Analysing the Effectiveness of 20mph Speed Limit and Speed Distribution Based on Key Spatial and Temporal Attributes in Scottish Borders Area

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Abstract
The aim of this paper is to analyse the effectiveness of the 20mph speed limit based on the speed distribution before and after the intervention considering the different spatial and temporal attributes. Using a quantitative approach, the speed shift, and the impact of the 20mph speed limit on several dimensions of vehicle speeds. Specifically, a "before-after" analysis of vehicle speeds based on different spatial and temporal attributes, including the local area, settlement type, school presence, road alignment, and the day of the week. The speed data deployed for the analysis were drawn from the 156 sites across the five local areas of the Scottish Borders. The variability in the speed in the pre-and-post 20mph speed limit intervention was based on the mean and 85th percentile speed metrics. A further statistical analysis was carried out to examine the statistical difference between the various speed outcomes of the speed survey waves relating to the key spatial and temporal attributes.
The outcomes show that the speed distributions are likely influenced by the characteristics of the key spatial and temporal attributes of the sites across the local areas of the study. For instance, the variability of the average speed and 85th percentile speed. Overall, the outcomes indicated vital speed reductions when subjected to examination based on different spatial and temporal attributes in most sites across all survey waves. The study concludes that the 20-mph speed limit is a powerful interventionist tool which capable of curbing exceeding speeds in both semi-urban and rural areas with the associated school presence, road alignment, and temporal characteristics.

Keywords: 20mph speed limit, Mean and 85th Percentile speed, safety, spatial and temporal attributes

1 Introduction

Addressing road safety issues has continued to generate global concerns as the evidence of the speed of the vehicles remains a pivotal factor in the frequencies of collisions and their associated injury severity. Several studies have associated high speeds with a greater number of road collisions with higher severe crash injuries. Researchers across the globe are advocating for the implementation of traffic calming measures such as speed breakers, repeaters and 20mph speed limits, especially in residential and school areas to mitigate both the frequency of collisions and severe injuries. As such some of the local Highway Authorities have introduced different traffic calming measures to deal with the results of high speeds on the safety of pedestrians, cyclists, and other vehicle drivers. In particular, the implementation of the 20mph speed limit has recorded a high performance in terms of crash frequency reduction and the overall public health concerns linked to high speed (Steinbach et al., 2013). There is a plethora of evidence of 20mph speed limit implementation in urban areas (Cleland et al. 2020), with little evidence of similar interventions in rural areas in the literature. Besides, the performance and the effectiveness of this intervention based on the key spatial and temporal attributes in predominantly rural areas have not been fully evaluated. This study intends to provide a response to the research gap in the performance and effectiveness of 20mph speed limit implementation in predominantly rural areas.

Across the globe, vehicles' speed has been identified to have massive impacts on road safety among other key factors. It is proven that high speed is linked to higher frequencies of road collisions with associated higher injury severities. This consistent connection between higher speeds and a higher chance of severe collisions resulting in Killed or Seriously Injured (KSI) casualties have been validated (Quddus, 2013; Sarkar et al., 2018; Fountas et al., 2021).

Considering the KSI casualties and the public health issues emanating from the negative effects of speeding of different vehicle types, the clamour for measures to calm the traffic is becoming more pronounced and receiving attention from stakeholders which include the policymakers, researchers, and the public. With the different configurations of the urban and rural environments with different types of land use with growing traffic which to some extent put pedestrians and cyclists at high risk; measures become a necessity. Therefore, the introduction of a 20mph speed limit has become a veritable interventionist tool to reduce the non-residential traffic and non-school traffic from residential areas and school routes to protect vulnerable pedestrians and cyclists. This interventionist tool has proven to be an effective measure for reducing collision frequency and KSI casualties (Steinbach *et al.*, 2013; Fountas *et al.,* 2022; Olowosegun *et al.*, 2022).

Cleland (2020) posits that the significance of the 20 mph speed limit as a transport intervention in urban areas is not potent for speed reduction but has shown evidence of road safety enhancement, collision frequencies and severity reduction. It is accounted that about five percent (5%) of total collisions and fifteen percent (15%) of total fatal crashes are a result of drivers' speed limit violations (Department of Transport, 2017).

Previous studies looked at the cost and benefits of 20mph (Steinbach *et al.*, 2013); the effect of 20mph interventions relating to public health and health inequalities (Cairns *et al.*, 2015; Cleland *et al.*, 2020), the cost-effectiveness of 20mph zones (Peters and Anderson, 2013), and support and compliance (Tapp, Nancarrow and Davis, 2015) all focus on the urban areas. However, there is a dearth of similar research in the literature on rural areas, especially in rural Scotland. This study will provide the missing links in research on 20 mph intervention in predominantly rural areas.

The overarching aim of this study is to an empirical evaluation of the performance and the effectiveness of a 20mph trial in the Scottish Borders, UK based on key spatial and temporal characteristics. The Scottish Borders are situated in the East of Scotland' Southern Uplands comprising predominately settlements with populations mostly less than 5,000 dwellers. Notably, this trial study is unparallel and unique, in terms of the magnitude of the scheme in rural areas in the UK and globally.

2 Background and Methods

2.1 Background

An experimental trial of 20mph speed limits was commissioned by the Scottish Borders Council (SBC) in October 2020. The scheme constitutes the largest traffic calming intervention with a wide of rural spatial coverage making it a unique scheme in Scotland and across the World. The overarching aim of this study is to promote safer mobility and active travel. Apart from the 20mph scheme, the new trial also included additional road safety interventions, such as the installation of speed limit repeater signs, Vehicle Activated Signs (VAS), buffer zones, and others, which are expected to foster traffic calming synergies in combination with the 20mph trial.

The 20mph speed limit scheme was implemented in 97 settlements in the area of Scottish Borders, which all previously had a 30mph speed limit. These settlements are located across five local areas: Tweeddale, Cheviot, Teviot & Liddesdale, Eildon and Berwickshire. Figure 1 shows the map of the overall area in Scottish Borders where the trial took place.

Considering the role of vehicle speed which as one of most influential factors in road safety which its magnitude does not only link with higher frequencies of road collisions, but also with more severe injury outcomes. Previous studies in traffic safety in rural and urban environment have proven a consistent association between higher speeds and greater probabilities for severe collisions, which may result in Killed or Seriously Injured (KSI) casualties (Quddus, 2013; Sarkar et al., 2018; Fountas et al., 2020; 2021). Undoubtedly, there exist significant evidence that excessive speed patterns can lead to major safety issues over the years, as such appropriate countermeasures must be implemented. This would effectively address speeding behaviour and its significant burden on traffic safety and public health. In this context, the implementation of lower speed limits is a widely employed policy action aiming to curb the high levels of collision occurrence and injury-severity, in the UK and overseas.

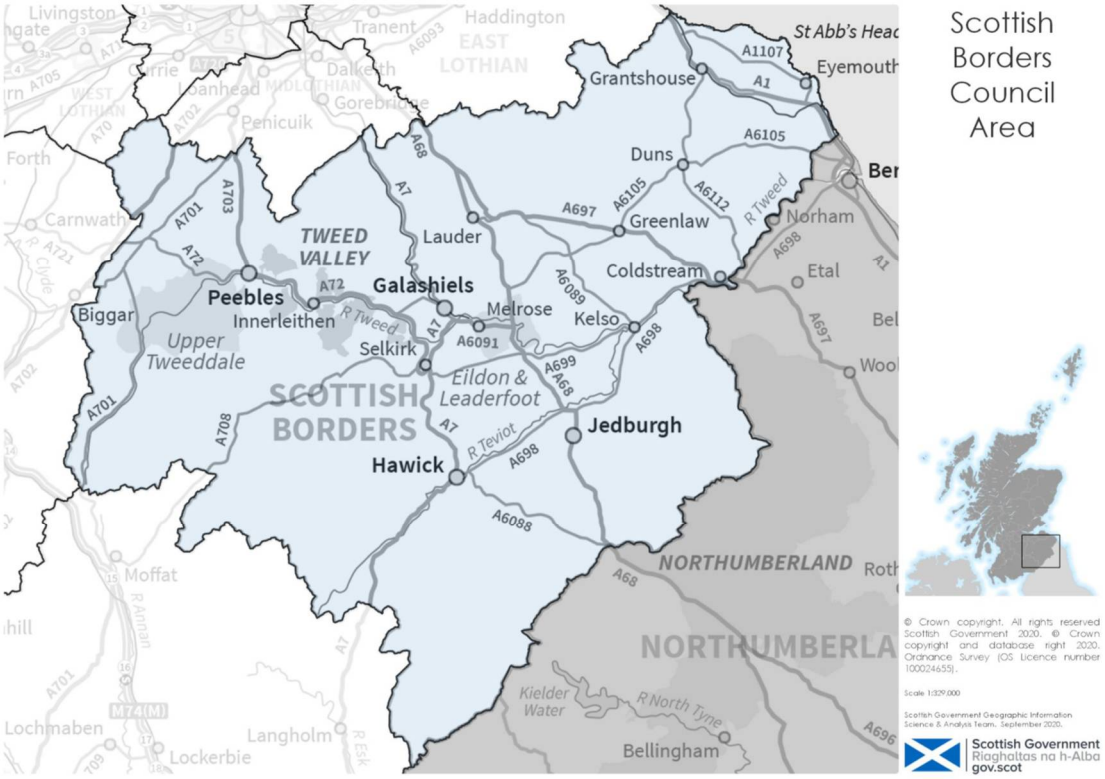


Figure 1: Map of the Scottish Borders area (Source: Scottish Government)

2.2 Methods

This evaluation study of the effectiveness of 20mph speed limit used a quantitative analysis approach to identify the impact of the 20mph on various dimensions of vehicle speeds. Analysis of a "before-after" vehicle speeds was carried out on the account of the 20mph speed limit introduction as the threshold that explains the "before" and "after" traffic speed situations in a comparative manner. The quantitative data is drawn from traffic surveys conducted at different stages of the intervention.

2.3 Data Sources

Speed data was collected through traffic surveys conducted by Tracsis by the instance of Scottish Borders Council. The traffic and speed data were collected at locations across the Scottish Borders in different stages of the 20mph intervention. For this study, the focus of the analysis is primarily on surveys 1, 2 and 4. The survey waves were processed and analysed corresponding to distinct phases of the intervention.

Survey 1 was carried out a few weeks before the introduction of the 20mph speed limit signifying the pre-intervention state of vehicle speeds. And it is also referred to as "before" survey in the analysis and results. Furthermore, Survey 2 was carried out in most of the site about 4 -5 weeks after the introduction of the 20mph speed limit. The Survey 2 data expected to capture the post-intervention state of vehicle speeds in a short period following intervention. And it is also referred to as "After I" survey in the analysis and results. While Survey 4 was conducted up to 7 to months after the introduction of the 20mph speed limit this post intervention survey captured the vehicle speeds in a longer interval after the introduction of the 20mph speed limit. It is also referred to as "After III" survey in the analysis and results.

The identification of school presence, the identification of straight or curved segments was accomplished through virtual inspection of sites using images from Google maps and Google Earth.

3 Analysis and Discussion

3.1 Descriptive analysis of vehicle speeds before and after the 20mph intervention

the distributions of sites per range of mean and 85th percentile speeds are analysed for surveys 1, 2 and 4, as survey 3 is excluded in the results presented in this paper. Specifically, based on the previous research and practice for speed surveys, sites are classified in groups (otherwise referred to as "bands") based on the range of mean or 85th percentile speed the sites are associated with. In this context, successive speed ranges are specified for each band beginning from zero to 20mph and considering a separate range per each 5-mph increment afterwards. Therefore, the occurrence of sites associated with each speed range was determined by using various speed metrics as criteria for classification, i.e., the mean and 85th percentile speed. Such a configuration of speed data can give a broader summary of the distribution of sites across various levels of the examined speed metrics.

Data for one hundred and nine (109) common sites across Survey 1, Survey 2 and Survey 4, as such used for the purpose of the analysis. All these sites were previously 30mph speed limits before the introduction of the 20mph scheme. Thus, the measurement of impact of the change in speed limit from 30 mph to 20 mph on vehicle speeds by comparing the speed values for these sites.

Figures 2 shows the distribution of sites per **mean speed** band in Survey 1, 2 and 4 survey waves. the outcomes shown that the "after III" speed distribution is extremely like the "after I" distribution. In other words, the percentage of sites in the >30-35 mph band is almost zero, while over 75% of sites have mean speeds lower than 25 mph. The distribution in Survey 4 gives evidence of reductions in mean speeds observed "after I" seem to be greatly sustained long time (almost 8months) after the 20mph speed limit introduction.

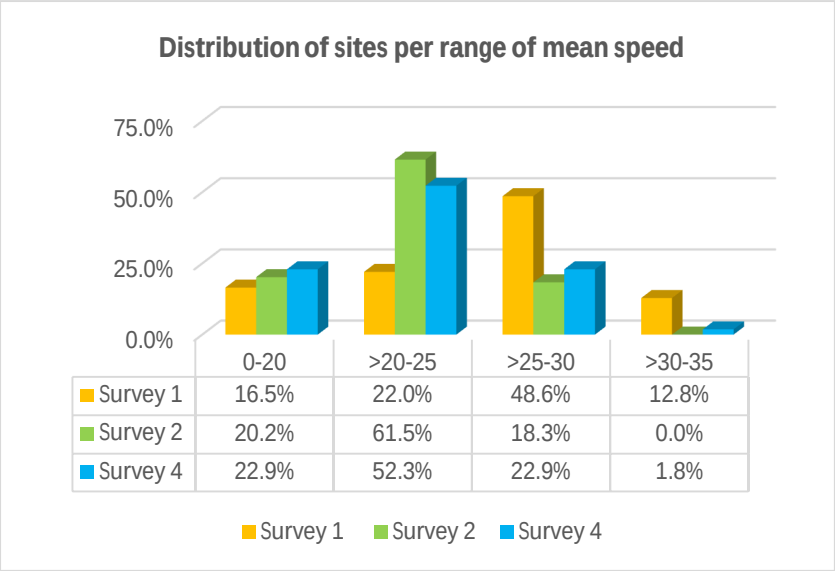


Figure 2: Distribution of sites per range of mean speed for Survey 1 vs Survey 2 vs Survey 4

The comparison of Survey 1, 2 & 4 (Table 1 and Table 2) gave more insights on the progression of speed metrics over period. The overall finding indicates that Survey 2 and Survey 4 show the mean and 85th percentile speed recorded reduced speed to a considerable extent. Remarkably, there is convergence of speed values of the mean and 85th percentile to close values “after I” and “after III” showing speed reductions in the range of 2.7-3.2 mph compared to “before”. There are noticeable lower standard deviations of mean and 85th percentile speeds in Survey 2 & 4 compared to “before”. This is a further prove on the presence of more homogeneous speed patterns after the 20mph speed limit introduction.

Table 1:Descriptive statistics of mean speed for Survey 1("before”), Survey 2 ("after I") and Survey 4 ("after III")

Mean speed	N	Minimum	Maximum	Mean	Std. Deviation
Survey 1	109	14.50	34.80	25.33	4.564
Survey 2	109	14.20	27.60	22.22	3.018
Survey 4	109	13.50	30.20	22.64	3.274

Table 2:Descriptive statistics of 85th percentile speed for Survey 1 ("before”), Survey 2 ("after I") and Survey 4 ("after III")

85th percentile speed	N	Minimum	Maximum	Mean	Std. Deviation
Survey 1	109	18.10	42.40	30.21	4.896
Survey 2	109	17.30	34.10	27.03	3.753
Survey 4	109	16.20	35.60	27.59	3.932

3.2 Spatial and Temporal analysis of vehicle speeds before and after the 20mph intervention

The evaluation of the impact of the 20mph trial on distributions of speed metrics giving attention on key attributes of the sites which include, such as the local area, settlement type, school presence, as well as on temporal factors are presented in this section.

3.2.1 Speed distribution by local area

The various levels of impact of the 20mph speed limit introduction i on vehicle speeds in Tweeddale, Cheviot, Eildon, Teviot and Liddesdales, and Berwickshire which constitute the five local areas of the

Scottish Borders, i.e., is studied utilizing the mean and 85th percentile speed distributions. The sites that fall under each of these local areas was aggregated to identify any significant spatial variations in the distributions of these key speed metrics before and after the introduction of the 20mph speed limit.

Table 3 shows the mean speed distributions in Survey 1 ("before") and Survey 2 ("after I"), indicating the "before" mean speed is clustered around greater speed bands across all local areas, and specifically around the speed band >25 -30 mph. Nevertheless, Table 3 indicates that "after I" mean speeds tend to be linked with lower speed bands, with the most noticeable clustering of sites being observed around the speed band >20-25 mph. Sites in Teviot and Liddesdale exhibit the largest percentage in this speed band with 80.0%, Cheviot has a percentage of 43.5%, and Tweeddale yields a percentage of 70%. These outcomes suggest a significant effect of the intervention across all the local areas in the "after I" period, as a major transition of mean speeds is confirmed from higher to lower speed bands, and particularly, from the >25-30 mph band to the >20-25 mph speed band. Furthermore, an increase in the "after I" percentages of sites with mean speed in the band 0-20 mph, as compared to the "before" percentages, is also noticed for Cheviot, Eildon, Berwickshire and Teviot & Liddesdale.
Focusing on "after III" state (Survey 4), the distribution of mean speeds (as shown in the Appendix 1) indicates that for almost all local areas, most sites have mean speeds in the >20-25 mph range, which is a similar pattern with Survey 2. This is exception to Cheviot, which 40.9% of the locations possess mean speeds in the range >25-30 mph.

Table 3: Distribution of mean speed by local area in Survey 1 ("before") and Survey 2 ("after I")

Local Area	0-20		>20-25		>25-30		>30-35	
	S1(%)	*S2(%)*	*S1(%)*	*S2(%)*	*S1(%)*	*S2(%)*	*S1(%)*	*S2(%)*
Tweeddale	0.0	0.0	25.0	70.0	55.0	30.0	20.0	0
Cheviot	21.7	26.1	13.0	43.5	47.8	30.4	17.4	0
Eildon	20.6	26.5	29.4	58.8	41.2	14.7	8.8	0
Teviot & Liddesdale	10.0	20.30	40.0	80.0	50.0	0.0	0.0	0
Berwickshire	25.0	30.0	14.3	63.3	50.0	6.7	10.7	0

3.2.2 Speed distribution by settlement type

In order to account for the possible impact of the settlement type on vehicle speeds before and after the 20mph speed limit intervention, the study explored the differences in key speed metrics for three different types of settlements, which were defined on the basis of their built environment characteristics: very rural, rural, and urban.
The mean speed distribution of sites for Survey 1 ("before") and Survey 2 ("after I") by settlement type are presented in Table 4. For this comparison, 42 sites were classified as very rural, 42 sites were classified as rural, and 31 sites were classified as urban. As anticipated, most sites in all the settlement type are associated with mean speeds in the band >25-30 mph "before", with the urban sites showing a higher propensity towards this band. Further observation from Table 4, the "after I" mean speeds reduce, with rural and urban areas generating the greatest percentages of sites in the >20-25 mph band. while the very rural sites have the largest percentage in the 0-20 mph band of approximately 35% across all settlement types. In general, the comparison of "before-after I" indicates substantial changes towards lower speed bands for all the settlement types, and such changes are more demonstrated in very rural areas (0-20 mph: before 23.8%, after 39.4%; >20-25 mph: before 26.2%, after 48.8%). Also, a similar distribution of mean speeds is noticeable in Survey 4 ("after III"), as shown in Appendix 2; 69% of urban settlements and 47.5% of rural and very rural settlements have mean speeds in the >20-25 mph band. In general, the outcomes imply that changes towards lower speed bands are more evident in urban areas, specifically when focusing on the 85th percentile metric. This result is expected, possibly as result of the effect of more severe traffic patterns on vehicle speeds in urban areas (Pantangi *et al.*, 2020).

Table 4: Distribution of mean speed by settlement type in Survey 1 ("before") and Survey 2 ("after I")

Settlement Type	0-20		>20-25		>25-30		>30-35	
	S1(%)	*S2(%)*	*S1(%)*	*S2(%)*	*S1(%)*	*S2(%)*	*S1(%)*	*S2(%)*
Very Rural	28.8	34.9	26.2	48.8	35.7	16.3	14.3	0.0
Rural	19.0	20.9	23.8	65.1	50.0	14.0	7.1	0.0
Urban	6.5	6.5	16.1	71.0	61.3	22.6	16.1	0.0

3.2.3 Speed distribution by school presence

Considering the notable role of traffic speeds in determining the level of road safety in areas associated with school presence (Cleland et al., 2020), the examination of the mean and 85th percentile speeds changes before and after the 20mph speed limit intervention was carried out such areas. For this analysis, the presence within the vicinity of a range of approximately 300 metres to where speed data was captured as the key criterion for the classification of sites with school presence. The verification of the school presence was carried out by inspection of the surrounding area of each of the sites using Google maps and Google Earth images in conjunction with the relevant data provided by the Scottish Borders Council.

The mean speed distribution of Survey 1 ("before") and Survey 2 ("after I") for sites where a school is present in their vicinity are presented in Figure 3. The study shows that 25 sites out of the 115 common sites in Survey 1 and 2 were having a school in the vicinity. Also, Figure 2 indicates that 60% of sites with school presence yield "before" mean speeds that fall either in the >25-30 mph or the >30-35 mph band. But approximately 84% of sites with school presence result in "after I" mean speeds that belong either in the 0-20 mph band or the >20-25 mph band. This indicates an apparent reduction in mean speeds of sites with school presence between "before" and "after I". Also, similar percentages per speed band were observed for sites without school in their vicinity.

Addressing Survey 2, about 12% of sites have "after I" 85th percentile speeds that fall in the >20-25 mph speed band, while about 68% of sites fall under the >25-30 mph band. Notably, the percentage of sites in the band >30-35 mph declined from 52% in Survey 1 to 20% in Survey 2. All these percentages suggest apparent reductions in 85th percentile speeds "after I" compared to "before".

The comparison of mean and 85th percentile speed distributions across Survey 1, Survey 2, and Survey 4 ("after III") is given Figure 4. For Survey 4, the distributions do not show noticeable variations compared to Survey 2. Most sites, amounting to about 73.9% with school presence possess mean speed in the range >20-25 mph, while for 65.2% of sites, the 85th percentile speed belongs in the >25-30mph band. Furthermore, a slight increase is noticeable in Survey 4 for sites having 85th percentile speed in lower speed ranges (lower than 25mph).

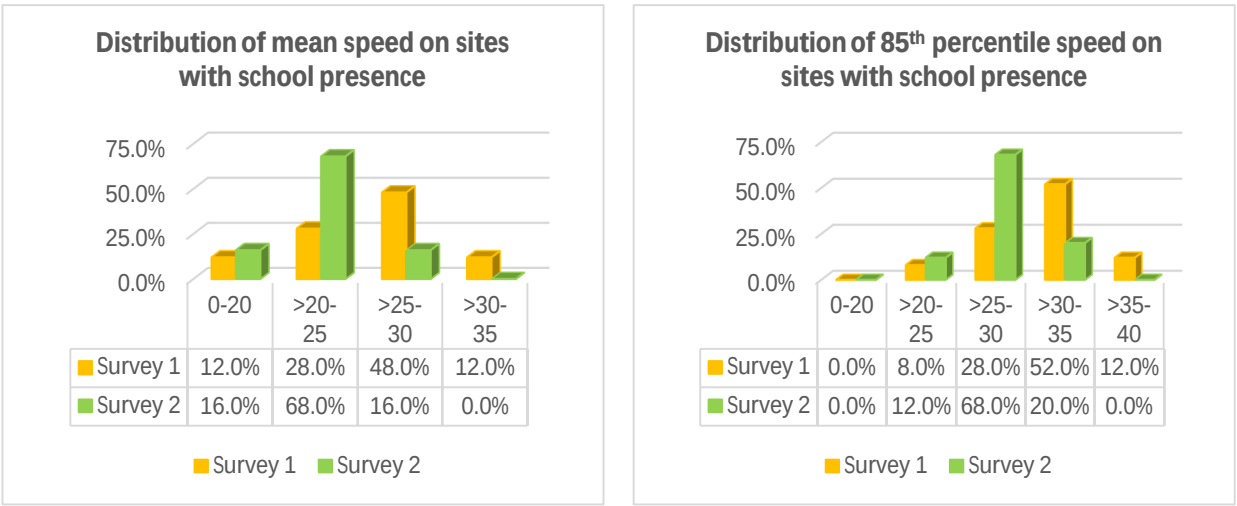


Figure 3:Distribution of mean speed and 85th percentile speed on sites with school presence for Survey 1 ("before"), Survey 2 ("after I")

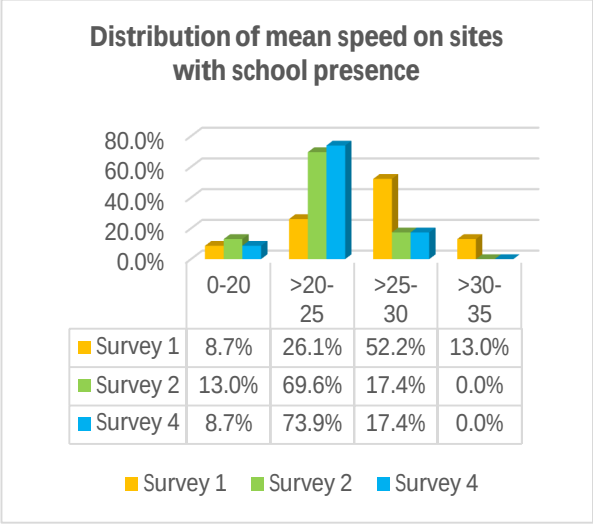


Figure 4: Distribution of mean speed and 85th percentile speed on sites with school presence for Survey 1 ("before"), Survey 2 ("after I") and Survey 4 ("after III")

3.2.4 Speed distributions by temporal characteristics

The findings revealed that the speed patterns "before" are characterized by stability overall, with the largest percentages of sites belong to the >25-30 mph band during Mondays and Tuesdays. In the same days, the lowest percentages of sites for speed bands greater than 30 mph was noticeable. However, On Fridays and weekends, relatively larger percentages of sites (compared to the other days of the week) are observed in the >30-35 mph speed band.

The Figure 4 presents the distributions of mean speed by day of the week for Survey 1 ("before") and Survey 2 ("after I") and Survey 4 ("after III").

The key finding analysed from the practical exclusion of sites linked with mean speeds higher than 30 mph across all days of the week in survey 2. Compared to "before", there was a significant decline in the percentages of sites with mean speeds in the band >25-30 mph. Also, simultaneously, a major increase in the percentages of sites in the band >20-25 mph across all days of the week, with the greatest increase, which amount to 42.2%, being identified on Mondays. Milder increases are equally noticeable in the percentages for the band 0-20 mph, particularly during the weekends.

In general, in Survey 4, the weekend indicates a slightly higher tendency for higher speeds in relation to the weekdays, as also shown in the Figures 5 and 6, which give the distributions of mean and 85th percentile speeds for weekdays and weekends, accordingly.

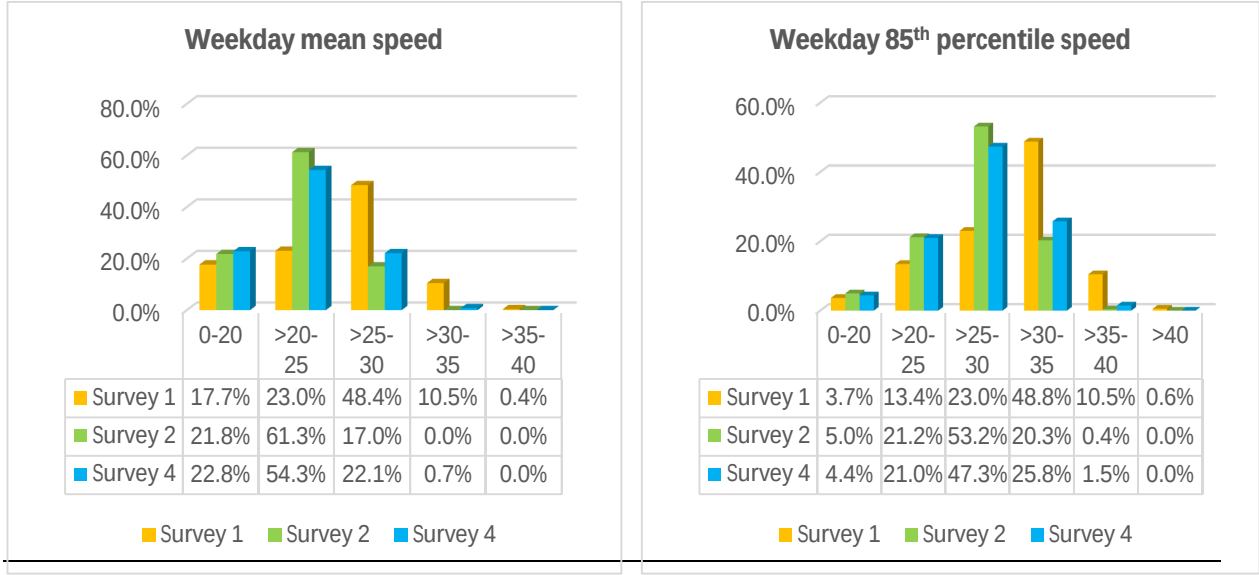


Figure 5: Weekday mean and 85th percentile speed distribution for Survey 1, Survey 2, and Survey 4

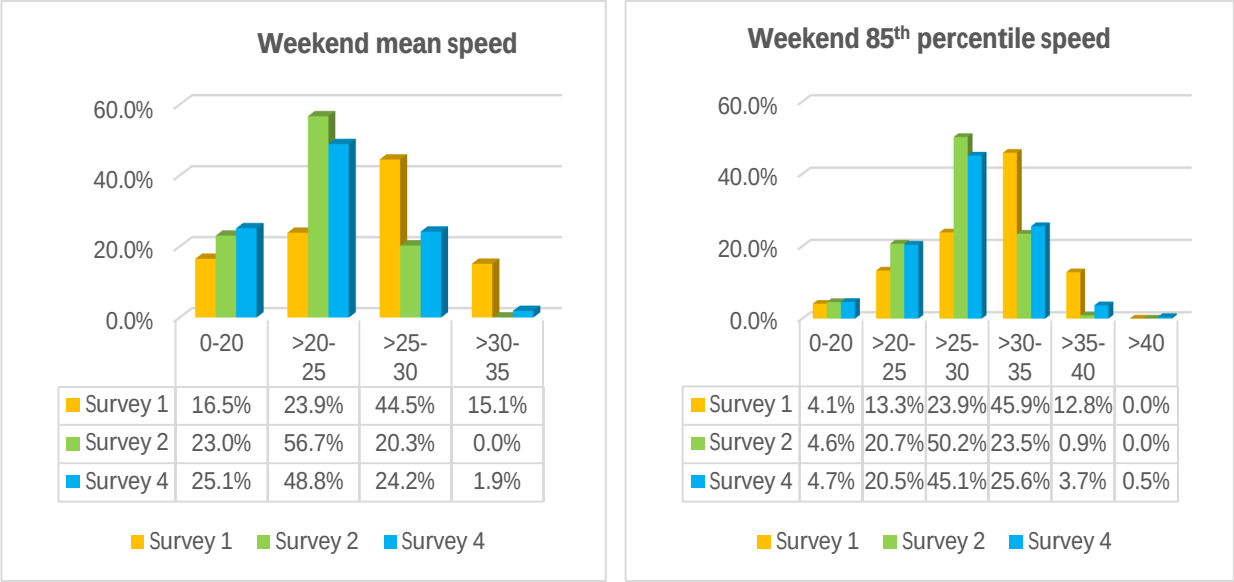


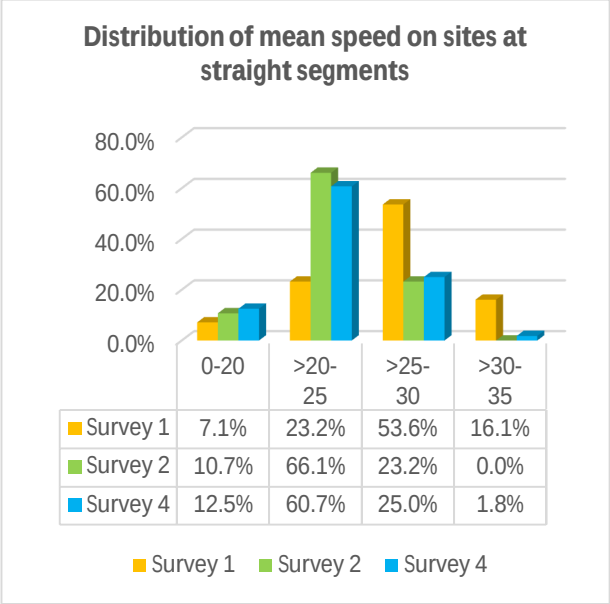
Figure 6: Weekend mean and 85th percentile speed distribution for Survey 1, Survey 2 and Survey 4

3.2.5 Speed distribution by road alignment characteristics

The findings from previous research study indicated that road alignment attributes may possess a substantial impact on driving performance, and consequently, on speed-associated decisions (Anastasopoulos and Mannering, 2016).Based on this significant finding, the analysis of the distributions of the mean and 85th percentile speed before and after the introduction of the 20mph speed limit for sites located on straight and curved segments as to compare their outcomes and possible impact on driving decisions.

Focusing on "before"-"after I" comparison, 59 sites were located on a straight segment, while 56 sites were located on a curved road segment. For the sites located on straight segment, over two thirds (67.8%) of the distribution of the "before" mean speed are placed above 25 mph, and especially under the >25-30 mph and >30-35 mph speed bands. But more than three fourths (78.3%) of the "after I" distribution fall either under the 0-20 mph or the >20-25 mph speed band. This result indicates a substantial reduction in mean speeds between the "before" and "after I" distribution for sites located on straight segments.

The distributions of mean and 85th percentile speeds in Survey 4 show similar pattens as Survey 2 as shown in Figures 7 and 8. In Survey 4, a slight increase was recorded in the sites located at straight segments, in particular the sites that have mean speed lower or equal to 20mph. Similarly, an increase in the proportion of curved segments that have mean speed in the range >25-30 mph was observed. Overall, the Survey 2 and Survey 4 85th percentile distributions for both straight and curved segments are very similar, with most sites having 85th percentile speeds in the >25-30 mph band as shown in Figures 6 and 7.



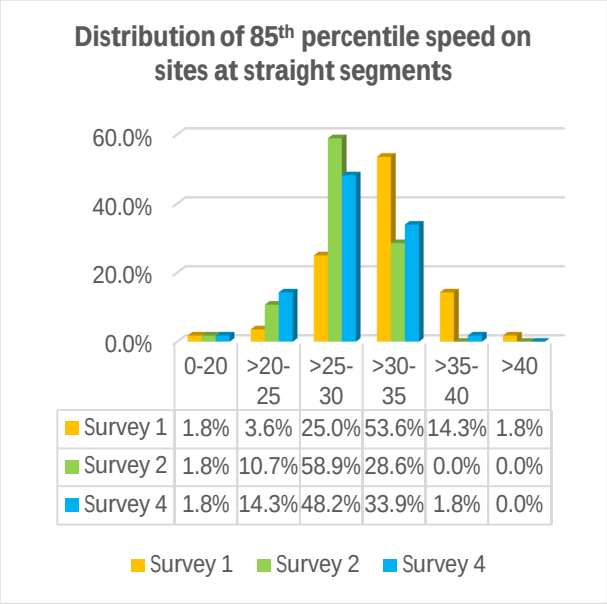
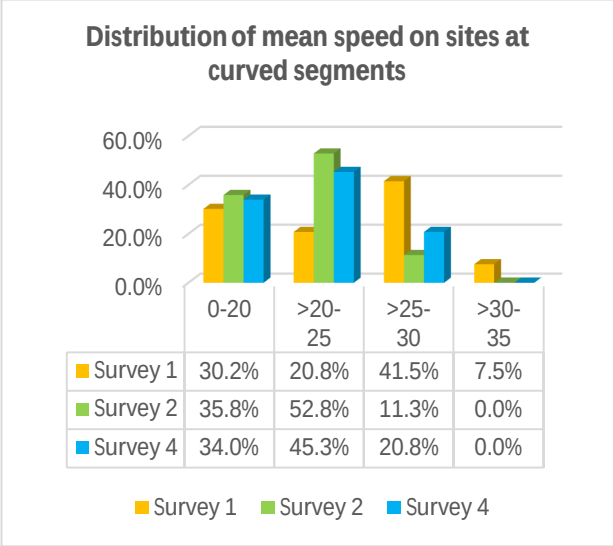


Figure 7:Distribution of mean speed and 85th percentile speed on sites at straight segments for Survey 1, Survey 2, and Survey 4



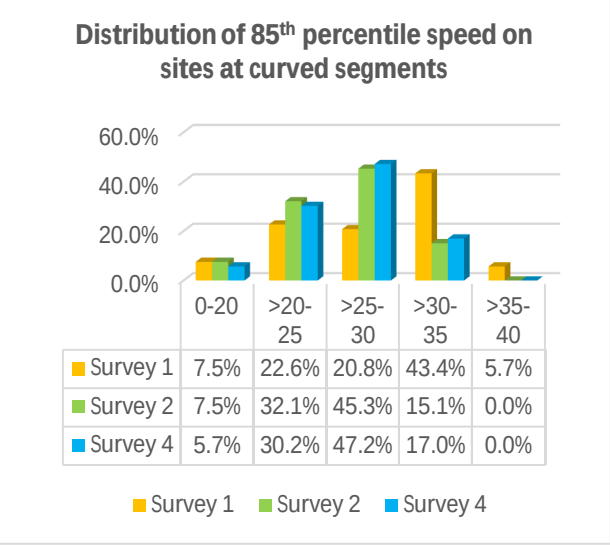


Figure 8: Distribution of mean speed and 85th percentile speed on sites at curved segments for Survey 1, Survey 2, and Survey 4

4 Conclusions

Vehicle speed in urban and rural environment is vital to the safety of all the road users. The study has established a downward shift observation in the key metrics after the intervention of 20mph speed limit. There were speed reductions across very rural, rural, and urban areas which constitute the settlement types after the intervention. Mostly, most urban locations were observed to yield mean speeds in the range of >20-25 mph after 20mph speed limit was introduced. Also, there were significant speed reductions found in locations with a school in their vicinity. However, before the 20mph speed limit intervention, most of these locations recorded mean speeds greater than 25 mph. There was downward shift in most of these sites to mean speeds lower than 25 mph after the intervention at a shorter and longer term. Th focus on both weekdays and weekends indicated speed reductions after the implementation of the 20mph intervention. Nevertheless, slightly greater decreases are found in weekdays. There were no significant differences observed in the speed reduction patterns when

compared the straight and curved segments, but speed reductions were found for both types of road alignments.

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Appendixes

Appendix 1: Distribution of mean speed by local area in Survey 1 ("before"), Survey 2 ("after I") and Survey 4 ("after III")

Local Area	0-20			>20-25			>25-30			>30-35		
	S1(%)	*S2(%)*	*S4(%)*	*S1(%)*	*S2(%)*	*S4(%)*	*S1(%)*	*S2(%)*	*S4(%)*	*S1(%)*	*S2(%)*	*S4(%)*
Tweeddale	0.0	0.0	11.1	22.2	66.7	61.1	55.6	33.3	27.8	22.2	0.0	0.0
Cheviot	22.7	27.3	27.3	13.6	40.9	31.8	45.5	31.8	40.9	18.2	0.0	0.0
Eildon	21.9	28.1	28.1	28.1	59.4	53.1	40.6	12.5	15.6	9.4	0.0	3.1
Teviot & Liddesdale	10.0	20.0	0.0	40.0	80.0	90.0	50.0	0.0	10.0	0.0	0.0	0.0
Berwickshire	25.9	29.6	29.6	14.8	63.0	51.9	51.9	7.4	18.5	74	0.0	0.0

Appendix 2: Distribution of mean speed by settlement type in Survey 1 ("before"), Survey 2 ("after I") and Survey 4 ("after III")

Settlement Type	0-20			>20-25			>25-30			>30-35		
	S1(%)	*S2(%)*	*S4(%)*	*S1(%)*	*S2(%)*	*S4(%)*	*S1(%)*	*S2(%)*	*S4(%)*	*S1(%)*	*S2(%)*	*S4(%)*
Very Rural	25.0	35.0	30.0	27.5	47.5	47.5	35.0	17.5	22.5	12.5	0.0	0.0
Rural	20.0	22.5	30.0	22.5	62.5	47.5	50.0	15.0	22.5	7.5	0.0	0.0
Urban	6.9	6.9	3.4	13.8	72.4	69.0	62.1	20.7	24.1	17.2	0.0	3.4