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# A close examination of speed limit credibility and compliance on UK roads

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A B S T R A C T

Speed is at the core of the road safety problem and speed management is a tool for road safety. Speed limits that are more credible are supposed to encourage drivers to comply with speed limits, with consequent benefits for road safety. Credible speed limit has been found to be affected by the features of the road surroundings in previous research. This study investigated, by using a questionnaire, whether or not the current legal speed limit is credible on a variety of current UK road environments and what the difference is between the proposed speed limit and the chosen, self-reported driving speed. The survey result revealed that road layout and the roadside environment affected the intrinsic perception of choice of speed and speed limit. Chosen speed limit and proposed speed are not identical but are related with each other. The higher the speed limit drivers perceived, the higher speed they tended to drive.


## 1. Background

Vision Zero/Safe System has a long-term goal for road traffic systems which is ultimately to be free from death and serious injury through the interaction of safe speeds, safe roads and roadsides and safe vehicles [1]. This target can be achieved in part by effective speed management. Speed management is a central part of safe system such that speed must be limited to a level commensurate with the inherent safety of the road system [2]. Speed is a risk contributing factor to the occurrence of a significant number of road accidents and the consequences of accidents generally increase with increasing speeds [3]. Setting speed limit aims at regulating the maximum speed at which vehicles operated on public roads in keeping with the overall strategy for speed management [4], especially for those who violate speed limit rules and endanger others.

The factors that influence a driver's choice of speed has been well established. Based on the literature, various road layouts and roadside environmental factors, such as the number of lanes, curved roads and urban roads with the potential for conflict between vehicle drivers and vulnerable road users, are shown to affect speed choice [5–7]. Higher speeds are chosen on roads which are wide, have an emergency lane, few bends, a smooth surface, clear road markings, few buildings or little vegetation, all of which facilitate following the road's course [4,5,8]. External circumstances such as road geometry and engineering elements have a key influence on drivers' speed choice. For example, the 'self-explaining' road (SER) provides a safe behaviour guide simply through its road layout and roadside environment design [9]. Weller and Dietze [10] show that, in the SER approach, the road layout and roadside environment (e.g. road markings and road width) play vital roles in influencing driving behaviour. Driver's intrinsic cognition, without speed limit signs, results in an individual's driving speed perception depending only on the road layout and the subjective risk.

There is limited literature on speed limit credibility. Previous literature shows that various features influenced the credibility of the 80 km/h speed limit on rural roads in the Netherlands where right-hand drive is adapted on Dutch roads. These features can be summarised as follows: the road width, the presence or absence of a bend, the view ahead, the view to the right, the clarity of the situation, the presence or absence of buildings, and the presence or absence of trees on the right [5]. In terms of speed limit credibility definition, SWOV [11] reports that a credible speed limit is a limit that matches the image which is evoked by the road and the traffic situation. Goldenbeld and van Schagen [5], Aarts et al. [12], and van Nes et al. [13] claim that certain specific road and environment combination features influence the credibility of the speed limit. In this research, credible speed limits are defined as the speed limits which are accepted by most drivers (over 50% of the respondent drivers) without the need of enforcement in a given road layout. If most drivers have a commonly

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perceived speed limit and the choice of speed is less than or equal to that limit, it can be assumed that the speed limit is credible for the road environment and drivers are compliant with the speed limit. So far, no studies have examined the effect of road layout and the roadside environment on speed limit credibility or speed on various UK road types.

Demographic characteristics influence a driver's choice of speed and tendency for accidents. The Department for Transport [14] show that 22% of personal injury road accidents involve at least one young car driver aged 17 to 24. Rolls and Ingham [15] indicate a number of factors which might explain the differences in driver behaviour and performance in younger male groups (17–25 years old). To be specific, previous literature [16–18] shows that young male drivers and high sensation seekers prefer higher speed than their counterparts. Young drivers are less competent at scanning the details of the driving environment for road safety than older drivers' defined as from 56 to 71 years [19]. Young drivers with only a few years of driving experience have a higher tendency for accidents. 20% of drivers aged 17–20 have an ‘own fault’ accident per year, while for drivers aged 31–40 the figure is 4.5% [15]. Demographic features affecting a driver's perception of speed limit need to be investigated.

## 2. Study aims

The present study aims to investigate whether the current speed limits are credible or not on UK roads by evaluating road layouts and roadside environments, focusing on rural motorways, urban motorways, rural single carriageways and urban roads.

The main objectives are:

- To investigate how road layout and the roadside environment affect the credible speed limit, and speed limit compliance.
- To investigate the difference between perceived safe speed limit and proposed choice of speed.
- To investigate how demographic characteristics influence a driver's perception of speed limit.

## 3. Method

### 3.1. Questionnaire design

To answer the question of how road environment affects credible speed limit, compliance with the speed limit, and the relationship between speed limit credibility and compliance, a questionnaire survey was used as they were easy to manipulate, relatively low cost and easy to administer.

A questionnaire was used to get drivers' responses to the perception of speed limit credibility and the perception of speed choice. The following road characteristics were included in the analysis: rural motorways with various numbers of lanes, urban motorways, rural roads with or without curves, urban roads in a residential area with or without vulnerable road users. The lane width was 3.65 m across UK roads. Other factors, such as road radius, elevation, sight distance, friction and so on are not taken into consideration. Each factor, for a specific road environment, affects the speed limit credibility on:

- Rural motorway – 2 lane/3 lane/4 lane
- Urban motorway
- Rural single carriageway – presence of curve /absence of curve
- Urban road – presence of vulnerable road users /absence of vulnerable road users

The posted speed limit sign was erased for each road scene. Generally, the licenced drivers were expected to know the speed limit for each type of road, even if there are no signs presented. The legal speed limits posted on these roads in reality are:

- Rural Motorway: 70 mph
- Urban Motorway: 40 mph
- Rural single carriageway: 60 mph
- Urban road: 30 mph

As shown in Fig. 1, all the pictures were of real roads near Leeds, the A1(M), A64(M), A64, A59 and B6160. All the pictures in the questionnaire were taken from the perspective of a driver's line of sight in low traffic flow conditions. There were no speed limit signs or traffic signs visible on the pictures, as the speed limit signs could influence drivers' speed choice and speed limit choice. As the road pictures were static, the drivers were asked at what speed they would drive. West et al. [20] indicate that observed speeds are in accordance with drivers' self-report driving speed, which is validated for this study. The pictures were reduced in size to 9.00 cm $\times$ 6.75 cm followed by two questions for the respondent to read, which were based on similar credibility research from Goldenbeld and van Schagen [5]. The two questions were:

1. If there was no speed limit, how fast would you drive on the road section shown?
2. What speed limit do you think would be safe here? choose one

⑩ ⑳ ㉚ ㊵ ㊿ 60 70 80

Proposed driving speed and perceived safe speed limit can be generated from the above two questions. The two answers can be compared with legal speed limit and can be compared with each other separately.

### 3.2. Participants

Convenience sampling was used to find respondents amongst local drivers. Convenience sampling (also known as availability sampling) is a specific type of non-probability sampling method that relies on data collection from population members who are conveniently available to participate in the study [21]. 100 sample size meet the need for statistical test.

The demographic characteristics of the respondents are shown in Table 1. This approach to sampling allows for recruitment of a representative sample of the UK driving population. The 100-sample gender and age distribution was referred to UK drivers' demographic characteristic.

### 3.3. Procedure

The survey was conducted on weekdays outside Woodhouse Lane car park. The questionnaires were distributed to drivers randomly. The surveyor stopped passing by drivers and asked them whether they would like to take part in the questionnaire. The response rate was about 10%, due to most drivers being in a rush or not wanting to be disturbed. When the sample size reached 100, the surveyor stopped collecting data. Undertaking the questionnaire for the road survey involved presenting the questions on colour printed A4 paper. The questionnaire could be completed within 3 min. For each scenario, the respondents were asked to make an assessment of the speed limit and how they might react faced with the particular driving conditions depicted. It should be noted that these questions relied on the drivers self-reporting speed they would drive at, rather than any objective measurement of speed. The respondents were also asked about gender, age, how long it had been since they passed their driving test and how many speeding tickets they had received in the past 3 years. Whether attendance at a speed awareness course was not taken into consideration.

### 3.4. Statistical analysis

Descriptive analysis [22,23] was used to measure proposed driving speed and perceived safe speed limit characteristics. For the preferred choice of speed, the response could be any numerical value. Mean, median, standard deviation and 85th percentile of speed interpreted the

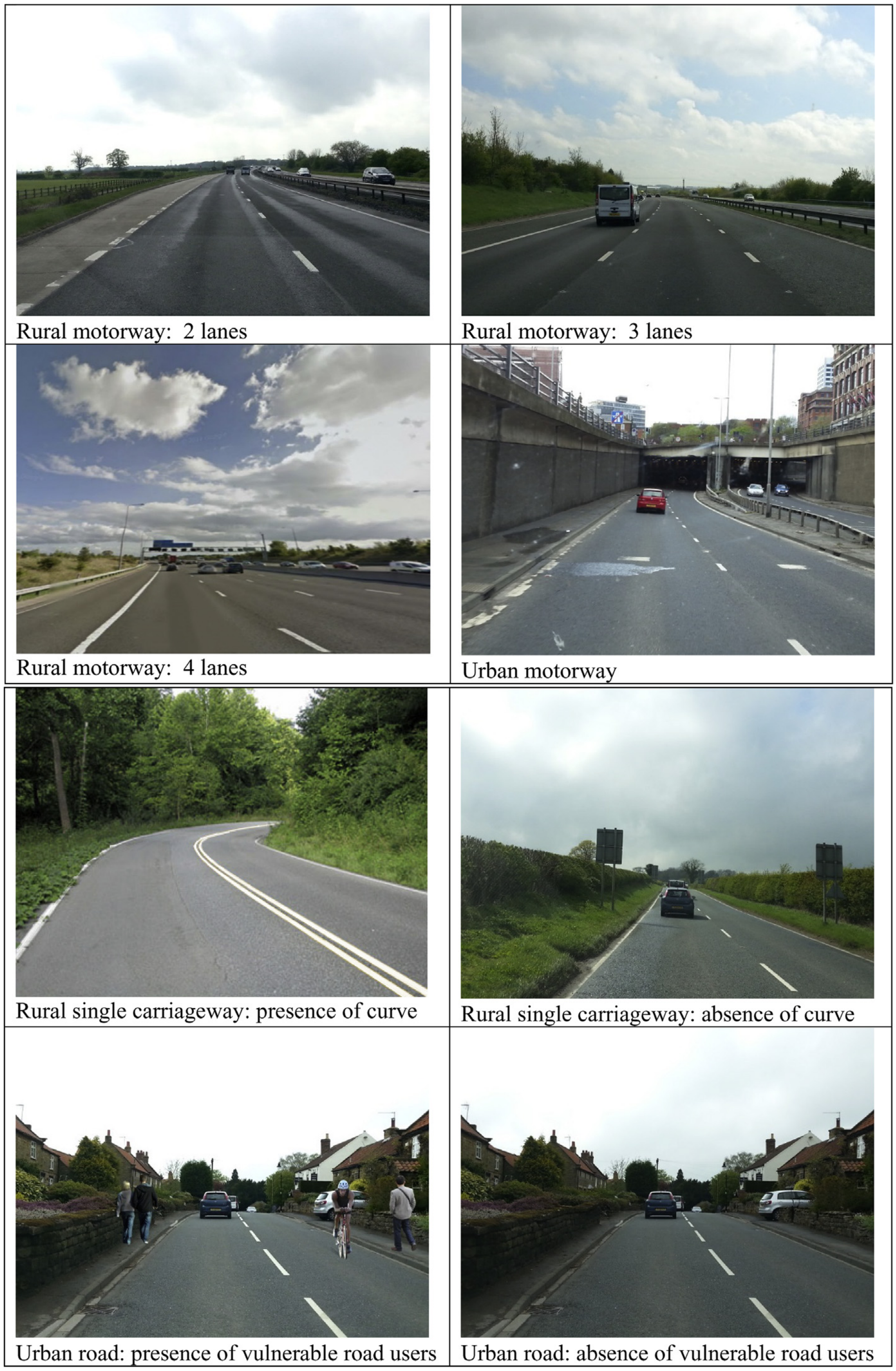


**Fig. 1.** Eight road scenes for questionnaire study.

proposed driving speed characteristics for the specific road. For the choice of safe speed limit, the response could be selected from a scale ranging from 10 mph to 80 mph in increments of 10 mph. The mode value was more valuable to evaluate the common choice of speed limit, denoted by the credible speed limit.

**Table 1**
100-sample driving licence holders: distribution by gender and age.

| Gender | Number | Percentage | Age | Number | Percentage |
|---|---|---|---|---|---|
| Male | 52 | 52% | 17–20 | 9 | 9% |
| Female | 48 | 48% | 21–30 | 27 | 27% |
| | | | 31–40 | 21 | 21% |
| | | | 41–50 | 19 | 19% |
| | | | 51–60 | 22 | 22% |
| | | | 61–70 | 2 | 2% |

The *t*-test can be used to determine if two sets of data are significantly different from each other [24]. A one-sample t-test was run to determine whether the proposed driving speed was different from legal speed limit, defined as 70 mph for rural motorways, 40 mph for urban motorways, 60 mph for rural single carriageways, and 30 mph for urban roads. Independent two-sample t-test was also used to test whether two independent subgroups were significantly different from each other in terms of perceived speed limit and proposed driving speed. For more than two groups, one-way ANOVA was useful for comparing group means for statistical significance [25].

A linear regression [26] was used to investigate the relationship between perceived speed limit and proposed driving speed, defined as perceived speed limit to be an independent variable and proposed driving speed to be a dependent variable.

## 4. Data analysis

### 4.1. Variables coding

To investigate how the road layout and the roadside environment affect the speed limit credibility and compliance, the data set distribution needs to be tested first. From the questionnaire, the road layout and the roadside environment and the demographic characteristics are independent variables; the average preferred speed and safe speed limit are both dependent variables. As the proposed driving speed data is a continuous variable, numerical measures of shape *skewness* can be used to test for normality in Table 2. Skewness is a measure of distribution symmetry [22].

As a general rule of thumb from Cohen and Cohen [27]:

- If skewness is less than −1 or greater than 1, the distribution is highly skewed.
- If skewness is between −1 and −0.5 or between 0.5 and 1, the distribution is moderately skewed.
- If skewness is between −0.5 and 0.5, the distribution is approximately symmetric.

The results showed that the proposed driving speed data distribution for each road layout was moderately skewed (Table 2), which were considered acceptable in order to prove normal univariate distribution [24]. Larger sample sizes (100 sample) were adopted for such motivations to be valid. Thus, a parametric test for proposed driving speed data was adopted. A parametric test usually has more statistical power than a non-parametric test [28]. The speed limit choice was selected from a set, from 10 mph to 80 mph with an increment of 10 mph. The speed limit choice can be treated as a categorical variable.

### 4.2. Rural motorway speed and speed limit performance

The average preferred speed and safe speed limit for all rural motorway scenes are presented in Table 3. The standard deviation for preferred speed illustrates the large differences between respondents. The 85th percentile speed is also presented. The theory behind the 85th percentile rule is that limits must be practical and enforced by engineering experts [29]. The mean proposed driving speed was not significant different from 70 mph on 2-lane motorway. The mean proposed driving speed was significantly higher than the legal speed limit on the 3-lane motorway (t (99) = 4.61, $p < .001$) and 4-lane motorway (t (99) = 6.72, p < .001). In terms of speed limit, this research aims to find a common choice of speed limit, so the mode value was adopted as the most credible speed limit. Mean and S.D. were excluded for testing speed limit credibility. The group comparison shows that there exists inconsistency between drivers' preferred safe speed limit and the choice of speed, which is also different from the legal speed limit.

**Table 2**
Choice of speed skewness test.

| | Skewness statistic |
|---|---|
| 2-lane motorway | 0.927 |
| 3-lane motorway | 0.617 |
| 4-lane motorway | 0.205 |
| Urban motorway | 0.517 |
| Rural single carriageway with curve | 0.372 |
| Rural single carriageway without curve | −0.139 |
| Urban road with vulnerable road users (VRU) | −0.311 |
| Urban road with no vulnerable road users (non-VRU) | −0.710 |

To enable the value of proposed driving speed to be predicted from speed limit choice, Figs. A.1 to A.3 in the appendix show a scaled scatter diagram of the drivers' choice of speed limit and proposed speed on rural motorways amongst 100 respondents. As with the scatter diagram, box plots can be particularly useful for presenting the distribution of the data. A linear regression establishes that the perceived safe speed limit significantly predicts the perceived choice of speed on 2-lane motorway, F (1, 98) = 132.159, $p < .01$; on 3-lane motorway, F (1, 98) = 73.031, p < .01; and on 4-lane motorway, F (1, 98) = 63.87, $p < .01$. The higher the speed limit drivers perceived, the higher speed they tended to drive.

Comparing the results for the three types of rural motorway shown in Table 3, the number of respondents choosing the 70 mph speed limit as credible was 48% for the 2-lane motorway, 43% for the 3-lane, and 47% for the 4-lane. Almost half the respondents chose other speed limits (e.g. 50 mph, 60 mph or 80 mph) which indicated that drivers did not have a common choice. 48% of respondents perceived 70 mph to be credible on a 2-lane motorway, and the mean speed on a 2-lane motorway was close to 70 mph and more respondents were willing to comply with the speed limit. Fewer drivers exceeding the speed limit and putting the mode speed limit as 70 mph means the road can be considered self-explaining in that condition. Thus, 70 mph on a 2-lane motorway was perceived as more credible than on other types of motorway.

From the proposed driving speed result, the proportion of respondents' speed choice below a 70 mph speed limit was 68% for the 2-lane motorway, 48% for the 3-lane, and 46% for the 4-lane. The 2-lane motorway had the highest degree of respondent compliance with the speed limit. For the 3-lane and 4-lane rural motorways, more than half of the respondents preferred to exceed the legal speed limit. Thus, both speed limit perception and speed choice were affected by motorway road layout and roadside environment.

### 4.3. Urban motorway speed and speed limit performance

The average preferred speed and safe speed limit for urban motorway scene are presented in Table 4. On the 2-lane urban motorway, the mean speed was 48.7 mph (±11.0) and the 85th percentile speed was 60 mph. The mode speed limit was 40 mph (42%). The mean proposed driving speed was significantly higher (8.7 mph) than the legal speed limit (t (99) = 7.866, $p < .001$) and 90% exceeded the speed limit.

To enable the value of proposed driving speed to be predicted from speed limit choice, Fig. A.4 in the appendix show a scaled scatter diagram of the drivers' choice of speed limit and proposed speed on urban motorways amongst 100 respondents. As with the scatter diagram, box plots can be particularly useful for presenting the distribution of the data. A linear regression established that perceived safe speed limit can statistically significantly predict perceived choice of speed, F(1, 98) = 99.808, $p < .01$ and perceived safe speed limit accounted for 50.5% of the explained variability in choice of speed. The higher the speed limit drivers perceived, the higher speed they tended to drive.

As shown in Table 4, both speed limit and speed choice were higher than the legal speed limit. Although 40 mph was the mode speed limit that 42% of the respondents considered credible, more than half the drivers (62%) exceeded the 40 mph speed limit, which indicates that drivers did not perceive 40 mph as appropriate for the road layout and roadside environment. Urban motorways usually have no hard shoulder, narrower lanes, walls alongside instead of vegetation, and buildings outside the road. As such, 40 mph was regarded as too slow for the situation, as using a motorway is mainly a mobility function. Therefore, with a lower speed limit credibility on the urban motorway, drivers' compliance with the speed limit was quite low as well.

**Table 3**
Mean and standard deviation of preferred speed and speed limit by road scene on rural motorways.

| Description of actual road scene | Preferred choice of speed | | | | Perceived safe speed limit | | Legal speed limit (mph) |
|---|---|---|---|---|---|---|---|
| | Mean (S.D) (mph) | 50th percentile of speed –median (mph) | 85th percentile of speed (mph) | Number of drivers exceeding legal speed limit (percentage) | Mode (percentage) (mph) | Number of drivers choosing speed limit greater than legal speed limit (percentage) | |
| 2-lane motorway | 69.2 (10.3) | 70 | 80 | 32 (32%) | 70 (48%) | 16 (16%) | **70** |
| 3-lane motorway | 74.5 (9.7) | 73.5 | 80 | 52 (52%) | 70 (43%)<br>80 (43%) | 43 (43%) | **70** |
| 4-lane motorway | 75.4 (8.1) | 75 | 85 | 54 (54%) | 70 (47%) | 44 (44%) | **70** |

### *4.4. Rural single carriageway speed and speed limit performance*

The average preferred speed and safe speed limit for rural single carriageway scenes are presented in Table 5. On the rural single carriageway curved road, the mean speed was 41.0 mph ($\pm$10.9) and the 85th percentile speed was 50 mph. The mean proposed driving speed was significantly lower than the 60 mph legal speed limit on the curved road ($t(99) = -17.32$, $p < .001$) and on the straight road ($t(99) = -11.00$, $p < .001$). The mode speed limit was 40 mph (34%). The mean speed on the rural curved road was 7.1 mph lower than that on the straight rural road. Most respondents perceived 40 mph to be the appropriate speed limit on the curve rural road. Almost all the respondents intended to drive below the 60 mph speed limit.

To enable the value of proposed driving speed to be predicted from speed limit choice, Figs. A.5 and A.6 in the appendix show a scaled scatter diagram of the drivers' choice of speed limit and proposed speed on rural single carriageways amongst 100 respondents. As with the scatter diagram, box plots can be particularly useful for presenting the distribution of the data. A linear regression establishes that perceived safe speed limit can statistically significantly predict perceived choice of speed, $F(1, 98) = 380.697$, $p < .01$ and perceived safe speed limit accounts for 78.9% of the explained variability in choice of speed. The higher the speed limit drivers perceived, the higher speed they tended to drive.

The speed limit choices varied from 20 mph to 80 mph on the two roads. The number of respondents who chose the actual 60 mph speed limit as safe speed limit in the presence and absence of the curve was only 10% and 27%, respectively. On the curved road, 34% of the respondents affirmed that 40 mph was an appropriate safe speed limit and 6% of the respondent chose 20 mph as the speed limit, which showed that they might perceived the rural road to have a higher risk situation. On the straight road, more respondents perceived 60 mph as more appropriate than on the curved road. The presence or absence of the curve was the main factor affecting speed limit credibility.

For the speed choice result, the proportion of respondents' driving speed below the 60 mph speed limit in the presence and absence of the curve was 98% and 89%, respectively. The main difference was that drivers perceived driving an average 19 mph below the speed limit on the curved road and drivers tended to drive an average 12 mph below the speed limit on the straight road. The presence or absence of the curve was the main factor affecting driving speed. Although there was a high compliant level, 60 mph was apparently too high on the rural single carriageway. Respondents preferred a lower speed limit on rural single carriageways. The lower speed limit setting needs to be explored further.

### *4.5. Urban road speed and speed limit performance*

The average preferred speed and safe speed limit for urban road scenes are presented in Table 6. The proportion of respondents choosing the legal speed limit of 30 mph as their speed limit choice for VRU present and VRU absent was 56% and 70%, respectively. More respondents perceived 30 mph would be credible on urban road without VRU. For the proposed driving speed result, the mean speed for both urban roads was lower than 30 mph. The mean proposed driving speed was significantly lower than the 30 mph legal speed limit on the urban road with VRU ($t(99) = -6.46$, $p < .001$) and on the urban road without VRU ($t(99) = -3.94$, $p < .001$). The mean proposed driving speed on urban road with VRU was significantly lower than that on urban road without VRU ($t(99) = -2.23$, $p < .001$). Respondent were willing to comply with 30 mph speed limit on both roads.

To enable the value of proposed driving speed to be predicted from speed limit choice, Figs. A.7 and A.8 in the appendix show a scaled scatter diagram of the drivers' choice of speed limit and proposed speed on urban roads amongst 100 respondents. As with the scatter diagram, box plots can be particularly useful for presenting the distribution of the data. A linear regression establishes that perceived safe speed limit can statistically significantly predict perceived choice of speed, $F(1, 98) = 71.116$, $p < .01$ and perceived safe speed limit accounts for 42.1% of the explained variability in choice of speed. The higher the speed limit drivers perceived, the higher speed they tended to drive.

The proportion of respondents' compliant with the 30 mph speed limit with VRU present and VRU absent was 90% and 90%, respectively. For the VRU present urban road scenario, although 40% of the respondents perceived 20 mph to be a safe speed limit for drivers, cyclists and pedestrians, not all were willing to drive within the 20 mph limit. VRU involved on the road might bring risk feeling for speed and speed limit perception. If more types of road users were present on the road, the interaction between the motorists and the VRU would be complicated and the number of potential conflicts would be greater.

### *4.6. The effect of demographic characteristics on speed limit and speed choice*

A conclusion needs to be drawn regarding the effects of gender, age, driving experience and having speed ticket on drivers' speed and speed limit perception. In the current study, the age groups used for the

**Table 4**
Mean and standard deviation of preferred speed and speed limit on urban motorway.

| Description of actual road scene | Preferred Speed | | | | Perceived safe speed limit | | Legal speed limit (mph) |
|---|---|---|---|---|---|---|---|
| | Mean (S.D) (mph) | 50th percentile of speed –median (mph) | 85th percentile of speed (mph) | Number of drivers exceeding legal speed limit (percentage) | Mode (percentage) (mph) | Number of drivers choosing a speed limit greater than the legal speed limit (percentage) | |
| Urban motorway | 48.7 (11.0) | 50 | 60 | 62 (62%) | 40(42%) | 48(48%) | 40 |

**Table 5**
Mean and standard deviation of preferred speed and speed limit on rural roads.

| Description of actual road scene | Preferred choice of speed | | | | Perceived safe speed limit | | Legal speed limit (mph) |
|---|---|---|---|---|---|---|---|
| | Mean (S.D) (mph) | 50th percentile of speed –median (mph) | 85th percentile of speed (mph) | Number of drivers exceeding legal speed limit (percentage) | Mode (percentage) (mph) | Number of drivers choosing speed limit greater than legal speed limit (percentage) | |
| Rural road, presence of curve | 41.0 (10.9) | 40 | 50 | 2(2%) | 40(34%) | 1(1%) | 60 |
| Rural road, absence of curve | 48.1 (10.8) | 50 | 60 | 7(7%) | 50(30%) | 3(3%) | 60 |

analysis are 17–25 for young drivers, 26–55 for middle-aged drivers and 56+ for older drivers. Those with driving experience of less than 3 years are defined as novice drivers while those with driving experience greater than 3 years are defined as well-experienced drivers. Well-experienced drivers are more aware of potential risk and more able to adapt their speed to the environment to avoid danger. For receiving speeding tickets, drivers are divided into two groups, those with no speeding tickets and those with speeding tickets. Due to gender, driving experience and having speed ticket has two variables respectively, independent two sample *t*-test was used to test the difference between two means in terms of the perception on speed limit choice and speed choice. Due to age group has three variables, one-way ANOVA was used to compare means of three samples. After performing the F-test, it is useful to carry out "post-hoc" analysis of the group means.

#### 4.6.1. Perceived safe speed limit

In terms of perceived safe speed limit, independent two sample t-test was used to test whether subgroups (gender, driving experience and speeding ticket) were significantly different from each other. For gender group, on rural motorways, the perceived safe speed limit of male drivers (Mean = 68.46) were significantly higher than those of female drivers (Mean = 65.625) on the 2-lane rural motorway ($t(98) = 1.69$, $p < .05$). The perceived safe speed limit of male drivers (Mean = 74.04) were significantly higher than those of female drivers (Mean = 71.04) on the 3-lane rural motorway ($t(98) = 1.96$, $p < .05$). There exists no significant difference for perceived safe speed limit across gender groups on the 4-lane rural motorway, urban motorway, rural single carriageway with a curve, rural single carriageway without a curve, urban road with VRU and urban road without VRU. For driving experience group, the perceived safe speed limit of well-experienced drivers (Mean = 44.75) were significantly lower than those of less experienced drivers (Mean = 49.50) on the urban motorway ($t(98) = 1.95$, $p < .05$). For speeding ticket group, the perceived safe speed limit of having speeding ticket group were significantly higher than those of without speeding ticket group on the 2-lane rural motorway ($t(98) = 1.68$, $p < .05$), 3-lane rural motorway ($t(98) = 1.99$, $p < .05$), 4-lane rural motorway ($t(98) = 1.92$, $p < .05$), and rural single carriageway straight road ($t(98) = 2.09$, $p < .05$). One-way analysis of variance (one-way ANOVA) can be used to compare perception of speed limit for three age groups on different road and roadside environment. On the rural motorway, three age groups showed a different perception of speed limit on the 3-lane rural motorway ($F(2, 97) = 4.57$, $p < .05$). A Tukey post hoc test revealed that 17–25 group have statistically significantly lower perception of speed limit than 26–55 group ($p < .05$) on 3-lane rural motorway. In addition, three age groups showed a different perception of speed limit on the 4-lane rural motorway ($F(2, 97) = 3.18$, $p < .05$). However, a Tukey post hoc test revealed that there was no statistically significant difference between age groups on 4-lane rural motorway. There exists no significant difference for perceived safe speed limit across age groups on other roads.

#### 4.6.2. Preferred driving speed

In terms of preferred driving speed, independent two sample *t*-test was used to test whether subgroups (gender, driving experience and speeding ticket) were significantly different from each other. On rural motorways, the preferred speeds of male drivers (Mean = 71.62) were significantly higher than those of female drivers (Mean = 66.48) on the 2-lane rural motorway ($t(98) = 2.57$, $p < .01$). The preferred speeds of male drivers (Mean = 76.19) were significantly higher than those of female drivers (Mean = 72.60) on the 3-lane rural motorway ($t(98) = 1.87$, $p < .05$). The preferred speeds of male drivers (Mean = 76.90) were significantly higher than those of female drivers (Mean = 73.85) on the 4-lane rural motorway ($t(98) = 1.91$, $p < .05$). There exists no significant difference for preferred driving speed across gender groups on the urban motorway, rural single carriageway with a curve, rural single carriageway without a curve, urban road with VRU and urban road without VRU. The female group had a more conservative preferred speed on the rural motorway. For the driving experience group, there exists no significant difference for preferred driving speed across driving experience groups on all of the roads. For speeding ticket group, the preferred speeds of with speeding ticket group were significantly higher than those of without speeding ticket group on the 2-lane rural motorway ($t(98) = 2.83$, $p < .01$), 3-lane rural motorway ($t(98) = 1.71$, $p < .05$). One-way analysis of variance (one-way ANOVA) can be used to compare preferred driving speed of three age groups for different road and roadside environment. On the urban roads, three age groups showed a different perception of speed in the presence of VRU ($F(2, 97) = 3.20$, $p < .05$) and absence of VRU ($F(2, 97) = 3.17$, $p < .05$). However, a Tukey post hoc test revealed that there was no statistically significant difference between age groups on urban roads. There exists no significant difference for preferred driving speed across age groups on other roads.

**Table 6**
Mean and standard deviation of preferred speed and speed limit on urban roads.

| Description of actual road scene | Preferred choice of speed | | | | Perceived safe speed limit | | Legal speed limit (mph) |
|---|---|---|---|---|---|---|---|
| | Mean (S.D) (mph) | 50th percentile of speed –median (mph) | 85th percentile of speed (mph) | Number of drivers exceeding legal speed limit (percentage) | Mode (percentage) (mph) | Number of drivers choosing speed limit greater than the legal speed limit (percentage) | |
| Urban road, presence of VRU | 26.4 (5.6) | 29 | 30 | 10 (10%) | 30 (56%) | 3 (3%) | 30 |
| Urban road, absence of VRU | 28.0 (5.0) | 30 | 30 | 10 (10%) | 30 (70%) | 4 (4%) | 30 |

## 5. Discussion

### 5.1. The effect of road and roadside environment

The results of the study show that rural motorway was the most self-explaining road based on more uniform driving speed than other road types. This result is in accordance with the result that motorways were an excellent example of SER, which did not need any further explanation or learning process to know what it means and what to expect [30,31]. For the rural motorway, with a speed limit of 70 mph, the number of lanes was an important factor affecting speed limit credibility and speed choice. The result is in accordance with Fildes and Lee [32] that the number of lanes affects speed choice. For the 2-lane motorway, driving speed was closer to the legal speed limit, while for the 3-lane and 4-lane motorways, drivers preferred to drive 4–5 mph faster than the speed limit. Motorists who exceeded the speed limit may have considered themselves to be safe on a 3-lane or 4-lane motorway and assessed their driving skills favourably compared to other drivers. This might be because drivers tend to accept more risk in familiar situations [5,33]. As the pictures all showed roads in good weather conditions with low traffic flow, this may have led respondents to report relatively higher speed preferences. Reasons the drivers complied with speed limits include, their subjective risk is higher than others or they may not be willing to break the law so keep within a margin above the speed limit. The 2-lane rural motorway had more common choices of speed and speed limit, meaning the 70 mph speed limit on the 2-lane motorway was more credible than on other types of motorways.

The urban motorway, with a 40 mph speed limit, showed a difference in road layout from the rural motorways. Although 40 mph is a safe speed limit, the proposed driving speed results show 40 mph to be too slow on the urban motorway for the situation as motorways undertake the mobility function the most. The urban motorway is not self-explaining. In addition, since there is no protection infrastructure protecting drivers if a vehicle loses control, the risk perceptions for urban motorways might be higher than other types of road.

For the rural single carriageway with a 60 mph speed limit, curve presence or absence is a factor affecting speed limit credibility and compliance. The preferred speed in the presence and absence of a curve was much less than 60 mph. For the rural road, the perceived safe speed limit ranged from 20 mph to 80 mph, which causes more overtaking behaviour in a real traffic situation. The more homogeneous the speed on rural single carriageways, the safer drivers are [34]. The reason for the speed limit not being credible might be because the lane width is relatively narrow and other vehicles are present ahead. The respondents were aware of the risk posed by the presence of the curve, as the chosen speed and speed limit were lower on the rural road. Thus, 60 mph is not credible on either the straight road or the curved road, which justifies personal risk being higher on a narrow road and a sharp curve.

On the urban road, the presence of vulnerable road users (VRU) was a key issue that affected speed limit credibility and compliance, with 30 mph in the absence of VRU being more credible than in the presence of VRU. In urban areas, various types of vehicle use the same roads. This leads to high potential risks, especially for non-motorised or vulnerable road users. Separation of road-user types is one way to substantially improve safety [35]. Vulnerable road users present on the road need to be taken into consideration and have an impact on drivers' awareness. In residential zones and school zones, a more credible speed limit integrated with traffic calming would be necessary. Another way is 20 mph zones which significantly decreased the risk of being injured in a collision. Their greater use would reduce the number of traffic injuries in the UK. Research also shows that, according to a survey, the overwhelming majority of the public want to see a 20 mph speed limit introduced in built-up areas, including around schools and town centres [36]. The Go 20 campaign proposes changing the default speed limit across areas to make the most cost-effective strides towards 20 mph limits in villages, towns and cities [37]. In addition, vehicles' situations differ from each other, especially on urban roads. Driving behaviour, such as accelerating, decelerating, car following, overtaking, turning and slow driving can all be observed on urban roads. Due to driving behaviours being more complex on urban roads than other types of roads, more types of crashes occur. The degree to which people feel safe is related to the separation of types of traffic and the share of heavy traffic [38].

### 5.2. The effect of demographic characteristics

A large difference is shown between demographic groups with regards to preferred speed and speed limit. The differences appear to be related to gender, age, driving experience and having speeding tickets on specific roads. With regards to the proposed speed limit, there are differences within groups for specific road scenes. Male group prefer a higher speed limit than females. Middle-aged group prefer a higher speed limit than other age groups. Having speeding ticket group prefer a higher speed limit than no speeding ticket group. There are some preferred speed limits in common, such as on 2-lane motorway, urban motorway and urban roads. In terms of the proposed driving speed, males and females differ in their judgement of driving speed. Male group prefer a higher driving speed than females on motorways. This finding is consistent with McKenna et al. [39] that males drive faster than females, although gender differences in preferred speed may have decreased over time [40]. Drivers' personality traits, such as risk-taking attitude, are related to risky driving behaviour, especially amongst young drivers [41,42]. For example, young-aged group proposed a higher driving speed than middle-aged and old groups on urban motorway, which indicated they might neglect the risk or prefer risk-taking behaviour.

### 5.3. The relationship between safe speed limit and proposed driving speed

Speed limit credibility is different to compliance with speed limit. Satisfaction with the speed limit does not mean that one obeys it. Respondents may perceive a lower speed limit as credible, but still choose a higher speed. For example, respondents perceived a 40 mph legal speed limit as credible on urban motorway but exceeding the speed limit substantially. Drivers' compliance level is highly uncertain due to the traffic situation, personal traits, road environment, vehicle dynamics etc. Drivers' lack of compliance with the speed limit might be due to the speed limit not being credible. Conversely, drivers' compliance with speed limit may not mean they perceive the speed limit as credible. They may be restricted by traffic laws and obeyed the rules.

There was a positive relationship between the perceived safe speed limit and the perceived speed when judged by drivers in a given road situation. The difference between preferred speed choice and safe speed limit shows how compliant motorists are with the speed limit. The safe speed limit and proposed driving speed results showed that motorists' perceptions of speed limit credibility affect their compliance with the speed limit; the more credible the speed limit, the more compliant they are.

### 5.4. Credible speed limit as a measure to support speed limit enforcement

Speed limit enforcement was adopted by local authorities to improve driver compliance with speed limit. Roadside speed camera, radar guns and automated in-vehicle systems have been used as speed enforcement methods around the world. Speed enforcement can also be supported by other measures such as credible speed limits and publicity. Credible speed limit research provides evidence that local highway agencies can use to achieve better speed management, mainly by changing guidance on speed limit setting to match road layouts and roadside environments. If the current speed limit was too high, the speed limit can be adapted according to the drivers' proposed driving speed. A lower speed limit can meet the requirement of the Safe

System by preventing serious or fatal injuries through effective speed management. Improving the credibility of the speed limit can improve road safety in the long run. Credible speed limit integrated with effective speed enforcement may work well on the roads for better speed compliance. Speed limit compliance will bring greater benefit to road safety.

### 5.5. Limitations with the study

With a response rate of only 10%, the questionnaire sample size was 100. The possible negative implication was that the respondents who were not in a rush participated in this study. Prospective respondents can be approached during different times of a day. A monetary reward can be provided to encourage the participants. The incentives motivate potential respondents to participate in the study optimally. In addition, as the number of subgroups was limited, the interactions between age and gender or driving experience and gender in terms of speed choice and speed limit choice were not taken into consideration. Drivers' personality traits were not evaluated in this study due to time limited.

## 6. Conclusion

This study has examined whether the current speed limit is credible or not on various UK roads in a given road layout and the roadside environment. A speed limit of 70 mph was credible on 2-lane rural motorways and a speed limit of 30 mph was credible on urban roads. A speed limit of 40 mph was too low on an urban motorway. A speed limit of 60 mph was too high on a rural single carriageway with curve. The mode value of the proposed safe speed limit is adopted as the most credible speed limit. The higher the speed limit drivers perceived, the higher speed they intended to drive. It is possible to determine a limit that is more credible for most motorists in a given road environment. Speed limit credibility need to be tested in further studies, measured by better matching the limit to certain characteristics of the road layout and the roadside environment to improve the credibility of the speed limit. In order to improve drivers' compliance, educational measures designed for speeding drivers focus on aspects of their risk perception and risk tolerance. Drivers' understanding of safe speed can be achieved by both road engineer and education.

## Appendix A. Appendix

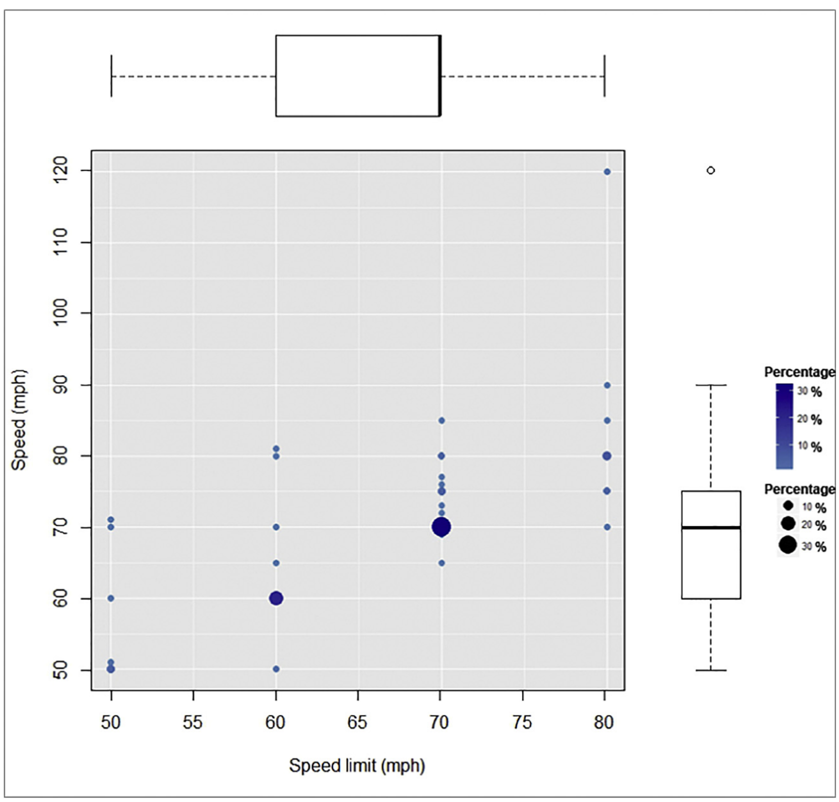


**Fig. A.1.** Proposed speed limit and driving speed profile on 2-lane motorway.

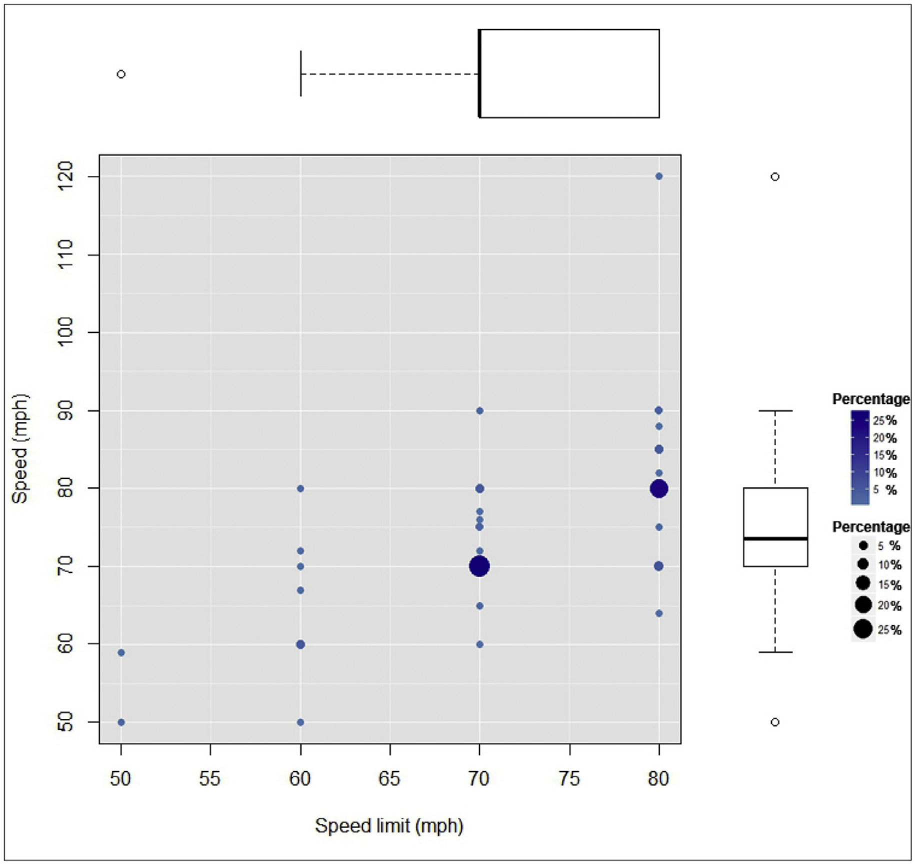


**Fig. A.2.** Proposed speed limit and driving speed profile on 3-lane motorway.

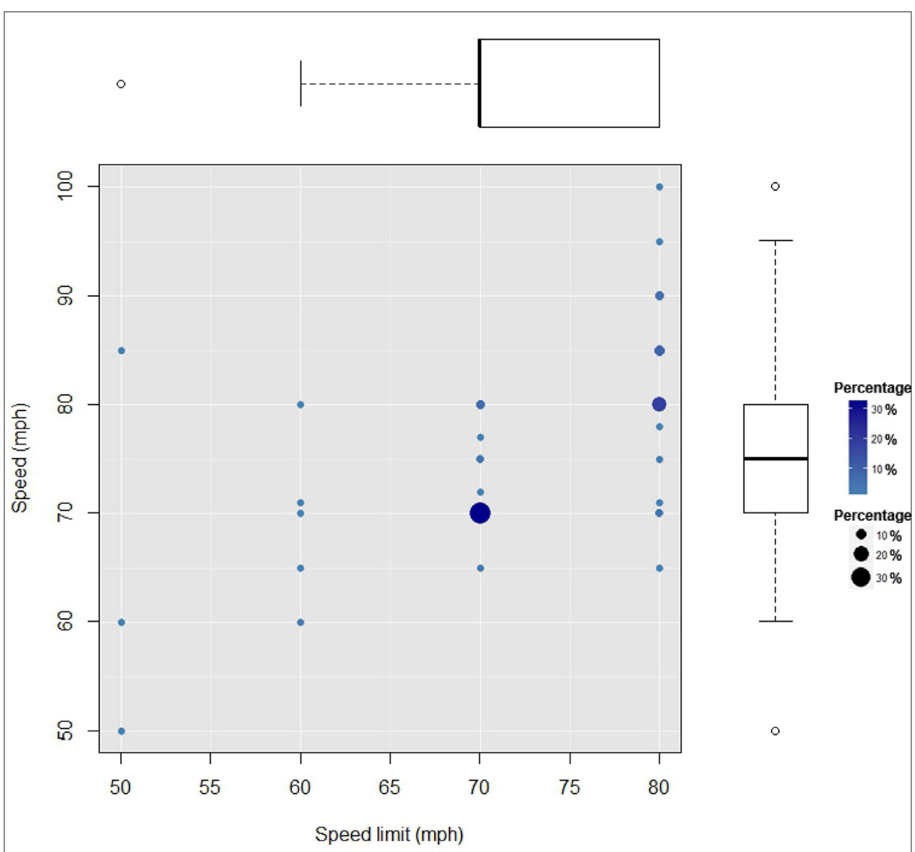


**Fig. A.3.** Proposed speed limit and driving speed profile on 4-lane motorway.

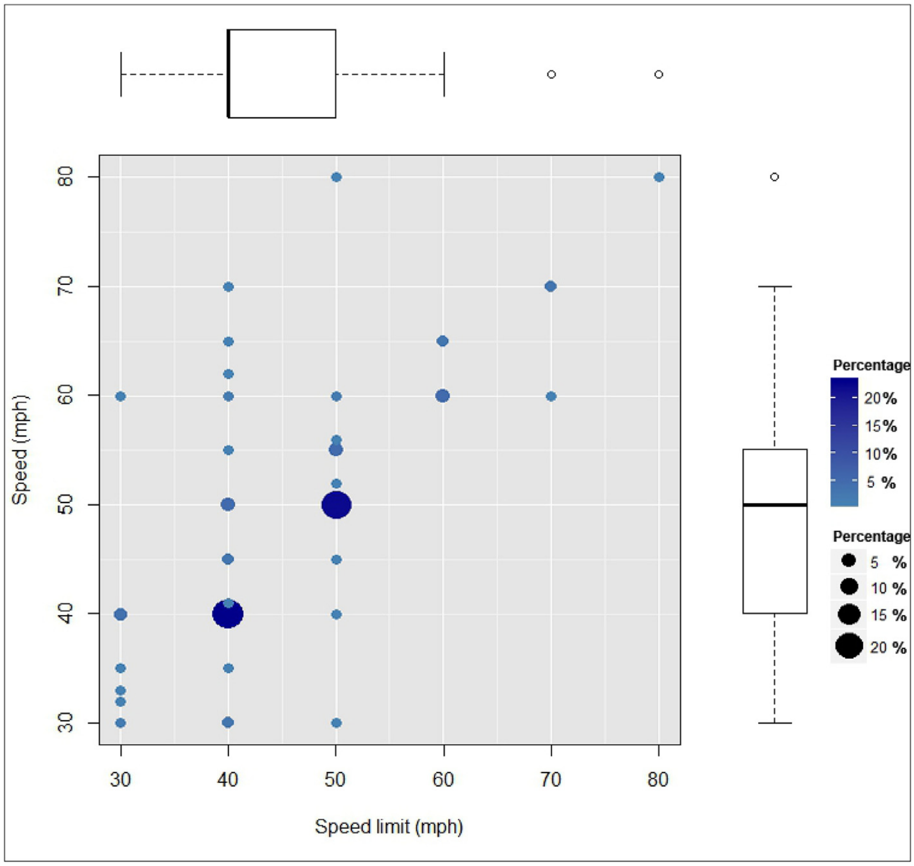


**Fig. A.4.** Proposed speed limit and driving speed profile on 2-lane urban motorway.

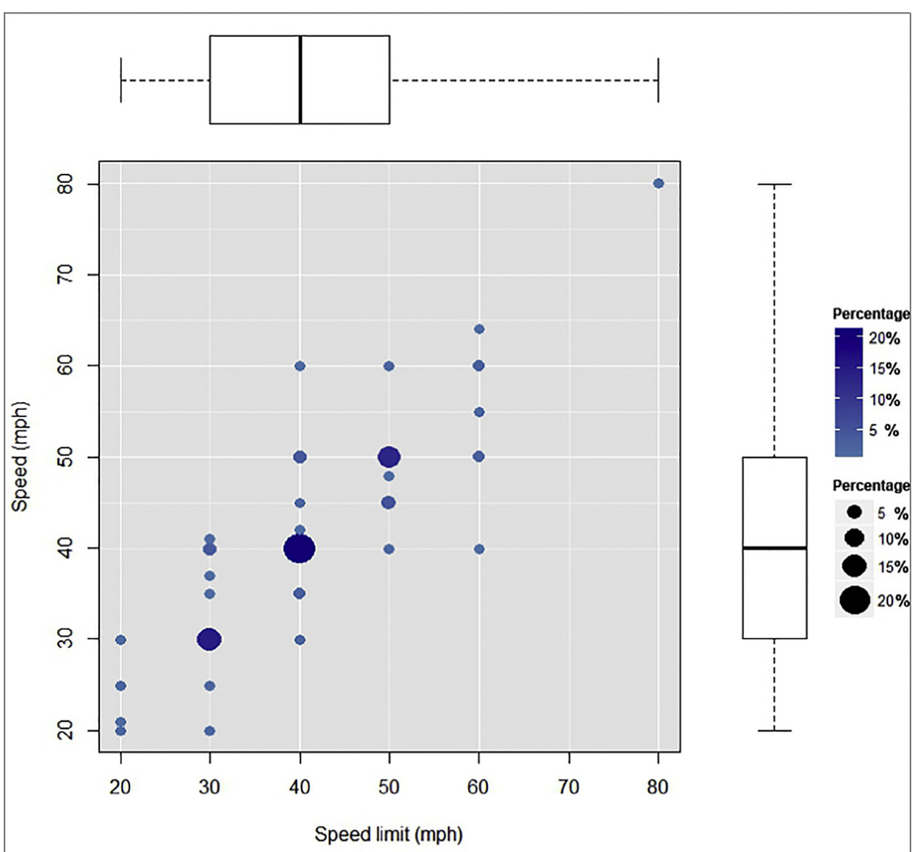


**Fig. A.5.** Proposed speed limit and driving speed profile on rural single carriageway with curve.

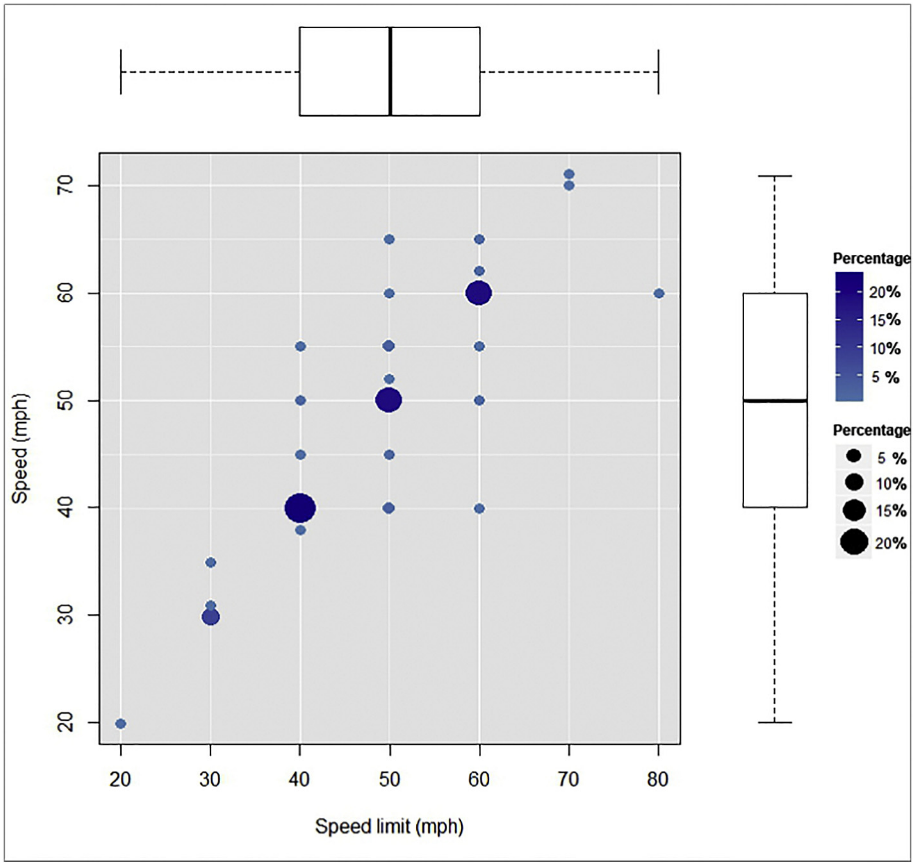


**Fig. A.6.** Proposed speed limit and driving speed profile on rural single carriageway without curve.

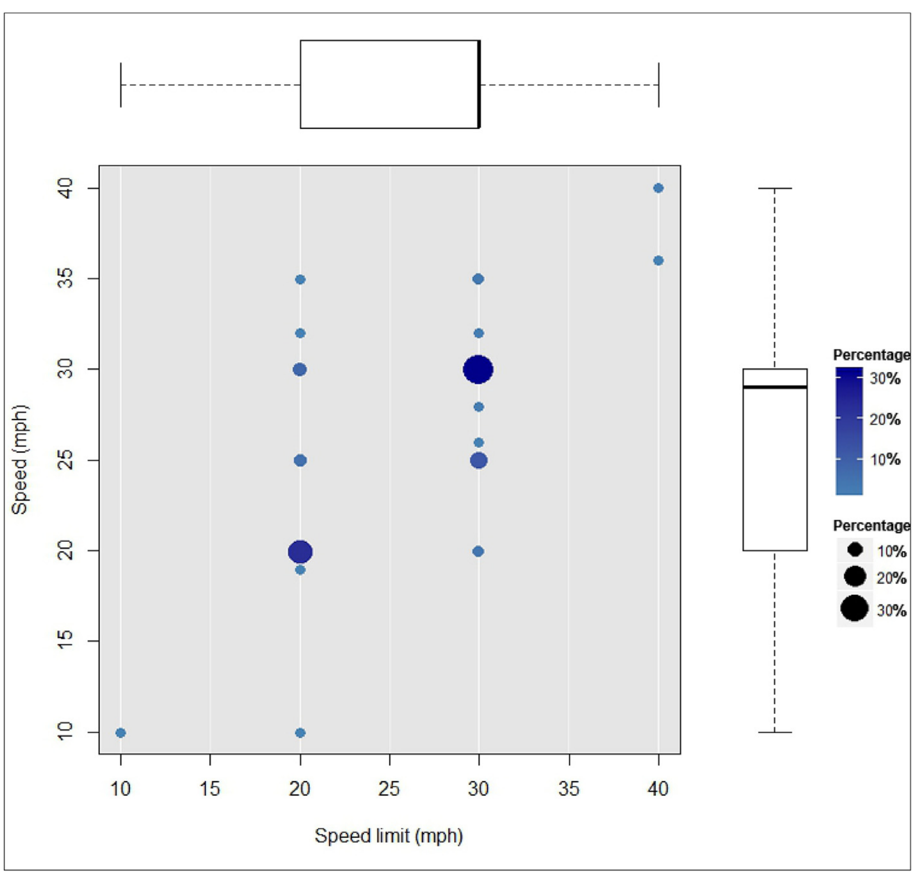


**Fig. A.7.** Proposed speed limit and driving speed profile on urban road with VRU.

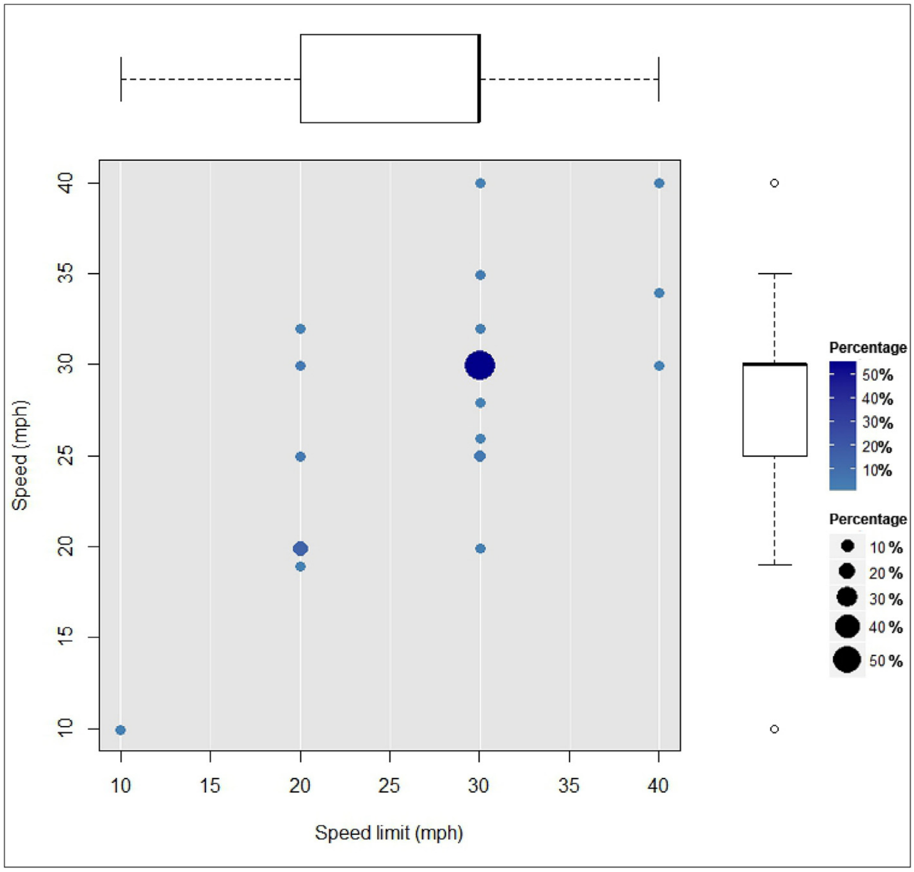


**Fig. A.8.** Proposed speed limit and driving speed profile on urban road without VRU.

## References

[1] PACTS, UK transport safety: who is responsible? in: T.S. Commission (Ed.), Transport Safety Commission, 2015 , London.
[2] C. Tingvall, N. Haworth, Vision zero: an ethical approach to safety and mobility, 6th ITE International Conference Road Safety & Traffic Enforcement, 2000.
[3] R. Elvik, et al., The Handbook of Road Safety Measures, Emerald Group Publishing, 2009.
[4] R. Elvik, Speed limits, enforcement, and health consequences, Annu. Rev. Public Health 33 (2012) 225–238.
[5] C. Goldenbeld, I. van Schagen, The credibility of speed limits on 80km/h rural roads: the effects of road and person (ality) characteristics, Accid. Anal. Prev. 39 (6) (2007) 1121–1130.
[6] M.A. Elliott, V. McColl, J.V. Kennedy, Road design measures to reduce drivers'speed via'psychological'processes: a literature review, TRL Rep. 564 (2003).
[7] Y.M. Lee, et al., The effect of speed limit credibility on drivers' speed choice, Transport. Res. F: Traffic Psychol. Behav. 45 (2017) 43–53.
[8] SWOV, Speed Choice: The Influence of Man, Vehicle, and Road, SWOV, Leidschendam, the Netherlands, 2012, http://www.swov.nl/rapport/Factsheets/UK/FS_Speed_choice.pdf.
[9] J. Theeuwes, H. Godthelp, Self-explaining roads, Saf. Sci. 19 (2) (1995) 217–225.
[10] G. Weller, M. Dietze, SER and SER Approaches: State-of-the-Art Definition, Comparison and Evaluation of Existing Self-Explaining Road Approaches in Europe, 2010 (WP01-01. ERASER, Project Nr.SRO1 AF).
[11] SWOV, SWOV Fact Sheet Towards Credible Speed Limits, 2012 Leidschendam, the Netherlands.
[12] L. Aarts, et al., Towards safe speeds and credible speed limits, 4th International Symposium on Highway Geometric Design, Netherlands, 2009.
[13] N. van Nes, et al., Towards a Checklist for Credible Speed Limits; Development of an Assessment Method Based on Road and Road Environment Characteristics, 2007.
[14] Department for Transport, Reported road accidents involving young car drivers: Great Britain 2011, Road Accident Statistics Factsheet No. 1, DfT, London, 2012.
[15] G. Rolls, R. Ingham, Safe' and 'Unsafe' -A Comparative Study of Younger Male Drivers, Automobile Association, Foundation for Road Safety Research, ARRB Group Limited, 1992.
[16] S. Oltedal, T. Rundmo, The effects of personality and gender on risky driving behaviour and accident involvement, Saf. Sci. 44 (7) (2006) 621–628.
[17] B.A. Jonah, Sensation seeking and risky driving: a review and synthesis of the literature, Accid. Anal. Prev. 29 (5) (1997) 651–665.
[18] B.A. Jonah, R. Thiessen, E. Au-Yeung, Sensation seeking, risky driving and behavioral adaptation, Accid. Anal. Prev. 33 (5) (2001) 679–684.
[19] L.C. McPhee, et al., Age differences in visual search for traffic signs during a simulated conversation, Hum. Factors 46 (4) (2004) 674–685 The Journal of the Human Factors and Ergonomics Society.
[20] R. West, et al., Direct observation of driving, self reports of driver behaviour, and accident involvement, Ergonomics 36 (5) (1993) 557–567.
[21] M.N. Marshall, Sampling for qualitative research, Fam. Pract. 13 (6) (1996) 522–526.
[22] R.C. Hootman, Manual on Descriptive Analysis Testing for Sensory Evaluation, ASTM, Philadelphia, PA, 1992.
[23] H. Stone, et al., Sensory evaluation by quantitative descriptive analysis, Descriptive Sensory Analysis in Practice 2004, pp. 23–34.
[24] C.A. Boneau, The effects of violations of assumptions underlying the t test, Psychol. Bull. 57 (1) (1960) 49.
[25] R.M. Heiberger, E. Neuwirth, One-Way Anova, in R Through Excel, Springer, 2009 165–191.
[26] J. Neter, et al., Applied Linear Statistical Models, vol. 4, Irwin, Chicago, 1996.
[27] J. Cohen, P. Cohen, Applied multiple regression/correlation analysis for the behavioral sciences, J. R. Stat. Soc. 52 (4) (2010) 691.
[28] H. Finch, Comparison of the performance of nonparametric and parametric MANOVA test statistics when assumptions are violated, Methodol. Eur. J. Res. Methods Behav. Soc. Sci. 1 (1) (2005) 27.
[29] AASHTO, Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, Washington, DC, 2001 **3**: p. 3.2.
[30] G.H. Walker, N.A. Stanton, I. Chowdhury, Self explaining roads and situation awareness, Saf. Sci. 56 (2013) 18–28.
[31] A. Stelling-Konczak, et al., Supporting drivers in forming correct expectations about transitions between rural road categories, Accid. Anal. Prev. 43 (1) (2011) 101–111.
[32] B.N. Fildes, S.J. Lee, The speed review: road environment, behaviour, speed limits, enforcement and crashes, Report CR 127. Federal Office of Road Safety, Department of Transport and Communication, Canberra, Australië, 1993.
[33] P. Slovic, Perception of risk, Science 236 (4799) (1987) 280–285.
[34] N. van Nes, S. Brandenburg, D. Twisk, Improving homogeneity by dynamic speed limit systems, Accid. Anal. Prev. 42 (3) (2010) 944–952.
[35] D. Shefer, P. Rietveld, Congestion and safety on highways: towards an analytical model, Urban Stud. 34 (4) (1997) 679–692.
[36] ITV, 'Overwhelming Majority' of Public Want 20 mph Speed Limit, Available from http://www.itv.com/news/2014-04-02/overwhelming-majority-of-public-want-20mph-speed-limit/ 2014.

[37] Living Street, In favour of 20 mph, Living Streets Policy Factsheet, 2014 , Available from http://www.livingstreets.org.uk/sites/default/files/content/library/Factsheets/20%20mph.pdf.
[38] SWOV, Subjective Safety in Traffic, Institute for Road Safety Research, Netherlands, 2012, https://www.swov.nl/rapport/Factsheets/UK/FS_Subjective_safety.pdf.
[39] F.P. McKenna, A. Waylen, M. Burkes, Male and female drivers: how different are they? University of Reading: AA Foundation for Road Safety Research, 1998 66.
[40] S. Stradling, et al., The Speeding Driver: Who, How and Why? 2003.
[41] C. Turner, R. McClure, Age and gender differences in risk-taking behaviour as an explanation for high incidence of motor vehicle crashes as a driver in young males, Inj. Control. Saf. Promot. 10 (3) (2003) 123–130.
[42] H. Iversen, Risk-taking attitudes and risky driving behaviour, Transport. Res. F: Traffic Psychol. Behav. 7 (3) (2004) 135–150.