, G. L., & Brewer, M. A. (2014). Driver perceptions of traffic calming versus active enforcement efforts in work zones. *Transportation Research Record: Journal of the Transportation Research Board*, 2425, 25-31.
- Wåhlberg, A., Barraclough, P., & Freeman, J. (2017). Personality versus traffic accidents; meta-analysis of real and method effects. *Transportation Research Part F: Traffic Psychology and Behaviour*, 44, 90-104.
- Wang, J., Hughes, W., Council, F., & Paniati, J. (1996). Investigation of highway work zone crashes: What we know and what we don't know. *Transportation research record: Journal of the transportation research board*, (1529), 54-62.
- Whiteside, S. P., & Lynam, D. R. (2001). The five factor model and impulsivity: Using a structural model of personality to understand impulsivity. *Personality and Individual Differences*, 30(4), 669-689.
- Yang, H., Ozbay, K., Ozturk, O., & Xie, K. (2015). Work zone safety analysis and modeling: a state-of-the-art review. *Traffic injury prevention*, 16(4), 387-396.

Appendix – Pictures and coding of road characteristics

Picture	Road characteristics analysed			
	1	2	3	4
1. 	X			
2. 	X			X
3. 	X	X	X	X
4. 		X	X	
5. 	X	X	X	X

6.		X	X	X	
7.		X			X
8.			X	X	
9.		X	X		
10.		X	X	X	X

Note. 1=curve; 2=roadside barrier, 3=center road marking, 4=delineators