The Impact of Speed Enforcement and Increasing the HGV Speed Limit on the A9(T)

Transport Scotland

Microsimulation Modelling and Accident Assessment

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THE IMPACT OF SPEED ENFORCEMENT AND INCREASING THE HGV SPEED LIMIT ON THE A9(T)

Description:	Microsimulation Modelling and Accident Assessment
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Background

The A9(T) forms the strategic road link between Central Scotland and the Highlands. The route comprises a mix of single and dual carriageways, together with a series of WS2+1 overtaking sections.

The A9(T) is governed by national speed limits that restrict Heavy Goods Vehicles (HGVs) in excess of 7.5 tonnes to 40mph on single carriageway sections. In reality, very few HGV drivers using the A9(T) comply with the speed restriction, but evidence suggests that those who do adhere strictly to the 40mph speed limit. Their impact on other traffic can be significant as lengthy platoons develop, increasing driver frustration and giving rise to difficult multiple overtaking manoeuvres through low headway traffic.

This problem is compounded during the summer months as the A9(T) is popular with tourist traffic motorhomes and caravans.

As part of Transport Scotland's Trunk Road Research programme, consultants were appointed to undertake a preliminary study to investigate the operational and safety impacts of increasing the single carriageway HGV speed restriction (for vehicles in excess of 7.5 tonnes) from 40mph to (a) 50mph and (b) 60mph (effectively 56mph).

Phase 1 Assessment

The study, carried out on Transport Scotland's behalf by SIAS Limited (SIAS) and the Transport Research Laboratory (TRL) involved the development of a microsimulation traffic model of the A9(T) covering 80km of the route between Dalwhinnie and Moy. The outputs from the traffic model were used to inform published relationships between the average speed of traffic and accidents.

The results of this assessment showed that an increase in the HGV speed limit would result in a slight increase in average speeds and a consequential reduction in journey times. Other predicted benefits included a reduction in vehicle emissions and a reduction in the desire to overtake.

While the research demonstrated that an increase in the HGV speed limit would be of benefit to the operation of the A9(T) the road safety implications were inconclusive. Department for Transport research undertaken in parallel with this study has drawn similar conclusions.

The results of the assessment were presented to Transport Scotland's Trunk Road Policy Steering Group (TRPSG) in September 2010. The Steering Group requested that the research be refined to include consideration of effective speed enforcement.

Phase 2 Assessment

The focus of the Phase 2 study was therefore refined, drawing on before/after data from the A77(T) following the introduction of SPECS average speed camera technology.

Microsimulation Modelling

The same (Dalwhinnie – Moy) traffic microsimulation model was used as the basis for the Phase 2 study, but an additional model was developed to replicate summer demand patterns. The models were then used to assess the impact of:

- the enforcement of all vehicle speeds, assuming the introduction of an average speed camera system, similar to that on the A77(T) SPECS trial route
- increasing the HGV speed limit to (a) 50mph and (b) 60mph (effectively 56mph) with average speed camera enforcement for all vehicles
- for the purposes of the assessment, models were developed to reflect an average 2010 "neutral" month and an average 2010 "summer" month.

Operational Assessment

The results of the microsimulation modelling can be summarised as follows:

<u>The Effect of Speed Enforcement (compared to the current situation)</u>

The results of the neutral month modelling indicated that, compared to the current situation, the introduction of effective speed enforcement would result in a:

- reduction of around 6mph in average speeds (all vehicles)
- corresponding increase of around 8% in modelled journey times
- reduction of up to 7% in the desire to overtake on single carriageway sections

The results for the summer models were similar, but slightly more pronounced.

The Effect of Speed Enforcement plus HGV Speed Limit Increases (compared to the current situation)

The results of the neutral month modelling indicated that, compared to the current situation, the introduction of effective speed enforcement combined with an increase in the HGV speed limit would result in a:

- slight reduction of 3mph in average speeds (all vehicles)
- slight increase of around 1min in journey times
- reduction of around 13% in the desire to overtake on single carriageway sections.
- reduction in the numbers of vehicles travelling at excessive speed
- general improvement in operational behaviour.

Again, the results for the summer models were similar, but slightly more pronounced.

In addition, the effect on vehicle emissions, speed distributions and operation were also assessed.

Together, the introduction of average speed cameras and the increase in HGV speed limits is predicted to help reduce overall emissions (Carbon Dioxide Equivalent, NOx and PM10). In general, there is a slight increase in the emissions for slow moving vehicles, but this would be offset by reductions in emissions for all other vehicle types.

In terms of vehicle speed distribution, the number of vehicles travelling at excessive speeds is predicted to reduce, as is the number of HGVs (and other slow moving vehicles) travelling at comparatively low speeds. This effect reduces the maximum speed and increases the minimum speeds respectively, thereby reducing the speed variation.

Operationally, the microsimulation modelling indicates that a general reduction in platoon lengths would result, with a reduction in the variation on vehicle headways.

Accident Assessment

As with the initial study, the outputs from the microsimulation modelling were used to estimate the effect on accidents using published relationships between the average speed of the traffic and accidents.

Modelled speed data for a number of locations on the A9(T) was used to derive comparisons between the current situation and the three scenarios identified above, using the 'neutral' month model.

<u>The Effect of Speed Enforcement (compared to the current situation)</u>

The results of the accident assessment indicated that:

- the introduction of effective speed enforcement alone, using average speed cameras similar to those on the A77(T), would result in a decrease in accidents. Fatal accidents would reduce by around 36 per cent, serious injury by around 25 per cent, and slight injury by up to 23 per cent. All injury accidents would decrease by 16 - 24 per cent.
- accident costs over the 80km section between Dalwhinnie and Moy were estimated to reduce by about £18,000 to £24,000 per km per year.

<u>The Effect of Speed Enforcement plus HGV Speed Limit Increases (compared to the current situation)</u>

The results of the accident assessment indicated that:

- if HGV speeds are increased to 50mph, a net reduction in accidents would still be achieved when compared to the current situation if effective enforcement is applied. Fatal accidents would reduce by around 27 per cent, serious injury accidents by around 18 per cent, and slight injury accidents by up to 17 per cent. All injury accidents would decrease by 12 to18 per cent. Compared with the current situation, accident costs were estimated to reduce by £14,000 to £18,000 per km per year, over the modelled section.
- even if HGV speeds are increased to 60mph (effectively 56mph) a net reduction in accidents would still be achieved when compared to the current situation if effective enforcement is applied. Fatal accidents would still reduce by around 23 per cent, serious injury accidents by around 15 per cent, and slight injury accidents by up to 14 per cent. All injury accidents would decrease by 10 to 14 per cent. The accident costs were estimated to reduce by £11,000 to £15,000 per km per year compared to the current situation.

Comparison with Government Objectives

The Scottish Government assesses all transport schemes against the transport planning objectives outlined in the Scottish Transport Appraisal Guidance (STAG). These objectives are: Environment, Safety, Economy, Integration, Accessibility and Social Inclusion. A qualitative assessment of the impacts of these measures against the stated objectives is summarised as follows:

- **Environment:** A small reduction in overall tailpipe emissions (all vehicles combined) could be expected from an increase in the speed limit for HGVs, whether in conjunction with speed enforcement measures or not. A slight, general increase in emissions for slow moving/heavy vehicles would be offset by reductions in emissions for all other vehicle types

- **Safety:** The safety impact of increasing the HGV speed limit alone was inconclusive. However, accident benefits were consistently predicted when an increase in HGV speed limits was combined with speed enforcement measures

- **Economy:** The operational improvements from an increase in HGV speed limit would be counter-balanced by speed enforcement measures. Reduced accident numbers would be achieved with speed enforcement measures in place, helping to offset any operational disbenefit. Uncertainty over the setup and enforcement costs of a speed enforcement system make it difficult to capture the full costs and benefits to the wider economy of these measures

- **Integration:** The impacts with respect to integration in transport, land-use and policy terms of these measures are likely to be negligible

- **Accessibility & Social Inclusion:** The impacts with respect to community/comparative accessibility and, hence social inclusion of these measures are likely to be negligible

Conclusions

The research demonstrated that effective speed enforcement, using an average speed camera system similar to that on the A77(T), results in a reduction in the numbers of vehicles travelling at excessive speed. The average speed of all vehicles would reduce and the results suggest that operational behaviour would improve. Therefore, while overall speeds would reduce and journey times would increase, there would likely be improvements in the reliability/variability of journey times. Additionally, longer platoons would likely occur less frequently, which could in turn reduce the likelihood or propensity for drivers to consider higher risk overtaking manoeuvres along the route.

With effective speed enforcement and the HGV speed limit increased to 50mph or 60mph (effectively 56mph), the average speed of all vehicles would remain lower than the current situation.

Together, the introduction of effective speed enforcement and the increase in HGV speed limits would reduce overall emissions. Analysis of the speed distributions suggests that the variation in vehicle speeds would reduce. Improvements in operation and behaviour are also predicted.

In terms of accidents, the assessment indicated that the number and severity of accidents would decrease compared with the current situation. The accident cost savings, compared with the current situation, are estimated as follows:

- the introduction of speed enforcement will result in savings of between £18,000 and £24,000 per km per year
- the introduction of speed enforcement plus increasing the HGV speed limit to 50mph will result in savings of between £14,000 and £18,000 per km per year
- the introduction of speed enforcement plus increasing the HGV speed limit to 60mph (effectively 56mph) will result in savings of between £11,000 – £15,000 per km per year

1 Introduction

1.1 Background

The A9(T) forms the strategic road link between Central Scotland and the Highlands. The route comprises a mix of single and dual carriageways, together with a series of WS2+1 overtaking sections.

The A9(T), as with all other S2 roads, is governed by national speed limits that restrict Heavy Goods Vehicles (HGVs) in excess of 7.5 tonnes to 40mph on single carriageway sections. In reality, very few HGVs using the A9(T) comply with the speed restriction, but evidence suggests that those that do, adhere strictly to the 40mph speed limit. Their impact on other traffic can be significant as lengthy platoons develop increasing driver frustration and giving rise to unsafe overtaking manoeuvres.

The problem is compounded during the summer months as the A9(T) is popular with tourist traffic comprising motorhomes and cars with caravans.

As part of Transport Scotland's Trunk Road Research programme, consultants SIAS Limited (SIAS) and the Transport Research Laboratory (TRL) were appointed to undertake a preliminary study to investigate the operational and safety impacts of increasing the single carriageway HGV speed restriction (for vehicles in excess of 7.5 tonnes) from 40mph to 50mph, or possibly 60mph.

The study involved the development of an S-Paramics microsimulation traffic model of the A9(T), covering the route between Dalwhinnie and Moy. The outputs from the traffic model were used to inform published relationships between the average speed of traffic and accidents.

In addition, the study considered the effects of demand flow seasonality and the economic impact of Transport Scotland's current WS2+1 improvement strategy.

1.2 Results from Initial Assessment

The findings from the initial assessment were reported in *Estimation of the Effect of Increasing the HGV Speed Limit on the A9(T) (SIAS Ref. 72377, February 2010)*.

1.2.1 <u>Traffic Modelling</u>

The results of the microsimulation modelling indicated that an increase in the HGV speed limit (over the modelled section) would result in:

- a reduction in average journey times by approximately 3%

- a significant reduction in the number of platoons greater than 16 vehicles

- no significant difference in the average headways between vehicles

- a predicted increase in average speeds (by up to 5mph)

- emissions levels would decrease slightly but that the slower moving HGVs would experience an increase of around 12%

- the total number of successful overtaking manoeuvres would increase by up to 4% and the number of unsuccessful overtaking manoeuvres would decrease by up to 5%

- improvements in journey reliability over the modelled section with minimum speeds predicted to increase, on average, by up to 7mph

1.2.2 <u>Accident Assessment</u>

The accident assessment was undertaken using two approaches; the first method used modifications to existing speed distributions, while the second approach was based on the findings of the microsimulation modelling.

The analysis using the first approach concluded:

- assuming that HGV compliance with the HGV limit *stays the same* and with the HGV speed limit increased to 50mph, the increase in accidents was less than 1%. Increasing the limit to 60mph, the increase was less than 2%.

- assuming that *100% of HGVs* comply with the speed limits and with the HGV speed limit increased to 50mph, the reduction in accidents was around 1 – 2%. Increasing the limit to 60mph, the reduction was less than 2%. With the HGVs speed limit unchanged at 40mph, the reduction was around 6 – 9%.

- assuming that *all vehicles* comply with their speed limits and with the HGV speed limit increased to 50mph, the reduction in accidents was around 13 – 18%. Increasing the limit to 60mph, the reduction was less than 7 – 13%. With the HGV speed limit unchanged at 40mph, the reduction was around 20%.

The results from the second approach, using the outputs from the microsimulation modelling, indicated:

- with the HGV speed limit increased to 50mph (Option 1), the number of injury accidents could be expected to increase by 3 – 4%, with the number of fatal injuries accidents expected to increase by 5%. Accident costs were estimated to increase by about £3,000 – £4,000 per km per year

- with the HGV speed limit increased to 60mph (Option 2), the number of injury accidents would be expected to increase by 4%, with the number of fatal injury accidents expected to increase by 7%. Accident costs were estimated to increase by about £3,500 – £4,500 per km per year.

Overall, while the research demonstrated that an increase in the HGV speed limit would be of benefit to the operation of the A9(T), the road safety implications were inconclusive. Department for Transport research undertaken in parallel with this study has drawn similar conclusions.

1.3 Requirement for Further Assessment

The results of the assessment were presented to Transport Scotland's Trunk Road Policy Steering Group (TRPSG) in September 2010. The Steering Group requested that the research be refined to include consideration of effective speed enforcement.

The focus of the further study was therefore refined, drawing on observations of the operational behaviour on the A77(T) following the introduction of the SPECS average speed camera technology.

This report summarises the results of further traffic modelling and accident assessments carried out to assess the impact of:

- the enforcement of all vehicle speeds, assuming the introduction of an average speed camera system, similar to that on the A77(T) (the SPECS trial site)
- increasing the HGV speed limit to 50mph, or 60mph, with average speed camera enforcement for all vehicles (as above)

2 Microsimulation Modelling Refinement

2.1 General

The same traffic microsimulation model used in the initial study was used as the basis for the further study.

As the requirements of Phase 2 study include the impacts of seasonal differences in traffic flow, the effect of speed enforcement and vehicle speed distributions, the model was refined to take account of:

- seasonality of demand flows
- impact of average speed camera enforcement
- slow moving vehicles

The following sections outline the various refinements to the microsimulation model.

2.2 Model Extents

The extents of the traffic model are illustrated in Figure 2.1. The model covers the A9(T) between Dalwhinnie and Moy, and comprises a mix of single and dual carriageway sections, along with WS2+1 overtaking lanes.

The model was developed for a 24hr period and has been calibrated to 2008 traffic levels.

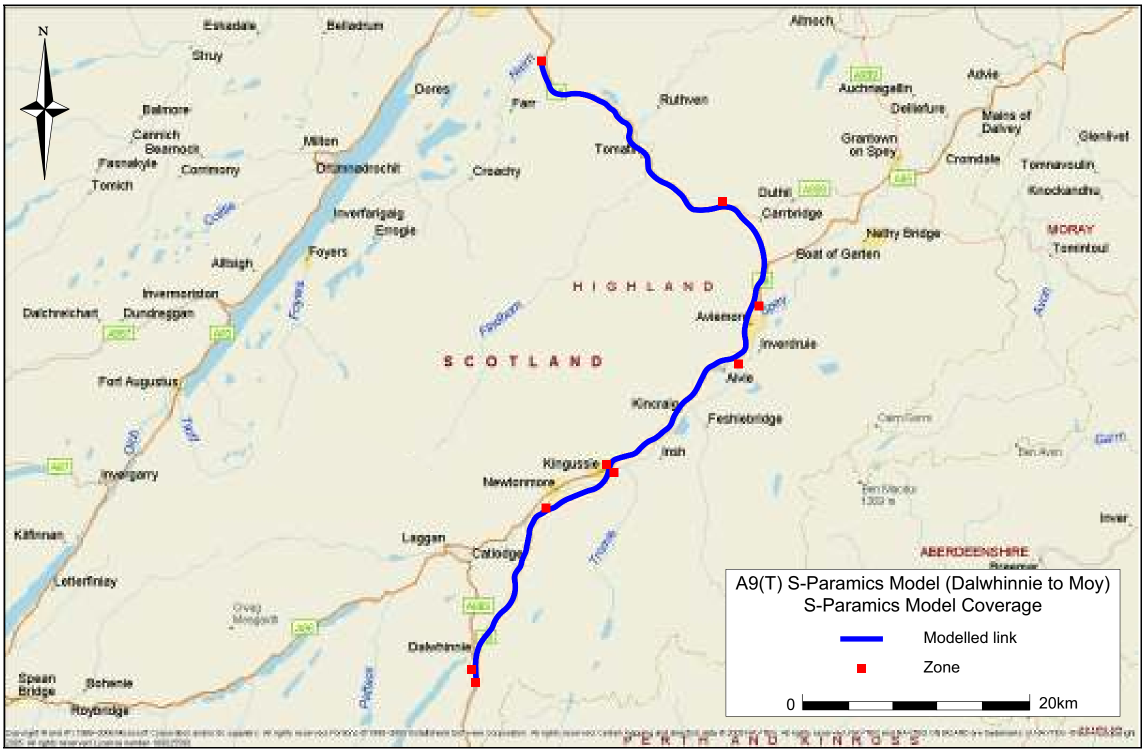

Figure 2.1 : Extent of A9(T) Microsimulation Model

The characteristics of the Base model are as follows:

- the network description was developed from 2008 OS mapping information
- 24hr trip matrices were derived from observed June 2008 traffic data
- the Base Year traffic demands were growthed to 2010 levels using 1997 National Road Traffic Forecasts (NRTF)

2.3 Impact of Seasonality

2.3.1 Seasonal Variation in Demands

The seasonal variations in demand flows were analysed using 2009 data from Automatic Traffic Counter (ATC) site JTC00313, located near Aviemore. The 2009 data from this site was selected because it was readily available within the study timescales.

Data for each month was averaged by hour using Tuesdays, Wednesdays and Thursdays for both northbound and southbound directions to create an average weekday profile.

The average weekday profiles for each month were compared to one another to allow any trends in the weekday flows to be established. The average two-way hourly weekday flow profile for each month is illustrated in Figure 2.2.

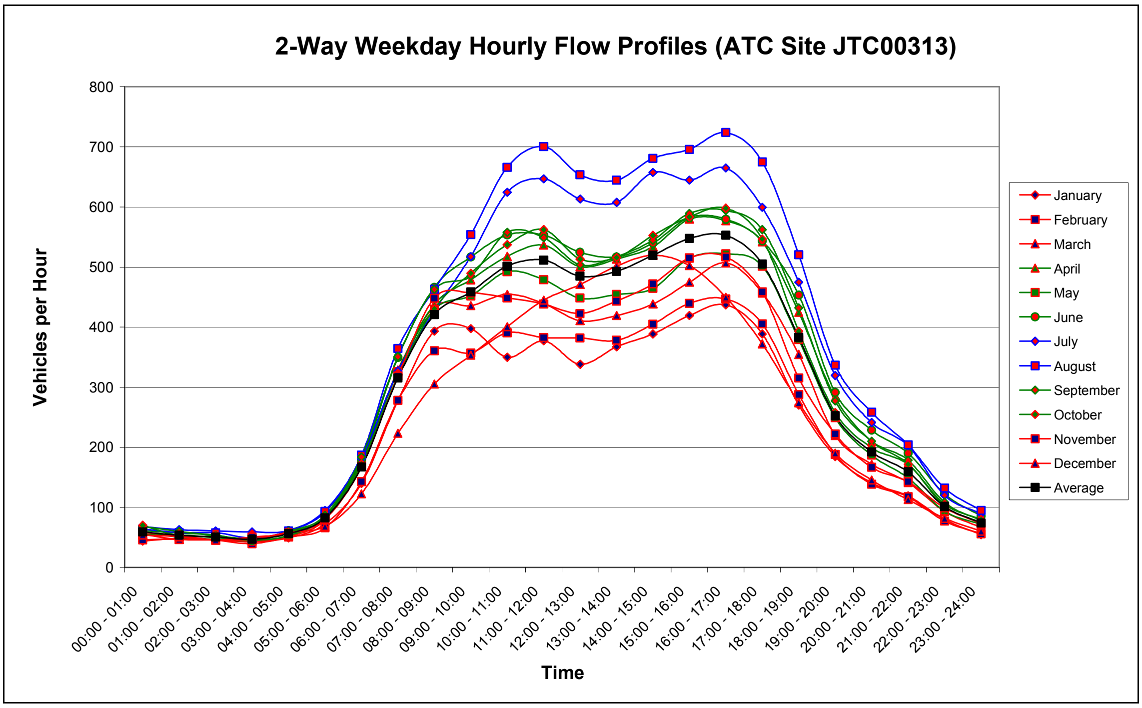

Figure 2.2 : Weekday Hourly Flow Profile (2009, Two-Way Average)

This analysis confirms that the 12 months typically fall into three categories, all of which are illustrated in Figure 2.3:

- lower than average daily flow, consisting of; January, February, March, November and December (highlighted in red)
- average or 'neutral' daily monthly flow, consisting of; April, May, June, September and October (highlighted in green)
- higher than average daily flow, consisting of; July and August (highlighted in blue)

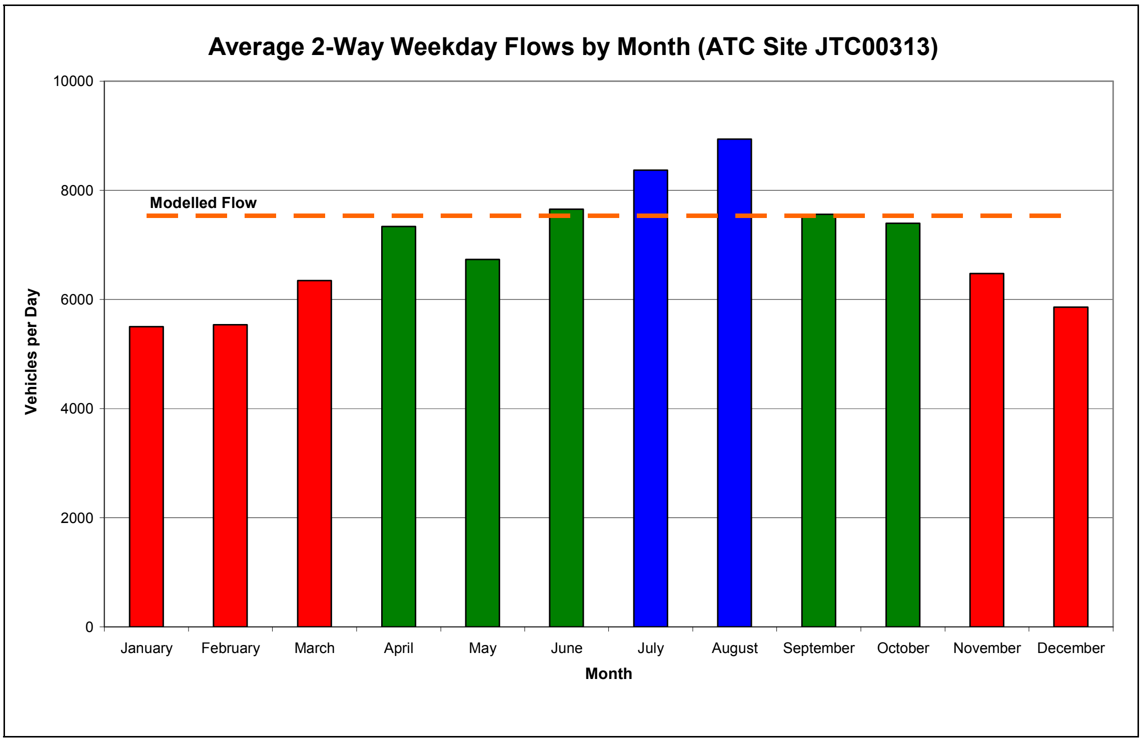

Figure 2.3 : Monthly Flow Profile (2009, Two-Way Average)

The analysis confirms that there is a pronounced peak in the demand flows on the A9(T) during the summer. In terms of reflecting the seasonality in the traffic model, it is important to understand what traffic is creating this peak flow.

It was felt that the seasonality would be best reflected through the development of a separate 'summer' demand model.

The volume of HGVs was also analysed for each month to identify whether the seasonality is applicable to all vehicle types. For the purposes of the modelling work, HGVs are defined as vehicles classification OGV2.

The HGV two-way average daily flow for each month in 2009 is shown in Figure 2.4.

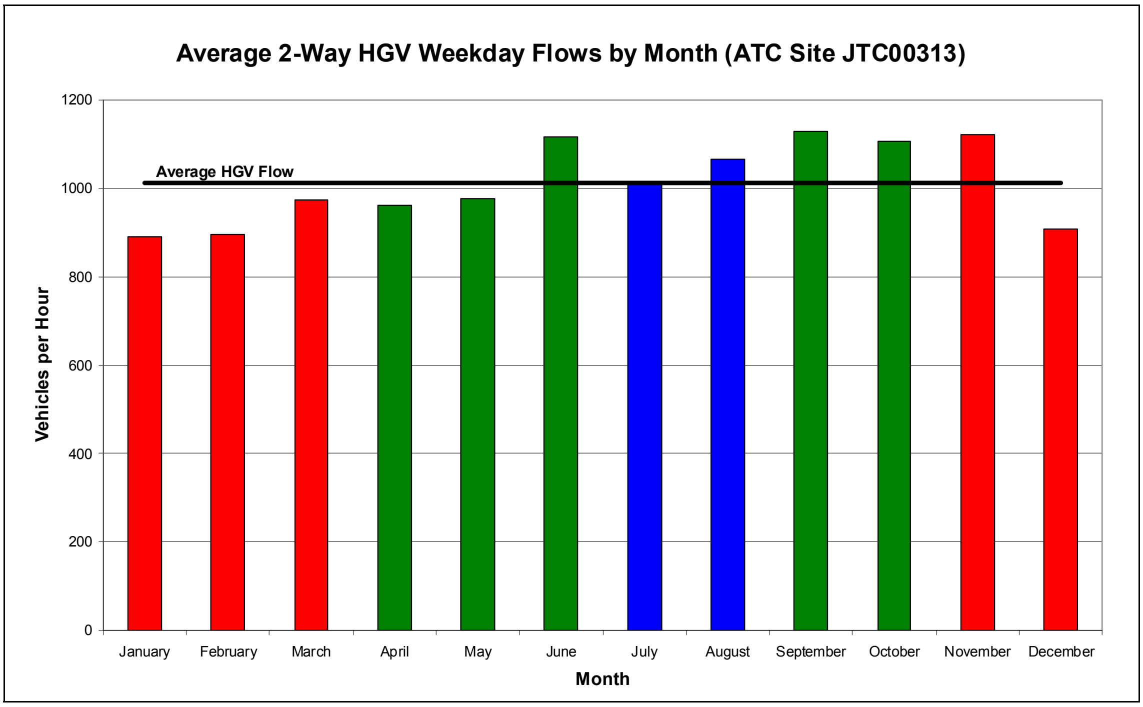

Figure 2.4 : HGV Flows (2009, Average Two-Way)

Figure 2.4 illustrates that throughout the year, the HGV flows remain fairly constant, and that a global factor should not be applied to the Base Year demand matrices, as this would result in disproportional changes to various matrix types.

2.3.2 Development of Summer Microsimulation Model

The results of the seasonality analysis were used in the creation of the summer demand matrices. Each modelled vehicle type was compared with the ATC flow data.

A multiplier for each vehicle type was derived by calculating the difference between the modelled flows and the average summer flows, using the 2009 data from ATC Site JTC00313. The factor was then applied to each individual vehicle type. The multiplier was not applied to the slow moving HGVs.

The 'neutral' to 'summer' month factors applied are shown in Table 2.1.

Table 2.1 : Neutral to Summer Month Growth Factors

Vehicle Type	Modelled to Summer Factor
Cars	1.07
Car + Trailers	2.66
LGV	1.07
OGV1	2.53
OGV2	0.93
Slow Moving OGV2	1.00
PSV	0.64
All Vehicles	1.15

The changes applied to the 2008 matrices are shown in Table 2.2.

Table 2.2 : 2008 Neutral & Summer Month Trip Matrix Summary

Matrix level	2008 Base Demands	2008 Summer Matrices	Increase
Cars	10,821	11,585	7%
Cars + Trailer	134	357	166%
LGV	1,837	1,967	7%
OGV1/OGV2	2,188	3,016	38%
PSV	184	117	-36%
Slow Moving OGV2	23	23	0%
Total	15,188	17,042	18%

Table 2.2 indicates that the overall increase from the ‘neutral’ to ‘summer’ month demands is in the order of 18%.

The summer 2010 matrices were derived by applying NRTF Central traffic growth to the 2008 summer matrices.

The growth factors applied to the matrices are summarised in Table 2.3.

Table 2.3 : NRTF Growth Factors

Growth Period	NRFT Growth Applied	Vehicle Type				
		Cars	LGV	OGV2	PSV	OGV
2008 - 2010	Central	1.031	1.044	1.050	1.013	1.043

The resultant summer demand matrices were used as the basis of the separate summer model.

2.4 Speed Enforcement

2.4.1 Average Speed Camera Technology

The principal requirement for this further study was to consider the impact of speed enforcement measures on the A9(T).

For the purposes of the assessment, it was assumed that this would take the form of average speed cameras, with the effect modelled in the microsimulation models using the results from a review of the A77(T) Average Speed Enforcement System (SPECS) trial site.

Analysis of the ATC site JTC00364, located on a single carriageway section of the A77(T) at Balkenna, South of Turnberry, was used to identify the change in driver behaviour following the introduction of the SPECS cameras.

Historical data from site JTC00364 was used to compare average speed distributions before and after installation of the SPECS cameras. Table 2.4 summarises the effect that the average speed camera enforcement had on the speeds distribution of vehicles on the A77(T).

Table 2.4 : Effects of Average Speed Cameras on the A77(T)

Date	Speed distribution changes > 60mph	>65 mph	> 70 mph	>75 mph
Installation average camera poles (04/07/05 - 10/07/05)	-5.7%	-3.4%	-1.9%	-1.0%
August 2005 - after launch	-12.7%	-5.8%	-2.8%	-1.3%

On the A77(T), the installation of the camera poles alone (without the system being operational) reduced vehicle speeds greater than 60mph by around 6%. The most significant change in speeds occurred in August 2005, when the cameras were operational for only one month. The number of vehicles travelling at speeds greater than 60mph reduced by 13%.

In terms of actual speeds, Table 2.5 summarises the influence of the cameras on average speeds on the A77(T).

Table 2.5 : Influence of SPECS Cameras on A77(T) Average Speeds

Date	Speed Difference (mph)
Installation average camera poles (04/07/05 - 10/07/05)	-1.8
August 2005 - after launch	-9.4

Table 2.5 indicates that there was a reduction in average speeds of 9.4mph following the introduction of the cameras on the A77(T).

In addition, analysis of the speed distributions allowed percentile speeds to be calculated for 5th%ile, 15th%ile, 50th%ile, 75th%ile, 85%ile and 95%ile speeds. The percentile speeds were calculated for both before and after the introduction of the SPECS cameras, with the figures for August 2005 adopted as best reflecting a 'first year' impact. Figure 2.5 illustrates the impact of the change in speeds.

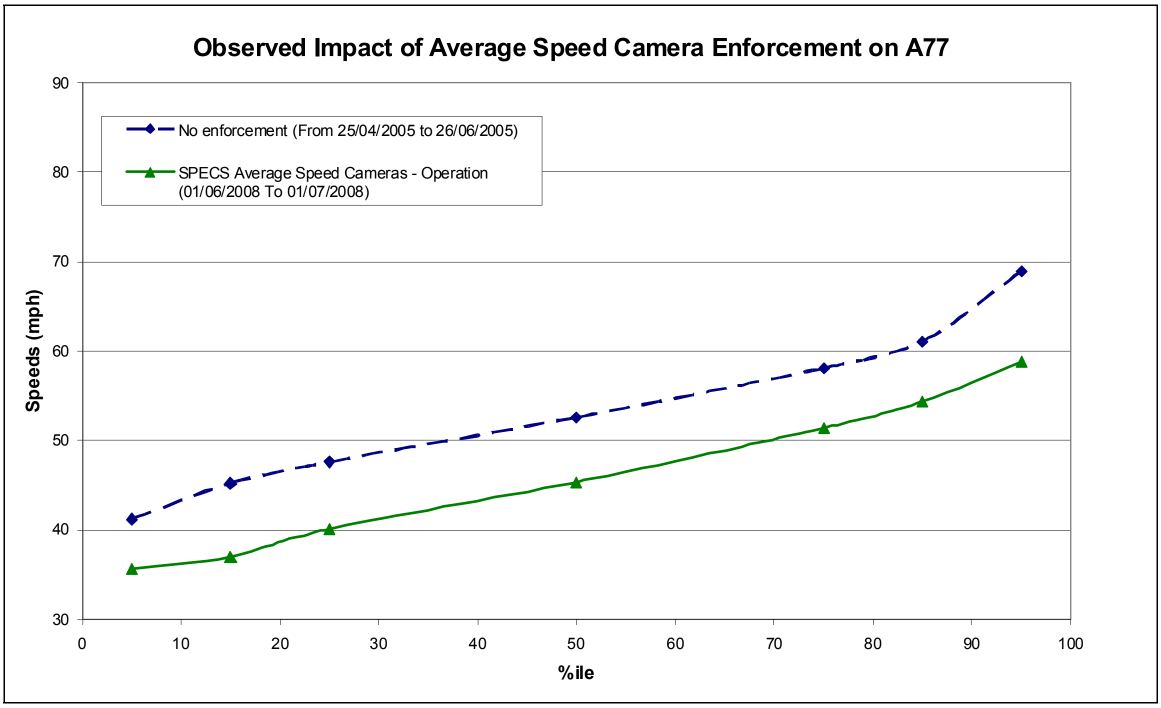

Figure 2.5 : Impact of SPECS on A77(T) Average Speeds

Having determined the impact of average speed cameras, both in terms of changes in speed distribution and changes in average speed, the impacts were then used as a proxy to reflect the introduction of average speed camera enforcement for the A9(T) study section.

2.4.2 Modelling Average Speed Camera Enforcement

The above analysis indicates that the effects of speed camera enforcement include the:

- impact on the number of drivers travelling at speeds greater than 60mph
- average speed of all vehicles
- distribution of speeds across all vehicles

The most appropriate way to reflect the change in speed distribution within an S-Paramics microsimulation model is to change the link speed parameter. Each link in an S-Paramics microsimulation model is attributed a target speed which all vehicles seek to achieve. With rural highway links, there is a distribution around this value (i.e. some vehicles drive faster and some drive slower).

The *Target Speed* parameter was therefore used to calibrate the behaviour of drivers to best reflect the average speeds and the distribution of speeds above and below the average.

As the *Target Speed* parameter was used in the calibration of the original Base model, it was felt that a similar approach should be used to reflect the change in behaviour as a result of the introduction of speed cameras. This approach is considered the most robust as no changes to the vehicle characteristics are required.

Consequently, the *Target Speed* parameter was adjusted from a value of 55mph in the Base to 46mph to reflect the SPECS enforcement.

The effect of the change in *Target Speed* resulted in:

- the number of vehicles travelling faster than 60mph reduced by 9.1% and the number of vehicles travelling faster than 65mph reduced by 5.6%
- the average speed reduced by 4.5mph from 53.6mph to 48.1mph.

It should be noted that although the data suggests that some vehicles choose to drive faster than 70mph, even although there are cameras present, these vehicles are not reflected in the model.

It was considered that the vehicles observed travelling at excessive speeds could be motorcyclists or foreign drivers who are not modelled explicitly.

The changes in the traffic speeds are considered reasonable when comparing with the observed values from the A77(T). Overall, the impacts accounted for a general reduction of traffic speeds above 60 mph.

Figure 2.6 illustrates the effect of “SPECS equivalent” enforcement on speed distributions across all speeds. Comparison with Figure 2.5 confirms that the changes in speed distributions are representative.

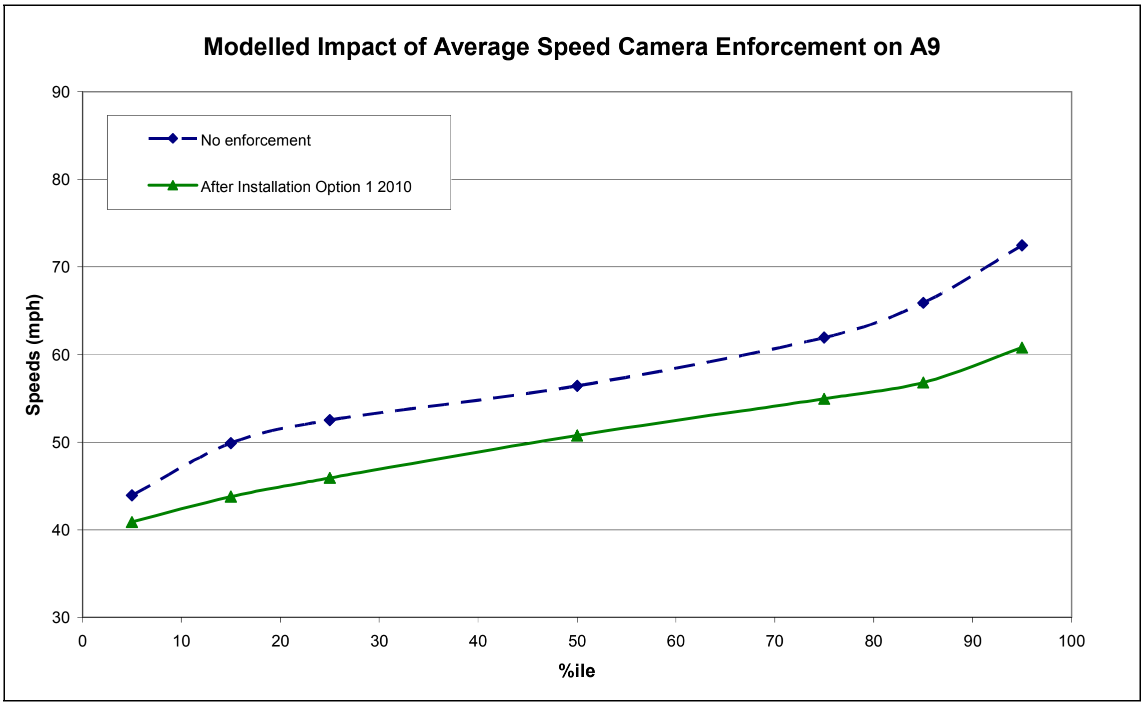

Figure 2.6 : Impact on A9(T) Modelled Speeds

2.4.3 Slow Moving Vehicles

One of the final requirements of the study was to revisit the speed distribution of slow moving vehicles, and to refine the assumption used in the model.

As indicated in Section 2.2 of the previous report, *Estimation of the Effect of Increasing the HGV Speed Limit on the A9(T), SIAS & TRL, February 2010,* few HGV drivers adhere to the 40mph speed limit. The adherence to the 40mph limit was reflected in the traffic model.

Figure 2.7 shows the speed distribution for the OGV2 vehicle type.

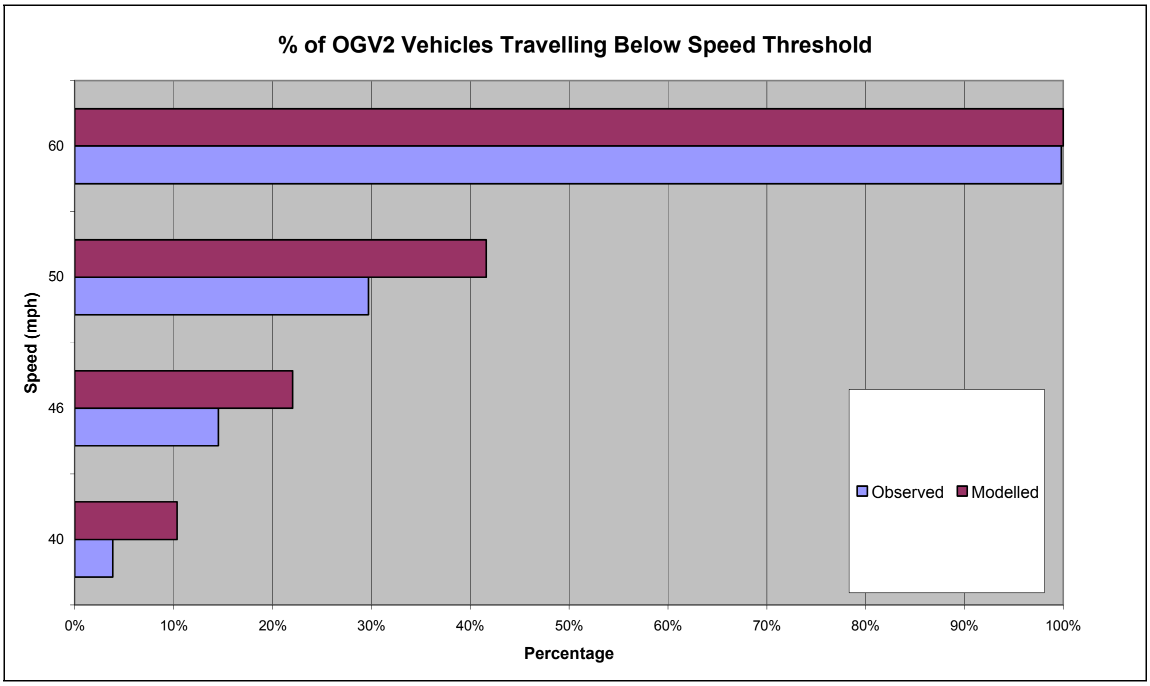

Figure 2.7 : A9(T) OGV2 Speed Distribution Validation

It can be seen that the modelled OGV2 speed distribution is consistent with the observed speed distribution.

Given the close comparison with the observed distribution, the OGV2 modelled speed distribution is considered representative.

2.4.4 Considerations for Model Validation with Speed Camera Enforcement

The comparison between modelled and observed data demonstrates that the representation of speed camera enforcement is suitably representative within the model in general terms.

Following a meeting with Transport Scotland's Strategic Road Safety team in November 2011, additional observed data became available showing the longer term impact of introducing speed camera enforcement. The additional data was examined and compared with more detailed model outputs to identify possible calibration improvements that could be incorporated when modelling speed camera enforcement schemes in the future.

The observed data was for the Traffic Scotland automatic traffic count site JTC00364 at Balkenna on the A77 between Turnberry and Girvan and covered 3 separate date ranges:

- 2nd to 8th May 2005 – pre-SPECS installation
- 19th to 25th September 2005 – shortly after SPECS installation

- 5th to 11th May 2008 – 3 years after SPECS installation

It should be noted that this observed data represents the impact of introducing SPECS at a single location. Therefore, whilst it provides a detailed set of information to compare with the modelled outputs, it is unknown how closely the impacts at this specific site could be considered to be representative at other locations. Nevertheless, the comparisons do provide a useful indication for future modelling exercises of this nature.

One of the most obvious trends evident in the observed data is that the longer term impact of introducing speed enforcement is substantially lesser than that shown in the short term, particularly for HGVs. Figure 2.8 shows an example of the northbound observed speed distribution for OGV1s prior to, immediately after and 3 years after installing SPECS.

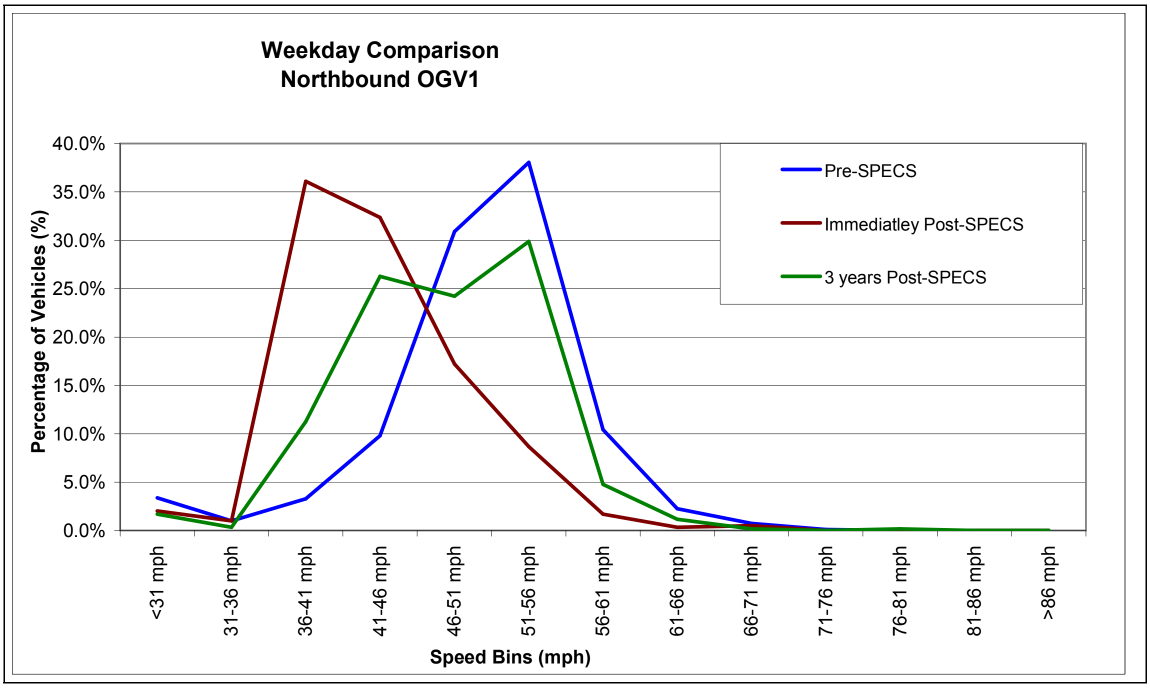

Figure 2.8 : A77 Balkenna (JTC00364) OGV1 Observed Speed Distribution

The above shows that the short term impact is substantial with a general slowing of vehicles and the peak of the distribution moving from the 51-56mph range to the 36-41mph range. Over the longer term the speed distribution edges back towards the pre-SPECS situation although the peak of the distribution is flatter, reflecting the general slowing of vehicles due to the enforcement measures. Similar trends can be seen for other vehicle types and with this in mind it is considered that the 3 years post-SPECS observations provide the most reliable data for comparison with modelled outputs.

It is also evident in the observed data that there are different trends by direction with respect to the speed distribution. Figure 2.9 shows the observed speed distribution for OGV1s both pre-SPECS and 3 years after the introduction of SPECS at Balkenna. It is clear that the OGV1 speeds in the northbound direction are generally higher than those in the southbound direction both before and after the introduction of SPECS. This demonstrates that there are site-specific issues (e.g. alignment, gradient, visibility, surrounding environment etc.) that can influence the speeds at which vehicles travel. Therefore the observed data from one site may not be wholly representative of the conditions at a range of different sites.

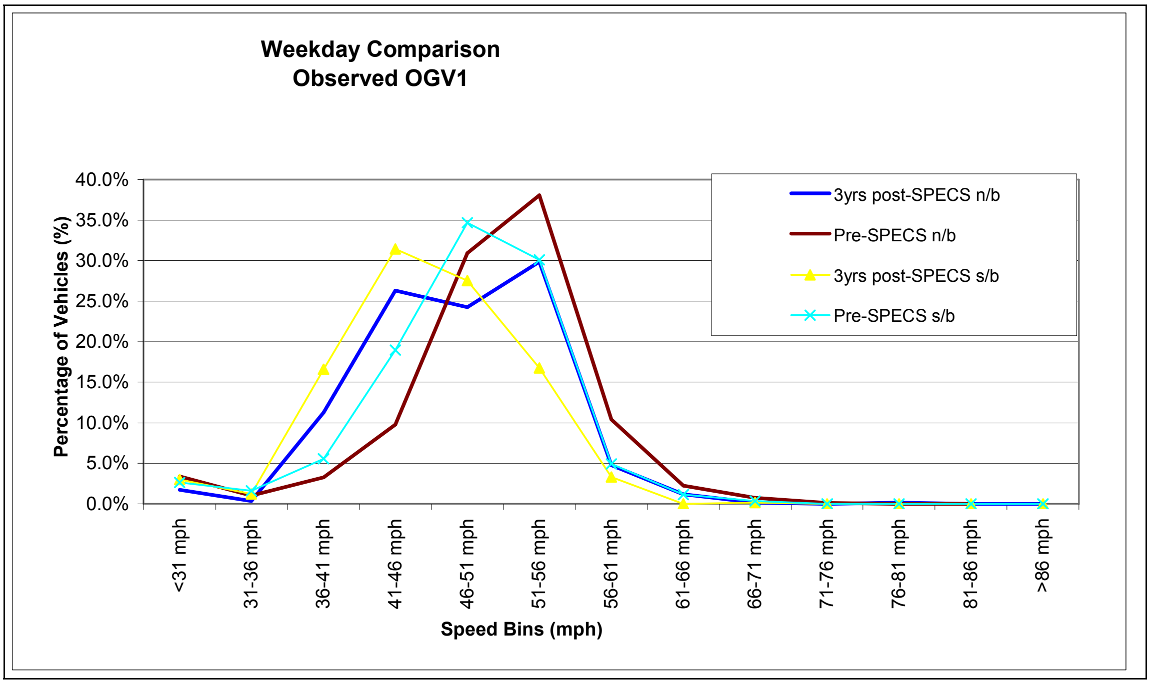

Figure 2.9 : A77 Balkenna Pre & Post SPECS OGV1 Speed Distribution

The observed speed distribution data from the A77 site at Balkenna for 3 years after introducing SPECS was then compared with modelled data by vehicle type by placing detector loops in the model and extracting the relevant data. The loops were placed in the model to coincide with actual detectors at the following 3 single carriageway sites on the A9:

- JTC00311 – A9 north of A889 at Dalwhinnie
- JTC00313 – A9 south of A95 at Aviemore
- JTC00368 – A9 north of Moy

The comparisons are presented for OGV1, OGV2 and “other” vehicle types by direction in Figures 2.10 to 2.15. The observed data in these graphs is from the A77 Balkenna site while the data labelled “JTC00311”, “JTC00313” and “JTC00368” was extracted from the A9 model.

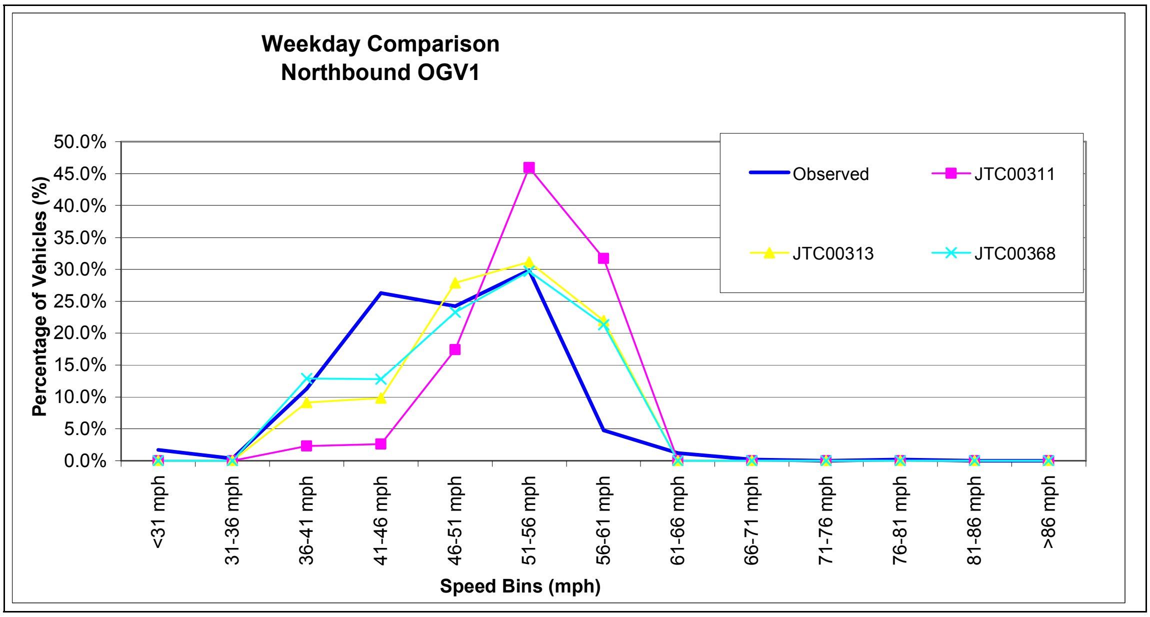

Figure 2.10 : Modelled v Observed OGV1 Speed Distribution northbound

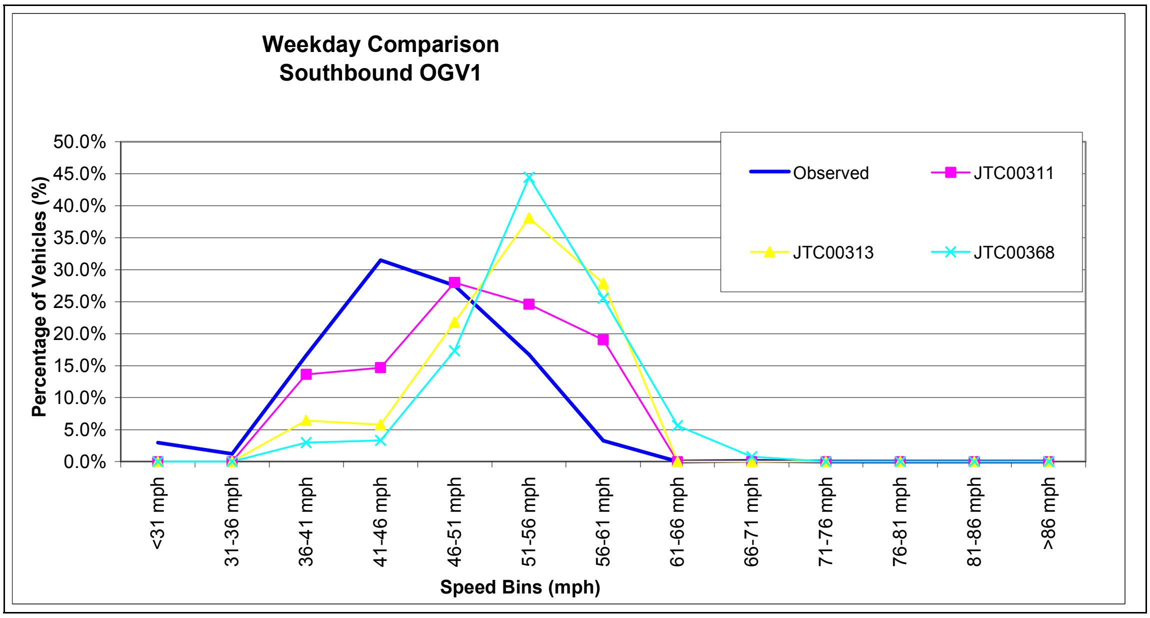

Figure 2.11 : Modelled v Observed OGV1 Speed Distribution southbound

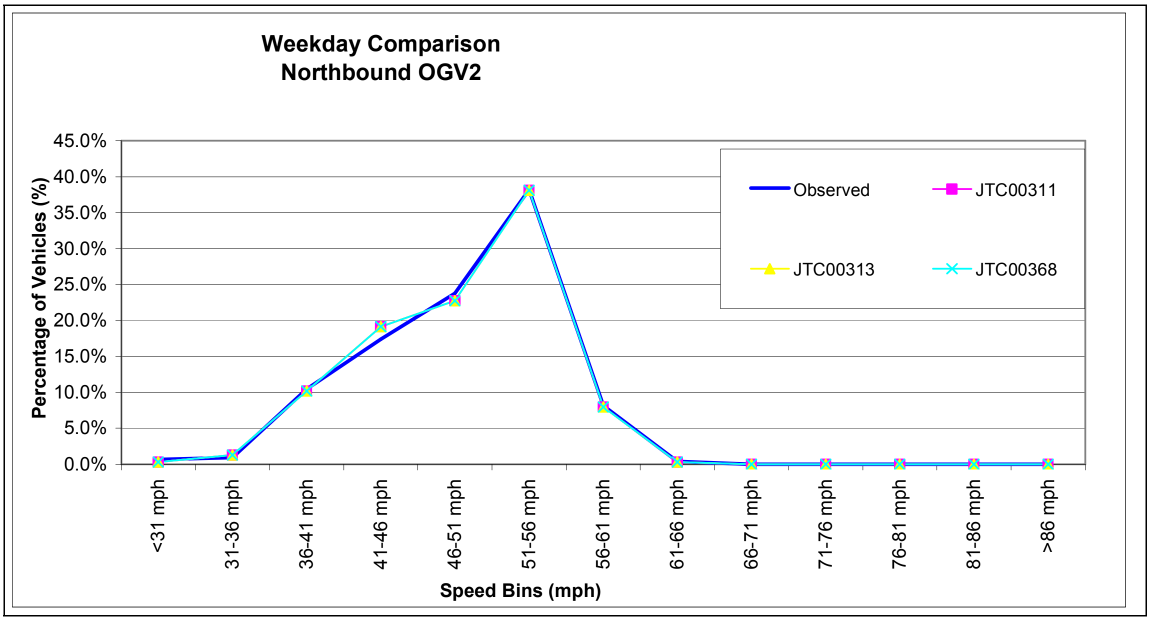

Figure 2.12 : Modelled v Observed OGV2 Speed Distribution northbound

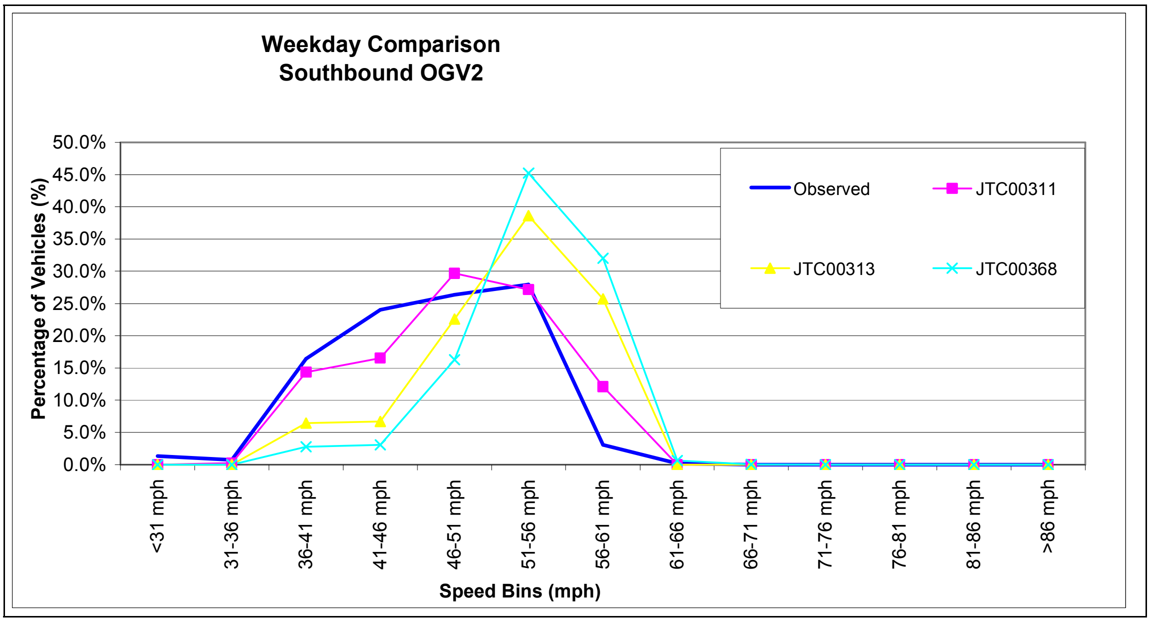

Figure 2.13 : Modelled v Observed OGV2 Speed Distribution southbound

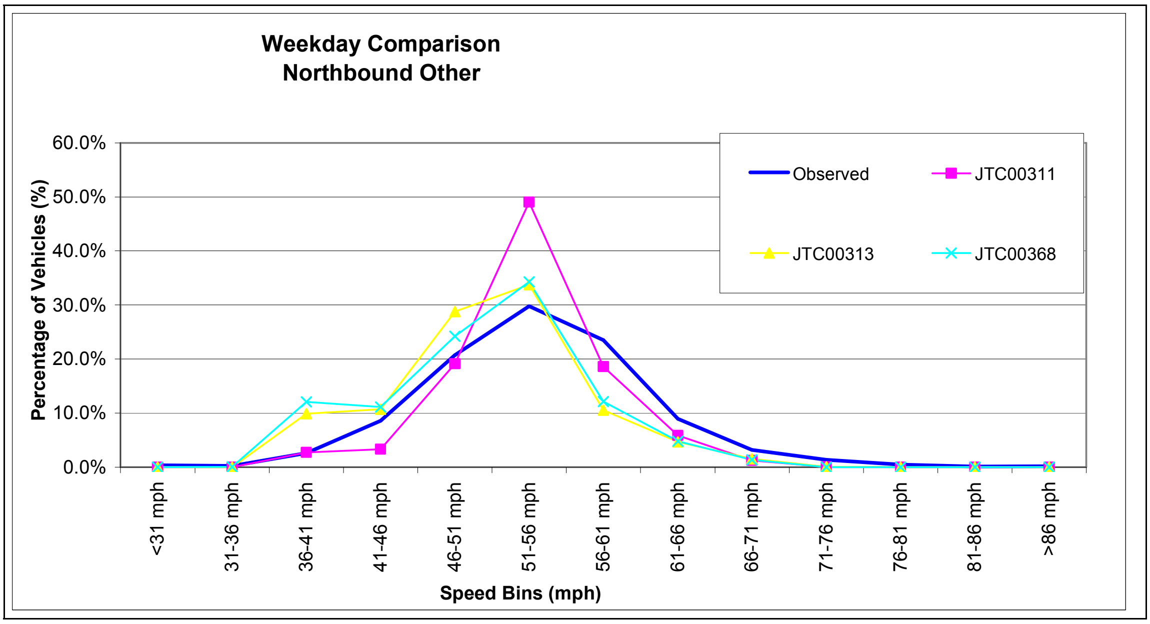

Figure 2.14 : Modelled v Observed Other Speed Distribution northbound

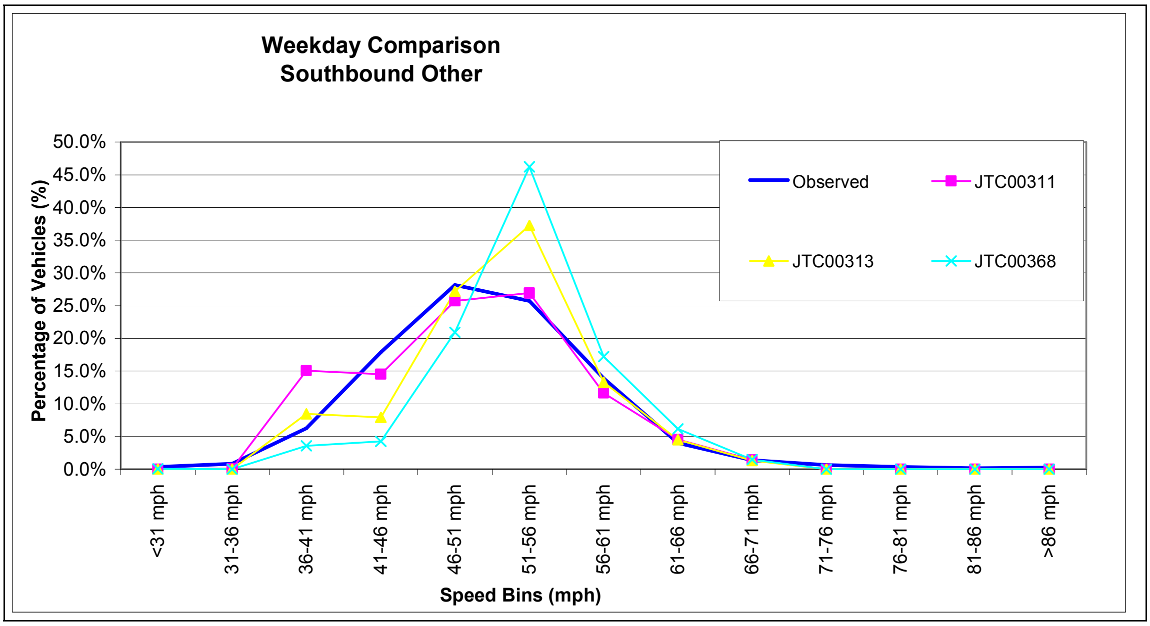

Figure 2.15 : Modelled v Observed Other Speed Distribution southbound

A summary of the comparisons between the modelled and observed data shows that:

- OGV1 northbound : The peak of the modelled distribution is in the correct speed range at each site. The modelled profile is generally well matched at sites JTC00313 and JTC00368 although there is a slight tendency towards the faster end of the distribution. The overall profile is less well matched at site JTC00311 where the modelled speeds are generally faster than observed

- OGV1 southbound : The peak of the modelled distribution is in a higher speed range than the observed for all 3 sites, in particular at JTC00313 and JTC00368. The overall distribution is similar to observed at site JTC00311

- OGV2 northbound : The comparison between modelled and observed speed distribution is excellent at all 3 sites

- OGV2 southbound : The peak of the modelled distribution is generally in the correct speed range at each site. The modelled profile is generally well matched at site JTC00311 but less well matched at sites JTC00313 and JTC00368 where the modelled speeds are generally faster than observed

- other northbound : The peak of the modelled distribution is generally in the correct speed range at each site. The modelled profile is generally well matched at sites JTC00313 and JTC00368. At site JTC00311 there are too many vehicles in the peak range with not enough in the extremes at either end of the distribution

- other southbound : The match between modelled and observed is very good for site JTC00311. At sites JTC00313 and JTC00368, while the peak of the distribution is in the correct speed range, there is a general tendency towards the faster end

In general it can be concluded that the model reflects the 3 years post-SPECS observations by vehicle type reasonably well, in particular when considering the northbound direction. There is a tendency for the model to reflect slightly higher speeds than observed, particularly when considering the southbound comparisons. With these findings in mind it is recommended that for future studies the following issues should be considered during the model calibration process:

- observed speed data should be collected from a wider sample of sites reflecting differing local conditions. This will enable the variations in the observed data to be better understood

- the local topography, geometry and general surrounding environment should be considered in terms of both the observed and modelled data. Trends in the data by differing site may enable more refined coding to be included in the model to better reflect the impact of these factors on local vehicle speeds

- further refinement of the operational performance parameters by vehicle type should be considered. Alteration of the target speeds has resulted in a reasonable comparison between modelled and observed values. To improve this and ensure a more refined match for all vehicle types, consideration should be given to further alterations in target speeds, application of the more detailed S-Paramics HGV deceleration model that impacts HGV speed/acceleration on gradients and application of the drag parameter that influences the top speed of vehicles

Overall, the influence of effective speed camera enforcement has been reasonably reflected in the modelling process in this study, therefore, the conclusions from this work can be considered to have been drawn from a reasonable analytical basis. The possible refinements outlined above are considered to be a practical method of improving the modelling process for future studies of this nature, which would in turn bolster the robustness of the analytical work from which any conclusions could be drawn.

3 Model Application

3.1 Background

The previous study considered only the increase in HGV speed limit:

- increasing the HGV speed limit to 50 mph
- increasing the HGV speed limit to 60mph (effectively 56mph due to engine limiters)

The development of the Base model, the future year forecasting and the results of the assessment are summarised in the report *Estimation of the Effect of Increasing the HGV Speed Limit on the A9(T) (SIAS & TRL, SIAS Ref. 72377, February 2010*).

This chapter revisits the change in HGV speed limits in conjunction with average speed camera enforcement. For the purposed of the assessment, an HGV is defined as a goods vehicle exceeding 7.5 tonnes.

3.2 Model Application

3.2.1 <u>Model Testing Programme</u>

The model testing programme focussed on two scenarios:

- the enforcement of all vehicle speeds, assuming the introduction of an average speed camera system, similar to that on the A77(T) (the SPECS trial site)
- increasing the HGV speed limit to 50mph, or 60mph (effectively 56mph due to engine limiters), with average speed camera enforcement for all vehicles (as above)

A 2010 'Opening' year was derived for both an average 'neutral' month and an average 'summer' month, as described in the previous section. This scenario is defined as the **Base** and reflects the current situation.

The intervention of average speed cameras on the single carriageway sections of the A9(T) is defined as **Option 1.**

Two further options were assessed, both of which include the average speed camera enforcement; **Option 2** considers average speed camera enforcement plus increasing the HGV speed limit to 50mph and **Option 3** considers average speed camera enforcement plus increasing the HGV speed limit to 60mph (effectively 56mph because of engine limiters).

Options 1, 2 and 3 are then compared to the Base (current) situation.

3.2.2 HGV Speed Redistribution

The impact of an increase in the HGV speed limit will result in heavy good vehicles travelling faster, with a speed distribution tending towards that seen on dual carriageways.

In order to provide a measure of the potential change in distribution at higher speeds, a comparative speed distribution was derived from data collected on the A1(T) dual carriageway at Haddington. This section of road is of D2AP standard and HGVs are permitted to travel at 50mph. The A1(T) was selected principally due to the availability of detailed information.

The analysis provided a reference for the potential impact on HGV speed distribution as a result of the change HGV speed limit.

The comparison is shown in Table 3.1.

Table 3.1 : Influence of HGV Speed Limit Adjustments

Speed	A1 Dual Carriageway	A9 Single	A9 50mph OGV2	A9 60mph OGV2
<50mph	10%	46%	26%	14%
>50mph	90%	54%	74%	86%

It can be seen from the A1(T) data that, where permitted, around 90% of HGVs will travel above 50mph. By comparison, and even although they are bound by the 40mph speed restriction, around 54% of HGVs using the A9(T) travel at speeds higher than 50mph.

If the HGV speed limit on the A9(T) was increased to 50mph, the proportion of HGVs travelling faster than 50mph would increase to 74%. If the HGV speed limit was increased to 60mph (effectively 56mph because of engine limiters), the proportion of HGVs travelling faster than 50mph would increase to 86%, more akin to that displayed on the A1(T).

3.3 Results

3.3.1 Operational Assessment

The effect of an increase in HGV speeds was quantified by means of an operational assessment of:

- platoon lengths
- headways
- speeds
- journey times
- overtaking events
- vehicle emissions
- speed reliability

3.3.2 Platoon Length

Information was collected for each link on the A9(T) to give an indication of changes in platoon length. Measurement parameters in the model were configured such that vehicles were considered to be in a platoon if:

- their speed was 50mph or less; and
- the headway to the vehicle in front was 5s or less

Consequently, free flow conditions were defined as traffic having a headway greater than 5s and travelling at 50mph (81kph) or more.

The frequency of platoon length (in vehicles) was compared between each scenario for both 'neutral' month, in Table 3.2, and 'summer' month, in Table 3.3.

Table 3.2 : 2010 Average Platoon Length Comparison (Neutral Month)

Platoon Length (vehicles)	Base 2010	Option 1 2010	Change in Average	Option 2 2010	Change in Average	Option 3 2010	Change in Average
<= 5	78,757	79,527	1.0%	82,337	4.5%	84,442	7.2%
6 - 10	10,705	11,258	5.2%	8,576	-19.9%	6,448	-39.8%
11 - 15	1,012	878	-13.3%	524	-48.2%	336	-66.8%
> 15	148	91	-38.5%	32	-78.4%	15	-89.7%

Table 3.3 : 2010 Average Platoon Length Comparison (Summer Month)

Platoon Length (vehicles)	Base 2010	Option 1 2010	Change in Average	Option 2 2010	Change in Average	Option 3 2010	Change in Average
<= 5	82,904	83,116	0.3%	86,213	4.0%	88,826	7.1%
6 - 10	13,060	13,810	5.7%	11,183	-14.4%	8,992	-31.1%
11 - 15	1,327	1,262	-4.9%	773	-41.7%	528	-60.2%
> 15	230	164	-28.5%	50	-78.3%	29	-87.4%

Both tables indicate that the introduction of speed enforcement (Option 1) will see the number of long platoons (those in excess of 15 vehicles) reduce, with a corresponding increase in the number of shorter platoons (6 to 10 vehicles). This characteristic is referred to as platoon dispersion.

If the HGV speed limit is then increased to 50mph, or 60mph, the effect increases with the number of shorter platoons increasing significantly, suggesting that traffic is less bunched on the network.

3.3.3 Headways

Vehicle loop detectors were coded into the model at the same locations as the ATC sites used in the model calibration. Headway data output from the model was defined as the number of seconds between vehicles as they passed over a loop detector.

Analysis focussed on two ATC sites; Site JTC00313 (to the west of Aviemore) and Site JTC00314 (to the north of Tomatin), in both north and southbound directions. Details of the results are contained in Appendix A.

The frequency of headway times between 5 and 360s was calculated for the Base, Option 1, Option 2 and Option 3 for the ‘neutral’ and ‘summer’ months. A comparison between the headways at Site JTC00313 is given in Table 3.4 and Table 3.5, for the ‘neutral’ and ‘summer’ months, respectively.

Table 3.4 : Headway Comparison at ATC site JTC00313 (Neutral Month)

Time (s)	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
Northbound							
<5	2,264	2,056	**-9%**	1,940	**-14%**	1,817	**-20%**
10 to 90	833	1,094	**31%**	1,243	**49%**	1,407	**69%**
>120	278	247	**-11%**	225	**-19%**	203	**-27%**
Southbound							
<5	2,179	2,117	**-3%**	2,013	**-8%**	1,924	**-12%**
10 to 90	1,577	1,654	**5%**	1,776	**13%**	1,881	**19%**
>120	163	156	**-5%**	153	**-6%**	146	**-11%**

Table 3.5 : Headway Comparison at ATC site JTC00313 (Summer Month)

Time (s)	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
Northbound							
<5	2,728	2,511	**-8%**	2,396	**-12%**	2,269	**-17%**
10 to 90	868	1,137	**31%**	1,287	**48%**	1,447	**67%**
>120	282	254	**-10%**	234	**-17%**	209	**-26%**
Southbound							
<5	2,649	2,566	**-3%**	2,448	**-8%**	2,355	**-11%**
10 to 90	1,683	1,777	**6%**	1,919	**14%**	2,026	**20%**
>120	165	160	**-3%**	154	**-7%**	151	**-8%**

The results indicate that the introduction of speed enforcement (Option 1) will see a reduction in variation of the headway between vehicles.

If the HGV speed limit is then increased to 50mph, or 60mph, the headway is shown to increase further.

Generally, both sites (JTC00313 and JTC00314) indicate a decrease of 3 to 20% in the number of headways of less than 5s, and a corresponding similar decrease in the number of headways greater than 120s. The headway times between 10 and 90s become more frequent with increases of up to 70%.

It may be the case that these characteristics are different at the other ATC locations, but these sites have not been considered within this analysis.

3.3.4 <u>Speeds</u>

Average speeds were compared at each of the 11 ATC sites within the modelled section. The results were compared for all vehicles, by each hour for Base, Option 1, Option 2 and Option 3.

The ATC site locations, and comparison of average speeds are given in Appendix B, with a summary provided in Table 3.6.

Table 3.6 : Difference in Average Speeds

	Northbound			Southbound		
Site	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
2010 Neutral Month	-6.03	-4.48	-3.78	-5.63	-3.96	-3.08
2010 Summer Month	-5.46	-3.88	-3.19	-5.30	-3.53	-2.65

All options, minus base

* mph

Table 3.6 confirms that the introduction of speed enforcement (Option 1) will result in a reduction in average speeds of between 5 and 6mph. Even if the

HGV speed limit is increased to 50mph (Option 2) or 60mph (Option 3), average speeds of all vehicles will still be lower than the current situation (Base).

A comparison of the maximum differences in average speeds was also carried out. Table 3.7 provides a comparison of the maximum change in average speeds for each scenario. Detailed analysis is presented in Appendix C.

Table 3.7 : Maximum Difference in Average Speeds

	Northbound			Southbound		
Site	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
2010 Neutral Month	-7.78	-6.79	-6.47	-8.60	-7.75	-7.33
2010 Summer Month	-7.17	-6.01	-5.67	-7.88	-6.63	-6.28

All options, minus base
* mph

Table 3.7 confirms that the maximum change in average speeds would be between 7 and 8mph following the introduction of speed enforcement measures (Option 1). With the HGV speed limit increased to 50mph (Option 2) or 60mph (Option 3), the maximum change in average speeds of all vehicles will be in the order of 6 to 7mph.

3.3.5 Journey Times

Average journey times between Aviemore and the B851 (south of Daviot) were extracted from the models.

Table 3.8 provides a summary of the modelled journey times for each scenario, for both 'neutral' and 'summer' months.

Table 3.8 : Journey Time Comparison

Average Journey Times 24 hour Period	Base	Option 1	Difference	Option 2	Difference	Option 3	Difference
Aviemore to B851							
2010 Neutral Month	25:29	27:32	**+ 02:03**	26:42	**+ 01:13**	26:19	**+ 00:50**
2010 Summer Month	26:02	27:53	**+ 01:51**	27:01	**+ 00:59**	26:38	**+ 00:36**
B851 to Aviemore							
2010 Neutral Month	25:03	27:09	**+ 02:06**	26:26	**+ 01:24**	26:09	**+ 01:06**
2010 Summer Month	25:30	27:25	**+ 01:55**	26:39	**+ 01:08**	26:21	**+ 00:51**

*(mm:ss)

Table 3.8 confirms that the introduction of speed enforcement (Option 1) will result in slightly increased (modelled) journey times of around 2min. If the HGV speed limit is increased to 50mph (Option 2) or 60mph (Option 3), average journey times will still be around 1min higher than the current situation (Base).

This analysis concludes that if both interventions are implemented, the change in journey times is marginal, around 1min higher than the current situation.

3.3.6 Overtaking Events

Microsimulation modelling allows the user to capture the discrete decisions or ‘events’ taking place for each trip in the simulation. One of the parameters collected is overtaking behaviour.

The overtaking event output was extracted from the models and the frequency of those events compared between the Base, Option 1, Option 2 and Option 3 for both the ‘neutral’ and ‘summer’ month models.

It should be noted that within S-Paramics microsimulation models, overtaking is defined as opportunistic passing of slower moving vehicles travelling in the same direction, usually in the face of oncoming traffic. Overtaking on a dual carriageway on the other hand is defined ‘passing’ as different algorithms are used to reflect the different decisions being made by the driver. Therefore, the overtaking analysis carried out in this assessment excludes passing on the dual carriageway sections at Crubenmore, Moy and Slochd.

For the purposes of this assessment, it was assumed that the average time for a vehicle to perform a safe overtaking manoeuvre was 10s. This parameter was selected based on video evidence. Overtaking events that took less than 10s were considered a ‘failed’ overtaking attempt and reflected a driver’s decision to give up and pull back in.

The total time spent overtaking and, therefore, on the opposite side of the carriageway (i.e. ‘exposure time’) was determined from the events analysis.

Table 3.9 and Table 3.10 compare the overtaking behaviour for each scenario for both the ‘neutral’ and ‘summer’ months.

Table 3.9 : Overtaking Analysis (2010 Neutral Month)

Time (s)	Base	Option 1		Option 2		Option 3	
<10	35,166	32,516	**-7.5%**	31,454	**-10.6%**	31,173	**-11.4%**
20	4,084	4,068	**-0.4%**	4,138	**1.3%**	4,212	**3.1%**
30	214	232	**8.4%**	245	**14.6%**	244	**14.1%**
>40	8	9		8		9	
Total Overtaking Manoeuvres							
	39,473	36,825	**-6.7%**	35,846	**-9.2%**	35,638	**-9.7%**
Total Overtaking Time							
	37:11:59	36:27:06	**-2.0%**	37:09:22	**-0.1%**	37:22:24	**0.5%**

Table 3.10 : Overtaking Analysis (2010 Summer Month)

Time (s)	Base	Option 1		Option 2		Option 3	
<10	42,125	38,341	**-9.0%**	37,168	**-11.8%**	36,832	**-12.6%**
20	4,835	4,820	**-0.3%**	4,912	**1.6%**	4,950	**2.4%**
30	327	347	**5.9%**	365	**11.6%**	364	**11.1%**
>40	12	14		13		13	
Total Overtaking Manoeuvres							
	47,299	43,522	**-8.0%**	42,458	**-10.2%**	42,159	**-10.9%**
Total Overtaking Time							
	44:46:41	43:47:18	**-2.2%**	44:44:43	**-0.1%**	44:48:20	**0.1%**

Table 3.9 and Table 3.10 confirm that the introduction of speed enforcement (Option 1) will result in a 6 to 8% reduction in the number of overtaking manoeuvres, and a consequential reduction of around 2% in the length of time a vehicle is on the other side of the carriageway.

If the HGV speed limit is increased to 50mph (Option 2) or 60mph (Option 3), the impact is amplified with the number of overtaking manoeuvres reducing by around 9 to 10%. The reduction in overtaking events can be equated to a reduced ‘desire to overtake’ slower moving vehicles. As HGV speeds increase, platoons are slower to form behind the lead vehicle.

This is reinforced in both the ‘neutral’ and ‘summer’ month assessments that the combination of speed enforcement (Option 1) and the increase in HGV speed limit (Options 2 and 3) will result in a reduction in the number of failed, or unsafe, overtaking manoeuvres. When compared with the current situation, the number of failed manoeuvres will reduce by up to 13%

Overall, the analysis suggests that the interventions will lead to a better journey experience.

3.3.7 Vehicle Emissions

The impact of the various interventions on vehicle emissions was investigated using Transport Scotland’s recently developed instantaneous emissions module AIRE (Analysis of Instantaneous Road Emissions). This incorporates over 3,000 Instantaneous Emissions Modelling (IEM) tables which are used to estimate tailpipe emissions from individual simulated road vehicles taking account of factors such as speed, acceleration, gradient and fleet composition. The IEM tables were derived from PHEM (Passenger car and Heavy Duty Emissions Model), which was developed by the Technical University of Graz.

AIRE can be used to process the detailed, vehicle by vehicle outputs produced by microsimulation models for each simulated time step and provides significantly more disaggregate and detailed emissions estimates compared with traditional, average speed-based methods.

AIRE produces estimates of the oxides of nitrogen, particulate matter and total carbon that result directly from the combustion of fuel throughout each simulated vehicle's journey.

Table 3.11, Table 3.12 and Table 3.13 summarise the impact of the various interventions on CO2(e), NOx and PM10s for both the 'neutral' and 'summer' months.

Table 3.11 : Carbon Dioxide Equivalents (tonnes)

Total CO2(e)	Base	Option 1	% Change	Option 2	% Change	Option 3	% Change
Neutral Month	194.499	190.711	-1.9%	190.968	-1.8%	190.784	-1.9%
Summer Month	236.654	233.656	-1.3%	233.304	-1.4%	233.347	-1.4%

Table 3.12 : Nitrogen Oxide (tonnes)

Total NOx	Base	Option 1	% Change	Option 2	% Change	Option 3	% Change
Neutral Month	0.749	0.730	-2.5%	0.734	-2.1%	0.727	-3.0%
Summer Month	0.959	0.950	-1.0%	0.941	-1.8%	0.948	-1.1%

Table 3.13 : Particulate Matter (tonnes)

Total PM10	Base	Option 1	% Change	Option 2	% Change	Option 3	% Change
Neutral Month	0.019	0.019	-1.0%	0.019	-1.0%	0.019	-2.6%
Summer Month	0.024	0.024	0.1%	0.023	-2.1%	0.023	-1.2%

The tables confirm that the introduction of speed enforcement (Option 1) will result in a slight reduction in emissions compared with the current situation.

If the HGV speed limit is increased to 50mph (Option 2) or 60mph (Option 3), the saving in emissions will be around 2 to 3 % compared with the current situation.

A breakdown of the vehicle emissions classified by vehicle type is contained within Appendix D.

When considering only the slow moving HGVs, the results are more complex. The CO2(e) and NOx emissions increase by up to 16% over the current situation for both Options 2 and 3, however, the PM10 emissions reduce for both options by up to 18%. The change in emissions as a result of Option 1 for slow moving vehicles show no conclusive pattern.

3.3.8 Speed Reliability

Average car speeds over the modelled section were analysed for each of the interventions, for both the 'neutral' and 'summer' months, including the maximum and minimum speeds.

This information provided a speed distribution for the modelled route between Dalwhinnie and Moy. The speed distribution graphs are presented in Appendix E for the northbound direction (Dalwhinnie to Moy) and the southbound direction (Moy to Dalwhinnie). Graphs were developed for the AM (07:00 – 10:00), inter-peak (12:00 – 15:00) and PM (16:00 – 19:00) periods. The change in average speeds for each period are shown in Table 3.14.

Table 3.14 : Average Car Speeds

	AM (07:00 - 10:00)				IP (12:00 - 15:00)				PM (16:00 - 19:00)			
		Option				Option				Option		
	Base	1	2	3	Base	1	2	3	Base	1	2	3
Northbound												
Neutral	56.5	52.0	53.6	54.8	58.0	51.8	53.1	53.7	58.4	51.8	53.4	53.7
Summer	54.4	50.5	52.1	53.2	56.5	50.6	51.8	52.7	56.4	49.9	51.7	52.9
Southbound												
Neutral	59.7	53.6	55.4	55.9	55.4	50.5	52.3	53.1	55.8	50.6	52.3	53.2
Summer	56.6	51.5	52.8	53.6	56.0	51.2	52.6	53.6	56.4	51.0	52.6	53.3

The introduction of speed enforcement (Option 1) will result in a pronounced reduction in the maximum speed of vehicles, of up to 11mph and a reduction of up to 6mph in the average speed.

If the HGV speed limit is increased to 50mph (Option 2) or 60mph (Option 3), there is a an increase in the minimum speeds of up to 5mph and an increase in the average speed of up to 4mph.

The important detail to note is that speed enforcement has reduced the maximum speed and the change in the HGV speed limit has increased the minimum speed. When combined, the interventions reduce the variation in speed on the A9(T) by up to 35%, thereby providing increased journey reliability.

4 TRL Accident Assessment

4.1 Background

4.1.1 Route Description

The route of the A9(T) is mainly single carriageway though about a quarter of its length consists of various sections of dual carriageway. Annual average daily traffic (AADT) in 2007 was between 12,000 and 14,000 vehicles per day between Perth and Pitlochry, falling to about 10,000 vehicles per day immediately north of Pitlochry and to about 5,000 vehicles per day near Kingussie. The AADT then rises steadily to about 9,000 vehicles per day near Moy and then to 13,000 vehicles per day immediately to the south of Inverness. Traffic flows are higher in the summer than in winter.

The percentage of heavy goods vehicles is relatively high, reaching 20 per cent at some locations. The comparable figure for rural trunk A roads is 9.2 per cent *[Ref. Scottish Transport Statistics, The Scottish Government. Scottish Transport Statistics No 27 2008 Edition].*

4.1.2 HGV Speed Limit

The speed limit for heavy goods vehicles exceeding 7.5 tonnes maximum laden weight is 40 mph on single carriageway roads. This is lower than for other goods vehicles, buses and minibuses, and cars towing caravans and trailers (for which the speed limit is 50 mph) and considerably lower than for cars and motorcycles (for which the speed limit is 60 mph).

4.2 Established Accident/Casualty-Speed Relationships

This study uses an approach based on the findings of micro-simulation modelling. The effect on accidents is estimated using published relationships between the mean overall speed of the traffic and accidents.

There are two main studies which are relevant and can be applied to accident predictions on the A9(T). The relationships developed from these studies are outlined in the subsequent sections of this report.

4.2.1 The Study of UK Single Carriageway Roads (Taylor et al)

Taylor, Baruya and Kennedy (2002) carried out an extensive investigation of the relationship between speed and accidents on rural single carriageway roads in England. The range of mean speeds was from 26 to 58mph.

Separate models were developed for the following categories of accident:

- all injury accidents
- fatal and serious injury accidents
- slight injury accidents
- link accidents
- junction accidents
- single vehicle accidents
- multiple vehicle accidents.

Level 1 models had the same form, which was:

$$A = k\ Qa\ Lb\ Vc\ G$$

where A is the accident frequency, k is a constant, Q is the AADT traffic flow in vehicles per day, L is the length of the link in km, V is the mean traffic speed in mph and G is a category variable which depends on the group to which each link was allocated (this was a measure of the quality of the road which depended on a combination of mean speed, accident rate, junction density, access density and hilliness).

Level 2 models were also developed by extending the Level 1 models by adding geometric variables and variables related to other road features where appropriate. The form was:

$$A = k\ Q^a\ L^b\ V^c\ G\ exp(d_1D_1 + d_2D_2 + \ldots)$$

where D_1 and D_2 represent these additional variables.

The values of the parameter c (exponent of the mean speed) are of most interest since these indicate the extent to which accidents are related to mean speed. These are presented in Table 4.1.

Table 4.1 shows that the relationship between accidents and mean speed is considerably different for junction accidents (power of 5.105 for Level 1 and of 4.114 for Level 2 models) than for link accidents (power of 1.309 for Level 1 and of 1.387 for Level 2 models).

For all injury accidents the models are:

$$A = k_1\ V^{2.479} \text{ (Taylor Level 1)}$$

$$A = k_2\ V^{2.431} \text{ (Taylor Level 2)}$$

If 'before' and 'after' refer to accident numbers and speeds before and after a change in mean speed, both relationships have the form:

Accidents After/Accidents Before = (Mean Speed After/Mean Speed Before)

Table 4.1: The Effect of Mean Speed on Accidents (Taylor et al)

Type of Accident	Value of c Level 1	Value of c Level 2
Fatal and serious injury	2.666	2.792
Slight injury	2.408	2.316
Link	1.309	1.387
Junction	5.105	4.114
Single vehicle	2.330	2.537
Multiple vehicle	2.616	2.372
All Injury Accidents	***2.479***	***2.431***

4.2.2 Elvik's Power Model

The second accident model was Nilsson (2004) who developed a relationship between speed and accidents known as the power model. It was subsequently reviewed, modified and evaluated by Elvik, Christensen and Amundsen (2004). The latter included a meta-analysis of 98 previous studies over the period from 1966 to 2004 which provided a total of 460 estimates of the relationship between speed and safety.

The previous analysis by Elvik et al. did not conduct separate meta-analyses of studies of speed changes in urban and rural areas. Cameron and Elvik (2010) added 17 new studies to the previous data set to provide 526 power estimates. This confirmed that the road environment is an important moderator of the effects of mean speed change on road trauma, perhaps related to the level of the initial speed. Separate estimates were produced for the higher speed road environments (rural highways and freeways) and the lower speed environments (urban arterial roads and residential streets).

Estimates for the former are quoted in Table 4.2 and these were used in the analysis presented in the section on Accident Prediction.

The form of the relationships is as follows:

Accidents After/Accidents Before = (Mean Speed After/Mean Speed Before)

'Before' and 'after' refer to accident numbers and speeds before and after a change in mean speed. This is precisely the same form as the Taylor et al relationships.

The values of c (exponent of mean speed) reported in Elvik et al for different severities of accident and casualty are presented in Table 4.2.

Table 4.2 shows that the values of c depend strongly on severity.

Elvik et al conclude that the relationship between changes in speed and changes in accidents holds for all speeds in the range from 25kph to 120kph and that the Nilsson model with its simplicity and generality makes it superior to other models.

Table 4.2: The Effect of Mean Speed on Accidents (Elvik et al)

Type of accident or casualty	Value of c
Fatal casualty	4.5
Seriously injured casualty	3.0
Slightly injured casualty	1.5
All Casualties	***2.7***
Fatal accidents	3.6
Serious injury accidents	2.4
Slight injury accidents	1.2
All Injury Accidents	***2.0***
Damage only accidents	1.0

4.3 Accident Prediction

4.3.1 Outline of Approach

The outputs from the microsimulation modelling were used to inform the above relationships.

Each set of data was formed from the average 10 runs of the microsimulation model and it was estimated that 10 runs was a number sufficient to provide estimates of the mean speed of cars that are consistent to about 0.1 mph between repeated 10 run averages.

Three Options were investigated:

- **Base:** This is existing condition in which the speed limit for heavy goods vehicles with gross weight exceeding 7.5 tonnes is 40mph and enforcement of speed limits is that which occurs currently on A9(T).
- **Option 1:** It is assumed that the speed limit for heavy goods vehicles with gross weight exceeding 7.5 tonnes remains at 40mph. The speed limit for all other vehicles remains the same as for the Base. The overall speed limit of 60mph is enforced using average speed cameras.

- **Option 2:** It is assumed that the speed limit for heavy goods vehicles with gross weight exceeding 7.5 tonnes is raised to 50mph. The speed limit for all other vehicles remains the same as for the Base. The overall speed limit of 60mph is enforced using average speed cameras.

- **Option 3:** It is assumed that the speed limit for heavy goods vehicles with gross weight exceeding 7.5 tonnes is raised to 60mph. Speed limiters on these vehicles will in effect restrict their speed to 56mph. The speed limit for all other vehicles is also 60mph. This represents an increase from 50mph for cars towing caravans or trailers, buses, coaches and minibuses and goods vehicles with a gross weight not exceeding 7.5 tonnes. The speed limit of 60mph is enforced using average speed cameras.

The existing speed limits for single carriageway roads are as follows.

- cars and motorcycles (including car-derived vans up to 2 tonnes maximum laden weight): **60mph.**

- cars towing caravans or trailers (including car-derived vans and motorcycles): **50mph**.

- buses, coaches and minibuses (not exceeding 12m in overall length): **50mph**.

- goods vehicles (not exceeding 7.5 tonnes maximum laden weight): **50mph**.

- goods vehicles (exceeding 7.5 tonnes maximum laden weight): **40mph**.

Data outputs from the microsimulation model were provided for the Base, Option 1, Option 2 and Option 3 for the appraisal year. Separate sets of data were provided for a 'neutral' month and a 'summer' month. The data consisted of the mean speed of all vehicles combined at the 11 counter sites together with daily traffic flows.

The aim of the accident assessment is to estimate the changes to accident and accident costs per km per year for the following cases:

- Base → Option 1

- Base → Option 2

- Base → Option 3

Accident costs were obtained using the values appropriate to Scotland published by Integrated Transport Economics and Appraisal Division, Department for Transport and are in 2009 prices and values. The values are those for 'Trunk roads only' and are as follows: fatal accidents (£1,838,976); serious injury accidents (£227,541); and slight injury accidents (£23,520).

4.4 Findings

4.4.1 'Neutral' Month

The findings are presented in Table 4.3 (Option 1), Table 4.4 (Option 2) and Table 4.5 (Option 3).

For each comparison at each site, the combined mean speed and the change in the mean speed from the Base case are presented. Also presented are the estimated percentage changes in accident numbers according to severity and the related estimated changes in accident costs per kilometre per year. The estimated changes in accidents and costs using the Taylor and the Elvik accident-speed models are presented separately for the purpose of comparison.

The Taylor Level 1 and Taylor Level 2 models are so similar that it was not considered worthwhile to present the findings using both and the Taylor Level 2 model was chosen.

Although separate Taylor models are available for link and junction accidents and according to single and multiple vehicle accidents, it was considered to be not worthwhile to conduct the analysis at that level of detail. Similarly, Elvik has produced casualty-speed relationships which might have been used alternatively.

Table 4.3, Table 4.4 and Table 4.5 show differences between the various ATC sites but in order to present a clearer picture, the data for all sites have been combined.

The results are as follows:

- Table 4.3 shows that the introduction of speed enforcement (Option 1) is estimated to reduce accidents by the following percentages: fatal (36 per cent); serious injury (25 per cent); fatal and serious combined (25 per cent); slight injury (11 to 23 per cent); and all injury accidents (16 to 24 per cent). Accident costs are estimated to reduce by about £18,000 to £24,000 per km per year.

- Table 4.4 shows that the introduction of speed enforcement plus increasing the HGV speed limit to 50mph (Option 2) is estimated to reduce accidents by the following percentages: fatal (27 per cent); serious injury (18 per cent); fatal and serious combined (19 per cent); slight injury (8 to 17 per cent); and all injury accidents (about 12 to 18 per cent). Accident costs are estimated to reduce by about £14,000 to £18,000 per km per year.

- Table 4.5 shows that the introduction of speed enforcement plus increasing the HGV speed limit to 60mph (Option 3) is estimated to reduce accidents by the following percentages: fatal (23 per cent); serious injury (15 per cent); fatal and serious combined (15 per cent); slight injury (7 to 14 per cent); and all injury accidents (10 to 14 per cent). Accident costs are estimated to reduce by about £11,000 to £15,000 per km per year.

Table 4.3: Findings for Option 1 (2010 'Neutral' Month)

Counter Site	Model	Mean Speed (mph) Ref Case	Option1	Reduction in Mean Speed (mph)	Percentage Reduction in Accidents Fatal	Serious	Fatal & Serious	Slight	All Injury Accidents	Reduction in Accident Cost (per km per year)
JTC00148	Taylor	58.37	51.78	6.59	-	-	28.4%	24.2%	25.3%	£20,534
	Elvik	58.37	51.78	6.59	38.8%	26.8%	-	12.3%	17.4%	£25,397
JTC00311	Taylor	55.54	49.80	5.74	-	-	26.3%	22.3%	23.3%	£18,976
	Elvik	55.54	49.80	5.74	36.1%	24.7%	-	11.3%	16.0%	£23,584
JTC00312	Taylor	55.80	50.17	5.63	-	-	25.7%	21.8%	22.8%	£18,553
	Elvik	55.80	50.17	5.63	35.3%	24.1%	-	11.0%	15.6%	£23,088
JTC00313	Taylor	53.84	49.21	4.63	-	-	22.2%	18.8%	19.6%	£16,042
	Elvik	53.84	49.21	4.63	30.8%	20.9%	-	9.4%	13.4%	£20,115
JTC00314	Taylor	57.64	50.56	7.07	-	-	30.6%	26.2%	27.3%	£22,131
	Elvik	57.64	50.56	7.07	41.5%	28.9%	-	13.4%	18.9%	£27,237
JTC00352	Taylor	56.20	50.83	5.38	-	-	24.5%	20.8%	21.7%	£17,687
	Elvik	56.20	50.83	5.38	33.8%	23.0%	-	10.5%	14.9%	£22,069
JTC00353	Taylor	54.91	49.20	5.70	-	-	26.4%	22.4%	23.4%	£19,060
	Elvik	54.91	49.20	5.70	36.2%	24.8%	-	11.4%	16.1%	£23,682
JTC00354	Taylor	54.13	48.54	5.59	-	-	26.2%	22.3%	23.3%	£18,965
	Elvik	54.13	48.54	5.59	36.1%	24.7%	-	11.3%	16.0%	£23,571
JTC00355	Taylor	54.78	49.74	5.03	-	-	23.6%	20.0%	20.9%	£17,048
	Elvik	54.78	49.74	5.03	32.7%	22.2%	-	10.1%	14.3%	£21,313
JTC00367	Taylor	56.77	50.51	6.27	-	-	27.9%	23.7%	24.7%	£20,127
	Elvik	56.77	50.51	6.27	38.1%	26.2%	-	12.1%	17.1%	£24,927
JTC00368	Taylor	56.67	50.31	6.36	-	-	28.3%	24.1%	25.1%	£20.446
	Elvik	56.67	50.31	6.36	38.6%	26.6%	-	12.3%	17.4%	£25,296
All Sites Combined	Taylor	55.88	50.06	5.82	-	-	25.4%	23.3%	23.9%	£18,433
	Elvik	55.88	50.06	5.82	36.2%	24.8%	-	11.4%	16.1%	£23,692

Table 4.4: Findings for Option 2 (2010 ‘Neutral’ Month)

Counter Site	Model	Mean Speed (mph) Ref Case	Option 2	Reduction in Mean Speed (mph)	Percentage Reduction in Accidents Fatal	Serious	Fatal & Serious	Slight	All Injury Accidents	Reduction in Accident Cost (per km per year)
JTC00148	Taylor	58.37	52.92	5.45	-	-	23.9%	20.3%	21.2%	£17,284
	Elvik	58.37	52.92	5.45	33.1%	22.5%	-	10.2%	14.5%	£21,592
JTC00311	Taylor	55.54	51.36	4.18	-	-	19.6%	16.6%	17.3%	£14,182
	Elvik	55.54	51.36	4.18	27.5%	18.4%	-	8.3%	11.8%	£17,882
JTC00312	Taylor	55.80	51.83	3.97	-	-	18.6%	15.7%	16.4%	£13,436
	Elvik	55.80	51.83	3.97	26.1%	17.4%	-	7.8%	11.1%	£16,978
JTC00313	Taylor	53.84	51.02	2.81	-	-	13.9%	11.7%	12.2%	£10,051
	Elvik	53.84	51.02	2.81	19.8%	13.0%	-	5.7%	8.2%	£12,826
JTC00314	Taylor	57.64	52.15	5.49	-	-	24.4%	20.7%	21.6%	£17,620
	Elvik	57.64	52.15	5.49	33.7%	22.9%	-	10.4%	14.8%	£21,990
JTC00352	Taylor	56.20	52.37	3.83	-	-	17.9%	15.1%	15.8%	£12,919
	Elvik	56.20	52.37	3.83	25.1%	16.8%	-	7.5%	10.7%	£16,350
JTC00353	Taylor	54.91	50.97	3.94	-	-	18.8%	15.8%	16.5%	£13,545
	Elvik	54.91	50.97	3.94	26.3%	17.6%	-	7.9%	11.2%	£17,111
JTC00354	Taylor	54.13	50.40	3.73	-	-	18.1%	15.2%	15.9%	£13,057
	Elvik	54.13	50.40	3.73	25.4%	16.9%	-	7.6%	10.8%	£16,518
JTC00355	Taylor	54.78	51.41	3.36	-	-	16.2%	13.7%	14.3%	£11,714
	Elvik	54.78	51.41	3.36	22.9%	15.2%	-	6.7%	9.6%	£14,878
JTC00367	Taylor	56.77	52.07	4.70	-	-	21.4%	18.1%	18.9%	£15,481
	Elvik	56.77	52.07	4.70	29.8%	20.1%	-	9.1%	12.9%	£19,445
JTC00368	Taylor	56.67	51.91	4.76	-	-	21.7%	18.4%	19.2%	£15,697
	Elvik	56.67	51.91	4.76	30.2%	20.4%	-	9.2%	13.1%	£19,703
All Sites Combined	Taylor	55.88	51.67	4.20	-	-	18.8%	17.2%	17.6%	£13,646
	Elvik	55.88	51.67	4.20	27.3%	18.3%	-	8.2%	11.7%	£17,801

Table 4.5: Findings for Option 3 (2010 ‘Neutral’ Month)

Counter Site	Model	Mean Speed (mph) Ref Case	Option 1	Reduction in Mean Speed (mph)	Percentage Reduction in Accidents Fatal	Serious	Fatal & Serious	Slight	All Injury Accidents	Reduction in Accident Cost (per km per year)
JTC00148	Taylor	58.37	53.49	4.87	-	-	21.6%	18.3%	19.1%	£15,601
	Elvik	58.37	53.49	4.87	30.0%	20.3%	-	9.1%	13.0%	£19,589
JTC00311	Taylor	55.54	52.16	3.38	-	-	16.1%	13.5%	14.1%	£11,602
	Elvik	55.54	52.16	3.38	22.7%	15.0%	-	6.7%	9.5%	£14,739
JTC00312	Taylor	55.80	52.70	3.10	-	-	14.8%	12.4%	13.0%	£10,652
	Elvik	55.80	52.70	3.10	20.9%	13.8%	-	6.1%	8.7%	£13,570
JTC00313	Taylor	53.84	51.95	1.88	-	-	9.5%	7.9%	8.3%	£6,834
	Elvik	53.84	51.95	1.88	13.6%	8.8%	-	3.8%	5.5%	£8,800
JTC00314	Taylor	57.64	52.91	4.73	-	-	21.3%	18.0%	18.8%	£15,358
	Elvik	57.64	52.91	4.73	29.6%	20.0%		9.0%	12.8%	£19,298
JTC00352	Taylor	56.20	53.10	3.11	-	-	14.7%	12.3%	12.9%	£10,598
	Elvik	56.20	53.10	3.11	20.8%	13.7%	-	6.1%	8.7%	£13,503
JTC00353	Taylor	54.91	51.87	3.04	-	-	14.7%	12.4%	12.9%	£10,610
	Elvik	54.91	51.87	3.04	20.8%	13.8%	-	6.1%	8.7%	£13,518
JTC00354	Taylor	54.13	51.35	2.78	-	-	13.7%	11.5%	12.0%	£9,897
	Elvik	54.13	51.35	2.78	19.5%	12.8%	-	5.6%	8.1%	£12,635
JTC00355	Taylor	54.78	52.35	2.43	-	-	11.9%	10.0%	10.4%	£8,584
	Elvik	54.78	52.35	2.43	17.0%	11.1%	-	4.9%	7.0%	£11,000
JTC00367	Taylor	56.77	52.72	4.05	-	-	18.7%	15.8%	16.5%	£13,488
	Elvik	56.77	52.72	4.05	26.2%	17.5%	-	7.8%	11.2%	£17,042
JTC00368	Taylor	56.67	52.59	4.08	-	-	18.8%	15.9%	16.6%	£13,593
	Elvik	56.67	52.59	4.08	26.4%	17.6%	-	7.9%	11.3%	£17,169
All Sites Combined	Taylor	55.88	52.47	3.40	-	-	15.4%	14.0%	14.4%	£11,190
	Elvik	55.88	52.47	3.40	22.6%	15.0%	-	6.6%	9.5%	£14,693

4.4.2 **'Summer' Month**

The findings are presented in Table 4.6 (Option 1), Table 4.7 (Option 2) and Table 4.8 (Option 3). As indicated previously, only the Taylor 2 and Elvik models are presented.

Table 4.6, Table 4.7 and Table 4.8 show differences between the various sites but in order to present a clearer picture the data for all sites have been combined.

- Table 4.6 shows that the introduction of speed enforcement (Option 1) is estimated to reduce accidents by the following percentages: fatal (35 per cent); serious injury (24 per cent); fatal and serious combined (25 per cent); slight injury (11 to 22 per cent); and all injury accidents (15 to 23 per cent). Accident costs are estimated to reduce by about £18,000 to £23,000 per km per year.
- Table 4.7 shows that the introduction of speed enforcement plus increasing the HGV speed limit to 50mph (Option 2) is estimated to reduce accidents by the following percentages: fatal (25 per cent); serious injury (17 per cent); fatal and serious combined (18 per cent); slight injury (8 to 16 per cent); and all injury accidents (11 to 16 per cent). Accident costs are estimated to reduce by about £13,000 to £17,000 per km per year.
- Table 4.8 shows that the introduction of speed enforcement plus increasing the HGV speed limit to 60mph (Option 3) is estimated to reduce accidents by the following percentages: fatal (21 per cent); serious injury (14 per cent); fatal and serious combined (14 per cent); slight injury (6 to 13 per cent); and all injury accidents (9 to 13 per cent). Accident costs are estimated to reduce by about £10,000 to £13,000 per km per year.

Table 4.6: Findings for Option 1 (2010 'Summer' Month)

Counter Site	Model	Mean Speed (mph)		Reduction in Mean Speed (mph)	Percentage Reduction in Accidents					Reduction in Accident Cost (per km per year)
		Ref Case	Option 1		Fatal	Serious	Fatal & Serious	Slight	All Injury Accidents	
JTC00148	Taylor	57.75	51.60	6.15	-	-	27.0%	23.0%	23.9%	£19,488
	Elvik	57.75	51.60	6.15	37.0%	25.4%	-	11.6%	16.5%	£24,182
JTC00311	Taylor	55.82	49.25	6.57	-	-	29.5%	25.2%	26.2%	£21,325
	Elvik	55.82	49.25	6.57	40.2%	27.8%	-	12.9%	18.2%	£26,311
JTC00312	Taylor	54.33	49.69	4.63	-	-	22.0%	18.6%	19.5%	£15,907
	Elvik	54.33	49.69	4.63	30.6%	20.7%	-	9.3%	13.3%	£19,954
JTC00313	Taylor	52.75	48.62	4.13	-	-	20.4%	17.2%	18.0%	£14,716
	Elvik	52.75	48.62	4.13	28.4%	19.1%	-	8.6%	12.2%	£18,526
JTC00314	Taylor	54.79	50.11	4.68	-	-	22.1%	18.7%	19.5%	£15,933
	Elvik	54.79	50.11	4.68	30.6%	20.7%	-	9.4%	13.3%	£19,985
JTC00352	Taylor	53.44	50.22	3.22	-	-	15.9%	13.4%	14.0%	£11,486
	Elvik	53.44	50.22	3.22	22.5	14.9%	-	6.6%	9.5%	£14,597
JTC00353	Taylor	52.92	48.74	4.19		-	20.6%	17.4%	18.2%	£14,847
	Elvik	52.92	48.74	4.19	28.7%	19.3%	-	8.7%	12.4%	£18,684
JTC00354	Taylor	54.40	47.89	6.51	-	-	29.9%	25.6%	26.6%	£21,632
	Elvik	54.40	47.89	6.51	40.7%	28.2%	-	13.1%	18.4%	£26,665
JTC00355	Taylor	56.32	49.08	7.23	-	-	31.9%	27.3%	28.4%	£23,033
	Elvik	56.32	49.08	7.23	43.1%	30.0%	-	14.0%	19.7%	£28,266
JTC00367	Taylor	57.64	50.10	7.54	-	-	32.4%	27.7%	28.9%	£23,407
	Elvik	57.64	50.10	7.54	43.7%	30.5%	-	14.3%	20.1%	£28,691
JTC00368	Taylor	55.66	49.88	5.78	-	-	26.4%	22.4%	23.4%	£19,064
	Elvik	55.66	49.88	5.78	36.2%	24.8%	-	11.4%	16.1%	£23,687
All Sites Combined	Taylor	55.07	49.56	5.51	-	-	24.5%	22.4%	23.0%	£17,777
	Elvik	55.07	49.56	5.51	34.9%	23.9%	-	10.9%	15.4%	£22,837

Table 4.7: Findings for Option 2 (2010 'Summer' Month)

Counter Site	Model	Mean Speed (mph) Ref Case	Option 2	Reduction in Mean Speed (mph)	Percentage Reduction in Accidents Fatal	Serious	Fatal & Serious	Slight	All Injury Accidents	Reduction in Accident Cost (per km per year)
JTC00148	Taylor	57.75	52.75	4.99	-	-	22.3%	18.9%	19.7%	£16,116
	Elvik	57.75	52.75	4.99	31.0%	21.0%	-	9.5%	13.5%	£20,204
JTC00311	Taylor	55.82	50.91	4.91	-	-	22.7%	19.2%	20.1%	£16,371
	Elvik	55.82	50.91	4.91	31.4%	21.3%	-	9.6%	13.7%	£20,508
JTC00312	Taylor	54.33	51.43	2.89	-	-	14.2%	11.9%	12.4%	£10,223
	Elvik	54.33	51.43	2.89	20.1%	13.3%	-	5.8%	8.4%	£13,039
JTC00313	Taylor	52.75	50.57	2.18	-	-	11.1%	9.3%	9.7%	£8,019
	Elvik	52.75	50.57	2.18	15.9%	10.4%	-	4.5%	6.5%	£10,292
JTC00314	Taylor	54.79	51.75	3.04	-	-	14.7%	12.4%	13.0%	£10,647
	Elvik	54.79	51.75	3.04	20.9%	13.8%	-	6.1%	8.7%	£13,563
JTC00352	Taylor	53.44	51.82	1.62	-	-	8.2%	6.9%	7.2%	£5,951
	Elvik	53.44	51.82	1.62	11.9%	7.7%	-	3.3%	4.8%	£7,683
JTC00353	Taylor	52.92	50.52	2.41	-	-	12.2%	10.2%	10.7%	£8,794
	Elvik	52.92	50.52	2.41	17.4%	11.4%	-	5.0%	7.2%	£11,262
JTC00354	Taylor	54.40	49.87	4.53	-	-	21.6%	18.3%	19.1%	£15,583
	Elvik	54.40	49.87	4.53	30.0%	20.3%	-	9.1%	13.0%	£19,567
JTC00355	Taylor	56.32	50.81	5.51	-	-	25.0%	21.2%	22.1%	£18,047
	Elvik	56.32	50.81	5.51	34.4%	23.5%	-	10.7%	15.2%	£22,493
JTC00367	Taylor	57.64	51.75	5.90	-	-	26.0%	22.1%	23.1%	£18,793
	Elvik	57.64	51.75	5.90	35.7%	24.5%	-	11.2%	15.9%	£23,370
JTC00368	Taylor	55.66	51.55	4.12	-	-	19.3%	16.3%	17.0%	£13,951
	Elvik	55.66	51.55	4.12	27.0%	18.1%	-	8.1%	11.6%	£17,602
All Sites Combined	Taylor	55.07	51.25	3.83	-	-	17.5%	15.9%	16.4%	£12,671
	Elvik	55.07	51.25	3.83	25.4%	16.9%	-	7.6%	10.8%	£16,506

Table 4.8: Findings for Option 3 (2010 'Summer' Month)

Counter Site	Model	Mean Speed (mph) Ref Case	Option 1	Change in mean speed (mph)	Percentage Change in Accidents Fatal	Serious	Fatal & Serious	Slight	All Injury Accidents	Change in accident cost (per km per year)
JTC00148	Taylor	57.75	53.26	4.49	-	-	20.2%	17.1%	17.8%	£14,596
	Elvik	57.75	53.26	4.49	28.2%	19.0%	-	8.5%	12.1%	£18,381
JTC00311	Taylor	55.82	51.65	4.17	-	-	19.5%	16.5%	17.2%	£14,084
	Elvik	55.82	51.65	4.17	27.3%	18.3%	-	8.2%	11.7%	£17,764
JTC00312	Taylor	54.33	52.35	1.97	-	-	9.8%	8.2%	8.6%	£7,088
	Elvik	54.33	52.35	1.97	14.1%	9.2%	-	4.0%	5.8%	£9,121
JTC00313	Taylor	52.75	52.35	1.97	-	-	6.5%	5.4%	5.7%	£4,704
	Elvik	52.75	52.35	1.97	9.4%	6.1%	-	2.6%	3.8%	£6,094
JTC00314	Taylor	54.79	52.50	2.29	-	-	11.3%	9.4%	9.9%	£8,125
	Elvik	54.79	52.50	2.29	16.1%	10.5%	-	4.6%	6.6%	£10,426
JTC00352	Taylor	53.44	52.56	0.88	-	-	4.5%	3.8%	4.0%	£3,282
	Elvik	53.44	52.56	0.88	6.6%	4.2%	-	1.8%	2.6%	£4,268
JTC00353	Taylor	52.92	51.39	1.53	-	-	7.9%	6.6%	6.9%	£5,680
	Elvik	52.92	51.39	1.53	11.3%	7.3%	-	3.2%	4.6%	£7,338
JTC00354	Taylor	54.40	50.77	3.63	-	-	17.6%	14.8%	15.5%	£12,678
	Elvik	54.40	50.77	3.63	24.7%	16.5%	-	7.3%	10.5%	£16,056
JTC00355	Taylor	56.32	51.79	4.53	-	-	20.9%	17.7%	18.4%	£15,080
	Elvik	56.32	51.79	4.53	29.1%	19.6%	-	8.8%	12.6%	£18,964
JTC00367	Taylor	57.64	52.41	5.23	-	-	23.3%	19.8%	20.7%	£16,862
	Elvik	57.64	52.41	5.23	32.3%	21.9%	-	9.9%	14.1%	£21,091
JTC00368	Taylor	55.66	52.26	3.40	-	-	16.2%	13.6%	14.2%	£11,667
	Elvik	55.66	52.26	3.40	22.8%	15.1%	-	6.7%	9.6%	£14,820
All Sites Combined	Taylor	55.07	52.04	3.04	-	-	14.0%	12.8%	13.1%	£10,176
	Elvik	55.07	52.04	3.04	20.5%	13.6%	-	6.0%	8.6%	£13,324

5 Summary, Findings & Recommendations

5.1 Summary

As part of Transport Scotland's Trunk Road Research programme, consultants SIAS and TRL were re-appointed to refine earlier research work to investigate the operational and safety impacts of increasing the single carriageway HGV speed restriction (for vehicles in excess of 7.5 tonnes) from 40mph to (a) 50mph and (b) 60mph (effectively 56mph).

At the request of Transport Scotland's Trunk Road Policy Steering Group (TRPSG), the research was refined to include consideration of effective speed enforcement.

5.2 Findings of the Microsimulation Modelling

The results of the microsimulation modelling can be summarised as follows:

<u>The Effect of Speed Enforcement</u>

The results of the neutral month modelling indicated that, compared to the current situation, the introduction of effective speed enforcement would result in:

- a reduction of around 6mph in average speeds (all vehicles)
- a corresponding increase of around 8% in modelled journey times
- a reduction of up to 7% in the desire to overtake on single carriageway sections.

The results for the summer models were similar, but slightly more pronounced.

<u>The Effect of Speed Enforcement plus HGV Speed Limit Increases</u>

The results of the neutral month modelling indicated that, compared to the current situation, the introduction of effective speed enforcement combined with an increase in the HGV speed limit would result in:

- a slight reduction of 3mph in average speeds (all vehicles)
- a slight increase of around 1min in journey times

- a reduction of around 13% in the desire to overtake on single carriageway sections.
- a reduction in the numbers of vehicles travelling at excessive speed
- a general improvement in operational behaviour.

Again, the results for the summer models were similar, but slightly more pronounced.

In addition, the effect on vehicle emissions, speed distributions and operation were also assessed.

Together, the introduction of average speed cameras and the increase in HGV speed limits is predicted to help reduce overall emissions (Carbon Dioxide Equivalent, NOx and PM10). In general, there is a slight increase in the emissions for slow moving vehicles, but this would be offset by reductions in emissions for all other vehicle types.

In terms of vehicle speed distribution, the number of vehicles travelling at excessive speeds is predicted to reduce, as is the number of HGVs (and other slow moving vehicles) travelling at comparatively low speeds. This effect reduces the maximum speed and increases the minimum speeds respectively, thereby reducing the speed variation by around 35%.

Operationally, the microsimulation modelling indicates that a general reduction in platoon lengths would result, with a reduction in the variation on vehicle headways.

5.3 Findings of the Accident Assessment

Data outputs from the microsimulation model were used to estimate the changes to accident and accident costs per km per year. The assessment was carried out for both ‘neutral’ and ‘summer’ month models for:

- Base → Option 1
- Base → Option 2
- Base → Option 3

The results of the accident assessment indicated:

5.3.1 'Neutral' Month

- the introduction of speed enforcement (Option 1) is estimated to reduce accidents by the following percentages: fatal (36 per cent); serious injury (25 per cent); fatal and serious combined (25 per cent); slight injury (11 to 23 per cent); and all injury accidents (16 to 24 per cent). Accident costs are estimated to reduce by about £18,000 to £24,000 per km per year.

- the introduction of speed enforcement plus increasing the HGV speed limit to 50mph (Option 2) is estimated to reduce accidents by the following percentages: fatal (27 per cent); serious injury (18 per cent); fatal and serious combined (19 per cent); slight injury (8 to 17 per cent); and all injury accidents (about 12 to 18 per cent). Accident costs are estimated to reduce by about £14,000 to £18,000 per km per year.

- the introduction of speed enforcement plus increasing the HGV speed limit to 60mph (Option 3) is estimated to reduce accidents by the following percentages: fatal (23 per cent); serious injury (15 per cent); fatal and serious combined (15 per cent); slight injury (7 to 14 per cent); and all injury accidents (10 to 14 per cent). Accident costs are estimated to reduce by about £11,000 to £15,000 per km per year.

5.3.2 'Summer' Month

- the introduction of speed enforcement (Option 1) is estimated to reduce accidents by the following percentages: fatal (35 per cent); serious injury (24 per cent); fatal and serious combined (25 per cent); slight injury (11 to 22 per cent); and all injury accidents (15 to 23 per cent). Accident costs are estimated to reduce by about £18,000 to £23,000 per km per year.

- the introduction of speed enforcement plus increasing the HGV speed limit to 50mph (Option 2) is estimated to reduce accidents by the following percentages: fatal (25 per cent); serious injury (17 per cent); fatal and serious combined (18 per cent); slight injury (8 to 16 per cent); and all injury accidents (11 to 16 per cent). Accident costs are estimated to reduce by about £13,000 to £17,000 per km per year.

- the introduction of speed enforcement plus increasing the HGV speed limit to 60mph (Option 3) is estimated to reduce accidents by the following percentages: fatal (21 per cent); serious injury (14 per cent); fatal and serious combined (14 per cent); slight injury (6 to 13 per cent); and all injury accidents (9 to 13 per cent). Accident costs are estimated to reduce by about £10,000 to £13,000 per km per year.

5.4 Comparison with Government Objectives

A qualitative assessment of the impacts of the tested measures against the five STAG objectives is summarised as follows:

- **Environment:** A small reduction in overall tailpipe emissions (all vehicles combined) could be expected from an increase in the speed limit for HGVs, whether in conjunction with speed enforcement measures or not. A slight, general increase in emissions for slow moving/heavy vehicles would be offset by reductions in emissions for all other vehicle types

- **Safety:** The safety impact of increasing the HGV speed limit alone was inconclusive. However, accident benefits were consistently predicted when an increase in HGV speed limits was combined with speed enforcement measures

- **Economy:** The operational improvements from an increase in HGV speed limit would be counter-balanced by speed enforcement measures. Reduced accident numbers would be achieved with speed enforcement measures in place, helping to offset any operational disbenefit. Uncertainty over the setup and enforcement costs of a speed enforcement system make it difficult to capture the full costs and benefits to the wider economy of these measures

- **Integration:** The impacts with respect to integration in transport, land-use and policy terms of these measures are likely to be negligible

- **Accessibility & Social Inclusion:** The impacts with respect to community/comparative accessibility and, hence social inclusion of these measures are likely to be negligible

5.5 Study Recommendations

5.5.1 Validation of Speed Enforcement in Microsimulation Models

The influence of effective speed camera enforcement was reflected in the modelling process in this study using the data available at the time. With the subsequent availability of more detailed observations, further modelled to observed speed distribution comparisons have highlighted some areas which could be considered in future studies of this nature to refine the model validation. These include:

- collecting observed speed data from a wider sample of sites reflecting differing local conditions
- considering the local topography, geometry and general surrounding environment, which may enable more refined coding to be included in the model to better reflect the impact of these factors on local vehicle speeds
- further refinement of the operational performance parameters by vehicle type (e.g. alterations to target speeds could be accompanied by application of the more detailed S-Paramics HGV deceleration model that impacts HGV speed/acceleration on gradients and application of the drag parameter that influences the top speed of vehicles)

5.5.2 Identification of Further Accident Benefits

The findings from the S-Paramics micro-simulation model predict that the effect of increasing the speed limit for heavy goods vehicles shows significant variation between different locations on the A9(T). Furthermore, the predicted effect of changes to heavy goods vehicle speeds on the speeds of other categories of vehicle varies between locations. An investigation of these relationships would permit a better understanding of the likely safety effects of increasing the HGV speed limit on sections of the A9(T) that have not been subject to micro-simulation modelling and to roads other than the A9(T). The implications are as follows:

- there may be some sections of the A9(T) where it is more important to enforce speed limits than on other sections. This is important given that the section of the A9(T) between Perth and Inverness is 170 km long.
- it would be useful to have a more general understanding of the effect of speed limits on speeds if speed limits are to be changed on roads other than the A9(T) which may have different characteristics.

Accident severity on the A9(T) is higher than on other non built-up trunk roads in Scotland. This may be attributable only in part to the relatively high speeds on A9(T) and other factors may have a significant influence. It is recommended that the characteristics of accidents on A9(T) be compared with those on the other trunk roads in Scotland. For example, it may be that the occurrence of accidents involving other vehicles overtaking HGVs is greater on A9(T) than on other roads. If so, then there may be safety benefits in increasing the HGV speed limit that the current study has not identified.

The Impact of Speed Enforcement and Increasing the HGV Speed Limit on the A9(T)

Transport Scotland

Microsimulation Modelling and Accident Assessment – Appendices

May 2012

THE IMPACT OF SPEED ENFORCEMENT AND INCREASING THE HGV SPEED LIMIT ON THE A9(T)

Description: Microsimulation Modelling and Accident Assessment

Date: 30 May 2012

Authors: Ian Summersgill (TRL)/Malcolm Neil (SIAS Ltd)

CONTENTS:

FIGURES:

TABLES:

A Appendix A – Headways

Table A.1: Northbound Headway Comparison for ATC site West of Aviemore (2010 Neutral Month)

Time (s)	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
			Northbound				
<5	2,264	2,056	**-9%**	1,940	**-14%**	1,817	**-20%**
10	79	138	**75%**	157	**99%**	197	**148%**
15	70	127	**82%**	146	**110%**	165	**137%**
20	72	116	**61%**	137	**92%**	157	**119%**
30	139	188	**35%**	226	**62%**	272	**95%**
60	284	340	**20%**	386	**36%**	435	**53%**
90	189	185	**-2%**	191	**1%**	181	**-4%**
120	107	102	**-4%**	93	**-12%**	87	**-18%**
150	63	56	**-11%**	50	**-20%**	41	**-34%**
180	42	34	**-19%**	33	**-23%**	29	**-32%**
>360	66	55	**-17%**	49	**-26%**	46	**-30%**

Table A.2: Southbound Headway Comparison for ATC site West of Aviemore (2010 Neutral Month)

Time (s)	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
			Southbound				
<5	2,179	2,117	**-3%**	2,013	**-8%**	1,924	**-12%**
10	217	257	**19%**	309	**42%**	365	**69%**
15	212	244	**15%**	279	**32%**	299	**41%**
20	215	222	**4%**	245	**14%**	257	**20%**
30	336	332	**-1%**	360	**7%**	377	**12%**
60	446	441	**-1%**	435	**-3%**	439	**-2%**
90	151	158	**4%**	149	**-2%**	144	**-5%**
120	64	61	**-5%**	57	**-11%**	55	**-14%**
150	33	32	**-4%**	34	**3%**	31	**-7%**
180	24	21	**-13%**	21	**-14%**	21	**-13%**
>360	42	43	**0%**	41	**-3%**	40	**-7%**

Table A.3: Northbound Headway Comparison for ATC site Slochd dual (2010 Neutral Month)

	Northbound						
Time (s)	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
<5	2,799	2,791	**0%**	2,684	**-4%**	2,559	**-9%**
10	254	265	**4%**	289	**13%**	331	**30%**
15	158	188	**19%**	216	**36%**	250	**59%**
20	154	161	**4%**	182	**18%**	206	**33%**
30	256	241	**-6%**	272	**6%**	308	**21%**
60	422	392	**-7%**	433	**3%**	463	**10%**
90	203	185	**-9%**	185	**-9%**	177	**-13%**
120	79	90	**14%**	80	**1%**	69	**-13%**
150	39	44	**12%**	38	**-4%**	34	**-13%**
180	25	26	**7%**	24	**-3%**	23	**-6%**
>360	42	42	**0%**	39	**-7%**	37	**-12%**

Table A.4: Southbound Headway Comparison for ATC site Slochd dual (2010 Neutral Month)

	Southbound						
Time (s)	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
<5	2,688	2,588	**-4%**	2,520	**-6%**	2,482	**-8%**
10	544	549	**1%**	594	**9%**	622	**14%**
15	297	327	**10%**	352	**18%**	369	**24%**
20	208	241	**16%**	254	**22%**	266	**28%**
30	293	335	**14%**	336	**15%**	334	**14%**
60	401	427	**6%**	430	**7%**	418	**4%**
90	156	140	**-10%**	138	**-11%**	138	**-12%**
120	62	58	**-6%**	53	**-15%**	54	**-13%**
150	29	28	**-4%**	28	**-6%**	28	**-6%**
180	22	20	**-7%**	19	**-12%**	18	**-15%**
>360	43	38	**-10%**	39	**-9%**	38	**-11%**

Table A.5: Northbound Headway Comparison for ATC site West of Aviemore (2010 Summer Month)

			Northbound				
Time (s)	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
<5	2,728	2,511	**-8%**	2,396	**-12%**	2,269	**-17%**
10	81	148	**83%**	186	**130%**	209	**159%**
15	73	134	**83%**	152	**107%**	174	**137%**
20	72	114	**58%**	139	**93%**	160	**122%**
30	141	200	**42%**	231	**63%**	271	**92%**
60	312	354	**14%**	390	**25%**	450	**44%**
90	188	188	**0%**	189	**0%**	183	**-3%**
120	113	102	**-10%**	99	**-13%**	88	**-22%**
150	63	59	**-7%**	54	**-15%**	50	**-22%**
180	46	39	**-15%**	33	**-27%**	31	**-33%**
>360	60	55	**-9%**	48	**-20%**	41	**-31%**

Table A.6: Southbound Headway Comparison for ATC site West of Aviemore (2010 Summer Month)

			Southbound				
Time (s)	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
<5	2,649	2,566	**-3%**	2,448	**-8%**	2,355	**-11%**
10	251	291	**16%**	359	**43%**	414	**65%**
15	231	270	**17%**	309	**34%**	342	**48%**
20	240	250	**4%**	278	**16%**	294	**23%**
30	361	363	**1%**	375	**4%**	387	**7%**
60	449	456	**2%**	457	**2%**	459	**2%**
90	151	147	**-3%**	141	**-7%**	130	**-14%**
120	65	64	**-2%**	60	**-7%**	59	**-10%**
150	33	31	**-6%**	31	**-5%**	29	**-11%**
180	22	23	**3%**	22	**-1%**	22	**-2%**
>360	45	42	**-6%**	40	**-10%**	42	**-8%**

Table A.7: Northbound Headway Comparison for ATC site Slochd dual (2010 Summer Month)

			Northbound				
Time (s)	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
<5	3,283	3,266	**-1%**	3,160	**-4%**	3,038	**-7%**
10	269	275	**2%**	300	**12%**	346	**29%**
15	167	192	**15%**	229	**37%**	255	**53%**
20	160	167	**5%**	185	**16%**	199	**25%**
30	257	260	**1%**	286	**11%**	329	**28%**
60	417	389	**-7%**	435	**4%**	462	**11%**
90	204	200	**-2%**	184	**-10%**	176	**-14%**
120	83	88	**6%**	83	**-1%**	74	**-11%**
150	45	44	**-3%**	38	**-15%**	39	**-14%**
180	24	28	**18%**	26	**7%**	23	**-5%**
>360	42	42	**0%**	40	**-5%**	38	**-10%**

Table A.8: Southbound Headway Comparison for ATC site Slochd dual (2010 Summer Month)

			Southbound				
Time (s)	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
<5	3,178	3,062	**-4%**	2,985	**-6%**	2,965	**-7%**
10	549	563	**3%**	611	**11%**	620	**13%**
15	288	313	**9%**	338	**17%**	358	**24%**
20	199	244	**22%**	254	**27%**	254	**27%**
30	281	328	**17%**	337	**20%**	334	**19%**
60	372	405	**9%**	408	**10%**	402	**8%**
90	141	126	**-11%**	122	**-14%**	120	**-15%**
120	54	43	**-20%**	42	**-22%**	43	**-21%**
150	25	20	**-20%**	20	**-21%**	20	**-19%**
180	19	17	**-14%**	16	**-17%**	16	**-17%**
>360	36	35	**-3%**	33	**-8%**	33	**-9%**

B Appendix B – Average Speeds

Table B.1: Change in Average Speed (2010 Neutral Month)

Site Location	Base	Option 1	Option 1 - Base	Option 2	Option 2 Base	Option 3	Option 3 - Base
Northbound - Dalwhinnie JTC00148	62.54	54.23	-8.32	55.00	-7.54	55.29	-7.26
Southbound - Dalwhinnie JTC00148	54.76	49.67	-5.09	51.12	-3.63	51.95	-2.81
Northbound - North of Dalwhinnie JTC00311	58.95	52.07	-6.88	53.30	-5.65	53.79	-5.16
Southbound - North of Dalwhinnie JTC00311	52.47	47.75	-4.71	49.61	-2.86	50.70	-1.77
Northbound - South of A86 JTC00312	55.87	50.40	-5.47	52.02	-3.85	52.79	-3.08
Southbound - South of A86 JTC00312	55.73	49.97	-5.77	51.66	-4.07	52.62	-3.12
Northbound - West of Aviemore JTC00313	52.35	48.72	-3.62	50.62	-1.72	51.60	-0.75
Southbound - West of Aviemore JTC00313	55.14	49.63	-5.51	51.37	-3.77	52.26	-2.88
Northbound - Slochd dualling JTC00314	55.79	48.83	-6.96	50.63	-5.17	51.65	-4.14
Southbound - Slochd dualling JTC00314	59.38	52.20	-7.18	53.58	-5.80	54.10	-5.29
Northbound - North of B9150 JTC00352	57.64	52.56	-5.08	53.76	-3.88	54.10	-3.54
Southbound - North of B9150 JTC00352	54.89	49.24	-5.65	51.11	-3.78	52.18	-2.70
Northbound - Ralia Straight JTC00353	55.72	50.37	-5.35	51.98	-3.74	52.61	-3.11
Southbound - Ralia Straight JTC00353	54.16	48.14	-6.03	50.04	-4.12	51.19	-2.97
Northbound - South end of Insh JTC00354	57.20	50.12	-7.08	51.82	-5.38	52.60	-4.60
Southbound - South end of Insh JTC00354	51.31	47.09	-4.22	49.10	-2.21	50.20	-1.11
Northbound - North end of Insh JTC00355	57.33	51.28	-6.05	52.87	-4.46	53.68	-3.65
Southbound - North end of Insh JTC00355	52.41	48.32	-4.09	50.07	-2.35	51.12	-1.30
Northbound - North of Moy JTC00367	55.75	49.85	-5.90	51.57	-4.18	52.31	-3.44
Southbound - North of Moy JTC00367	57.73	51.12	-6.61	52.54	-5.19	53.10	-4.63
Northbound - 2nd North Moy dual JTC00368	54.28	48.67	-5.61	50.60	-3.69	51.49	-2.80
Southbound - 2nd North Moy dual JTC00368	58.92	51.84	-7.07	53.15	-5.77	53.63	-5.28
Average	55.92	50.09	-5.83	51.71	-4.22	52.50	-3.43

Table B.2: Change in Average Speed (2010 Summer Month)

Site Location	Base	Option 1	Option 1 - Base	Option 2	Option 2 Base	Option 3	Option 3 - Base
Northbound - Dalwhinnie JTC00148	61.80	54.09	-7.71	54.87	-6.93	55.15	-6.65
Southbound - Dalwhinnie JTC00148	54.23	49.44	-4.79	50.92	-3.31	51.62	-2.61
Northbound - North of Dalwhinnie JTC00311	57.79	51.72	-6.07	53.01	-4.78	53.52	-4.28
Southbound - North of Dalwhinnie JTC00311	51.19	47.01	-4.18	49.01	-2.18	49.95	-1.24
Northbound - South of A86 JTC00312	54.46	49.88	-4.58	51.46	-3.01	52.17	-2.29
Southbound - South of A86 JTC00312	55.09	49.52	-5.56	51.41	-3.67	52.51	-2.57
Northbound - West of Aviemore JTC00313	51.56	48.06	-3.50	50.07	-1.49	51.04	-0.52
Southbound - West of Aviemore JTC00313	54.12	49.11	-5.01	51.01	-3.11	51.89	-2.23
Northbound - Slochd dualling JTC00314	54.65	48.40	-6.25	50.20	-4.46	51.15	-3.50
Southbound - Slochd dualling JTC00314	57.89	51.73	-6.16	53.21	-4.68	53.77	-4.12
Northbound - North of B9150 JTC00352	57.31	52.12	-5.20	53.43	-3.88	53.75	-3.56
Southbound - North of B9150 JTC00352	54.15	48.48	-5.66	50.33	-3.81	51.45	-2.69
Northbound - Ralia Straight JTC00353	54.69	49.89	-4.80	51.50	-3.19	52.12	-2.57
Southbound - Ralia Straight JTC00353	53.59	47.68	-5.91	49.62	-3.98	50.73	-2.86
Northbound - South end of Insh JTC00354	55.90	49.46	-6.44	51.21	-4.69	51.95	-3.95
Southbound - South end of Insh JTC00354	50.60	46.43	-4.17	48.62	-1.98	49.67	-0.93
Northbound - North end of Insh JTC00355	55.89	50.57	-5.32	52.17	-3.72	53.05	-2.84
Southbound - North end of Insh JTC00355	52.03	47.70	-4.33	49.54	-2.49	50.61	-1.42
Northbound - North of Moy JTC00367	54.73	49.49	-5.24	51.25	-3.48	52.00	-2.73
Southbound - North of Moy JTC00367	56.74	50.68	-6.06	52.21	-4.53	52.79	-3.95
Northbound - 2nd North Moy dual JTC00368	53.15	48.19	-4.96	50.11	-3.04	51.00	-2.15
Southbound - 2nd North Moy dual JTC00368	57.94	51.47	-6.47	52.89	-5.04	53.45	-4.49
Average	54.98	49.60	-5.38	51.28	-3.70	52.06	-2.92

C Appendix C – Maximum Speeds

Table C.1: Maximum change in Average Speed (2010 Neutral Month)

Site	Option 1 minus Base NBD	Option 2 minus Base NBD	Option 3 minus Base NBD	Option 1 minus Base SBD	Option 2 minus Base SBD	Option 3 minus Base SBD
Dalwhinnie JTC00148	-9.64	-9.02	-8.82	-8.04	-7.24	-6.71
North of Dalwhinnie JTC00311	-8.20	-6.77	-6.22	-8.28	-7.21	-6.62
South of A86 JTC00312	-6.75	-5.62	-5.53	-8.34	-7.41	-7.04
West of Aviemore JTC00313	-5.89	-5.27	-4.74	-8.48	-7.59	-7.36
Slochd dualling JTC00314	-8.15	-7.45	-7.05	-9.44	-8.58	-8.32
North of B9150 JTC00352	-7.27	-6.01	-5.77	-8.31	-7.17	-6.61
Ralia Straight JTC00353	-6.80	-5.82	-5.34	-8.51	-7.68	-7.22
South end of Insh JTC00354	-8.47	-7.21	-6.78	-8.21	-7.51	-7.19
North end of Insh JTC00355	-7.73	-6.64	-6.24	-7.62	-7.05	-6.31
North of Moy JTC00367	-7.96	-6.85	-6.73	-9.95	-9.05	-8.66
2nd North Moy dual JTC00368	-8.74	-8.04	-7.91	-9.42	-8.79	-8.57
Average	-7.78	-6.79	-6.47	-8.60	-7.75	-7.33

* mph

Table C.2: Maximum change in Average Speed (2010 Summer Month)

Site	Option 1 minus Base NBD	Option 2 minus Base NBD	Option 3 minus Base NBD	Option 1 minus Base SBD	Option 2 minus Base SBD	Option 3 minus Base SBD
Dalwhinnie JTC00148	-9.10	-8.52	-8.30	-6.75	-5.84	-5.36
North of Dalwhinnie JTC00311	-7.78	-6.44	-6.03	-7.62	-5.89	-5.40
South of A86 JTC00312	-5.91	-5.15	-4.75	-7.30	-5.92	-5.58
West of Aviemore JTC00313	-4.97	-3.55	-3.46	-7.93	-6.78	-6.38
Slochd dualling JTC00314	-7.92	-6.64	-6.37	-8.09	-7.15	-6.82
North of B9150 JTC00352	-7.34	-5.44	-5.27	-8.44	-6.17	-5.50
Ralia Straight JTC00353	-6.13	-4.61	-4.35	-8.18	-6.78	-6.46
South end of Insh JTC00354	-8.02	-6.35	-5.85	-6.81	-5.76	-5.41
North end of Insh JTC00355	-7.17	-6.02	-5.15	-7.39	-6.33	-6.17
North of Moy JTC00367	-7.23	-6.72	-6.42	-9.42	-8.33	-8.16
2nd North Moy dual JTC00368	-7.27	-6.71	-6.44	-8.76	-8.02	-7.88
Average	-7.17	-6.01	-5.67	-7.88	-6.63	-6.28

* mph

D Appendix D – Emissions Analysis

D.1 Carbon Dioxide

Table D.1: Carbon Dioxide Equivalents by each vehicle type (2010 Neutral Month)

Vehicle Type	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
Car	83.34	79.72	-4.3%	79.92	-4.1%	80.13	-3.8%
Car and Caravan	1.05	1.03	-2.0%	1.04	-1.6%	1.03	-2.0%
LGV	17.84	17.26	-3.2%	17.30	-3.0%	17.34	-2.8%
Coach	5.68	5.73	0.8%	5.64	-0.8%	5.63	-1.0%
HGV	85.28	85.67	0.4%	85.67	0.5%	85.18	-0.1%
Slow HGV	1.30	1.29	-0.1%	1.39	7.6%	1.47	13.4%
Total	194.50	190.71	-1.9%	190.97	-1.8%	190.78	-1.9%

Table D.2: Carbon Dioxide Equivalents by each vehicle type (2010 Summer Month)

Vehicle Type	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
Car	89.21	85.57	-4.1%	85.87	-3.8%	85.88	-3.7%
Car and Caravan	2.83	2.78	-1.7%	2.78	-1.8%	2.79	-1.4%
LGV	19.20	18.59	-3.2%	18.62	-3.0%	18.64	-2.9%
Coach	3.68	3.72	1.1%	3.68	-0.2%	3.65	-0.7%
HGV	120.48	121.73	1.0%	121.01	0.4%	120.94	0.4%
Slow HGV	1.25	1.26	1.3%	1.35	8.6%	1.44	15.8%
Total	236.65	233.66	-1.3%	233.30	-1.4%	233.35	-1.4%

D.2 Nitrogen Oxide

Table D.3: Nitrogen Oxide by each vehicle type (2010 Neutral Month)

Vehicle Type	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
Car	0.119	0.106	-11.3%	0.108	-9.8%	0.108	-9.6%
Car and Caravan	0.001	0.001	-6.6%	0.001	-6.4%	0.001	-3.8%
LGV	0.071	0.062	-12.8%	0.064	-10.1%	0.064	-9.2%
Coach	0.041	0.041	-1.0%	0.040	-3.5%	0.041	-0.6%
HGV	0.509	0.513	0.8%	0.513	0.9%	0.504	-1.0%
Slow HGV	0.008	0.008	2.0%	0.008	2.3%	0.009	9.0%
Total	0.749	0.730	-2.5%	0.734	-2.1%	0.727	-3.0%

Table D.4: Nitrogen Oxide by each vehicle type (2010 Summer Month)

Vehicle Type	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
Car	0.127	0.114	-10.1%	0.116	-8.8%	0.117	-7.6%
Car and Caravan	0.004	0.004	-1.3%	0.004	-2.0%	0.004	-1.1%
LGV	0.075	0.066	-12.6%	0.067	-10.5%	0.069	-8.3%
Coach	0.026	0.026	2.1%	0.027	3.4%	0.026	1.8%
HGV	0.719	0.732	1.8%	0.720	0.1%	0.723	0.6%
Slow HGV	0.008	0.008	-6.0%	0.008	0.3%	0.008	3.3%
Total	0.959	0.950	-1.0%	0.941	-1.8%	0.948	-1.1%

D.3 Particulate Matter

Table D.5: Particular Matter by each vehicle type (2010 Neutral Month)

Vehicle Type	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
Car	0.0048	0.0045	-4.9%	0.0046	-4.0%	0.0045	-4.9%
Car and Caravan	0.0001	0.0001	-4.1%	0.0001	-4.7%	0.0001	0.3%
LGV	0.0032	0.0031	-3.0%	0.0031	-2.2%	0.0031	-1.6%
Coach	0.0010	0.0010	-0.1%	0.0009	-4.6%	0.0010	0.6%
HGV	0.0099	0.0101	1.3%	0.0101	1.2%	0.0097	-2.0%
Slow HGV	0.0002	0.0002	8.7%	0.0002	-6.5%	0.0002	-11.4%
Total	0.0191	0.0189	-1.0%	0.0189	-1.0%	0.0186	-2.6%

Table D.6: Particular Matter by each vehicle type (2010 Summer Month)

Vehicle Type	Base	Option 1	Difference between Base and Option 1	Option 2	Difference between Base and Option 2	Option 3	Difference between Base and Option 3
Car	0.0051	0.0049	-3.7%	0.0049	-3.7%	0.0049	-2.7%
Car and Caravan	0.0002	0.0002	2.5%	0.0002	1.6%	0.0002	3.2%
LGV	0.0035	0.0033	-3.8%	0.0033	-4.1%	0.0034	-2.1%
Coach	0.0006	0.0006	6.6%	0.0006	8.2%	0.0006	6.0%
HGV	0.0141	0.0144	2.3%	0.0139	-1.3%	0.0140	-0.6%
Slow HGV	0.0002	0.0002	-17.1%	0.0002	-17.9%	0.0002	-18.6%
Total	0.0236	0.0236	0.1%	0.0231	-2.1%	0.0233	-1.2%

E Appendix E – Speed Reliability

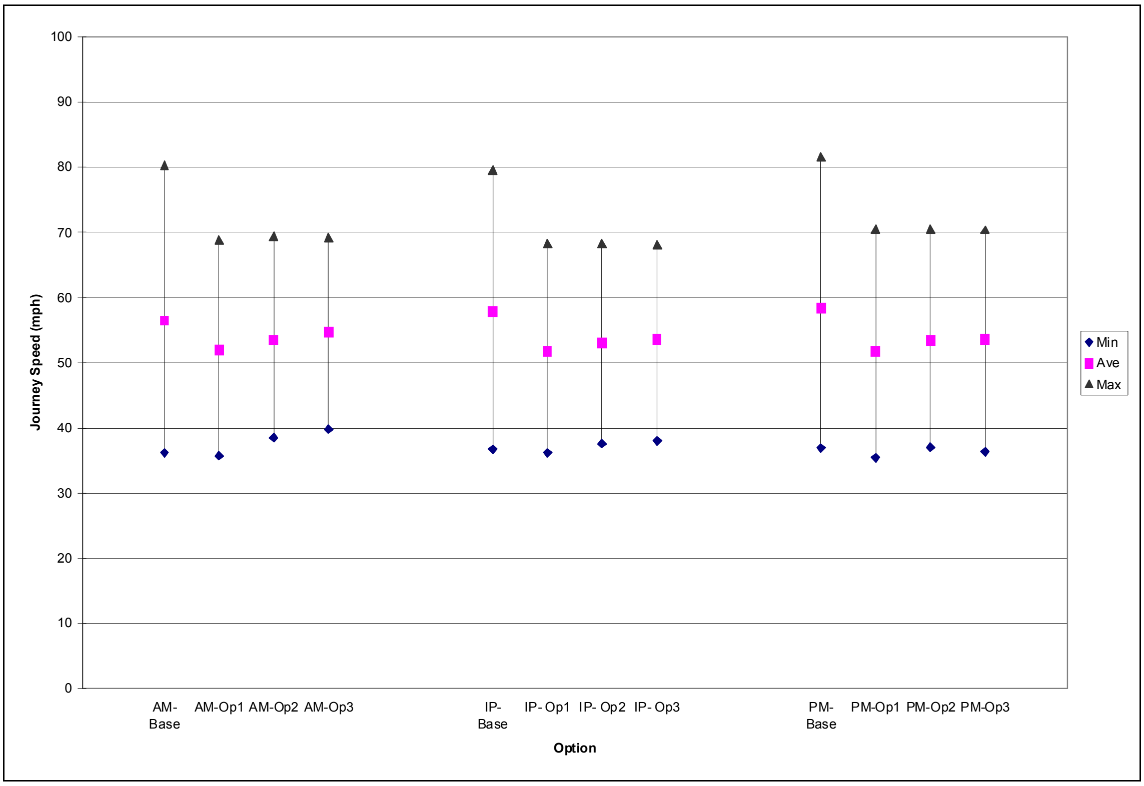

Figure E.1 : Northbound Speed Reliability (2010 Neutral Month)

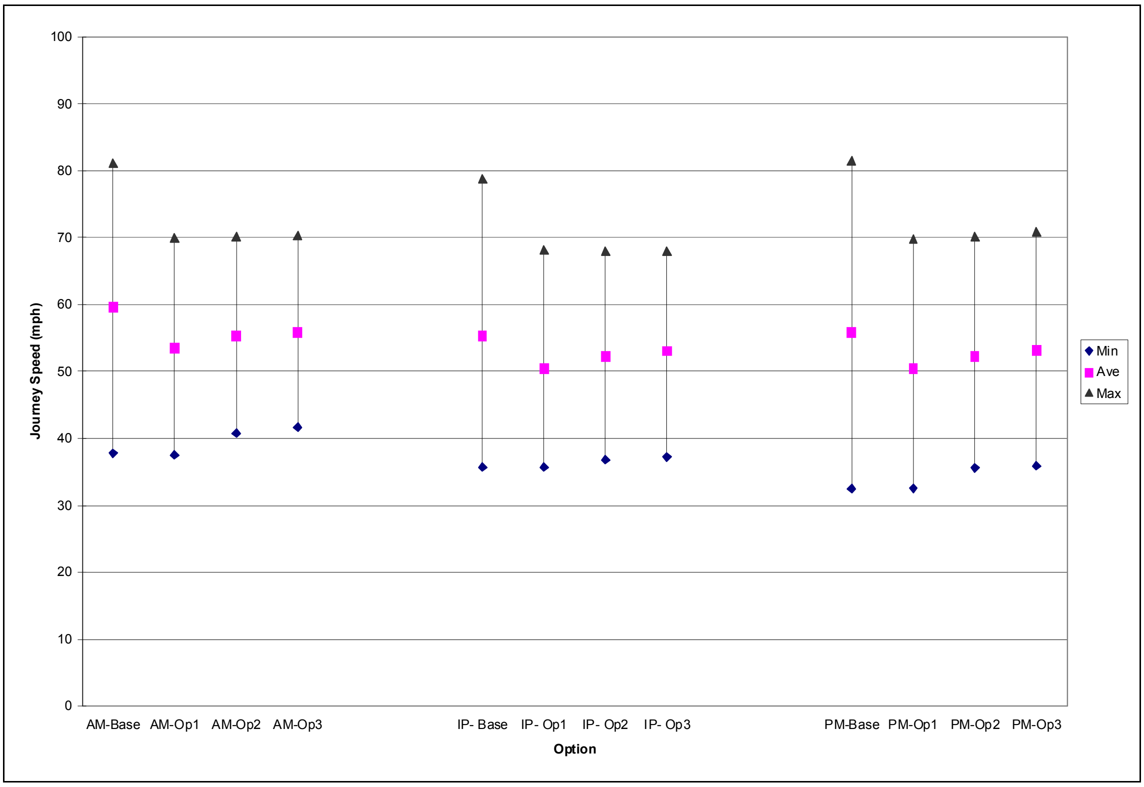

Figure E.2 : Southbound Speed Reliability (2010 Neutral Month)

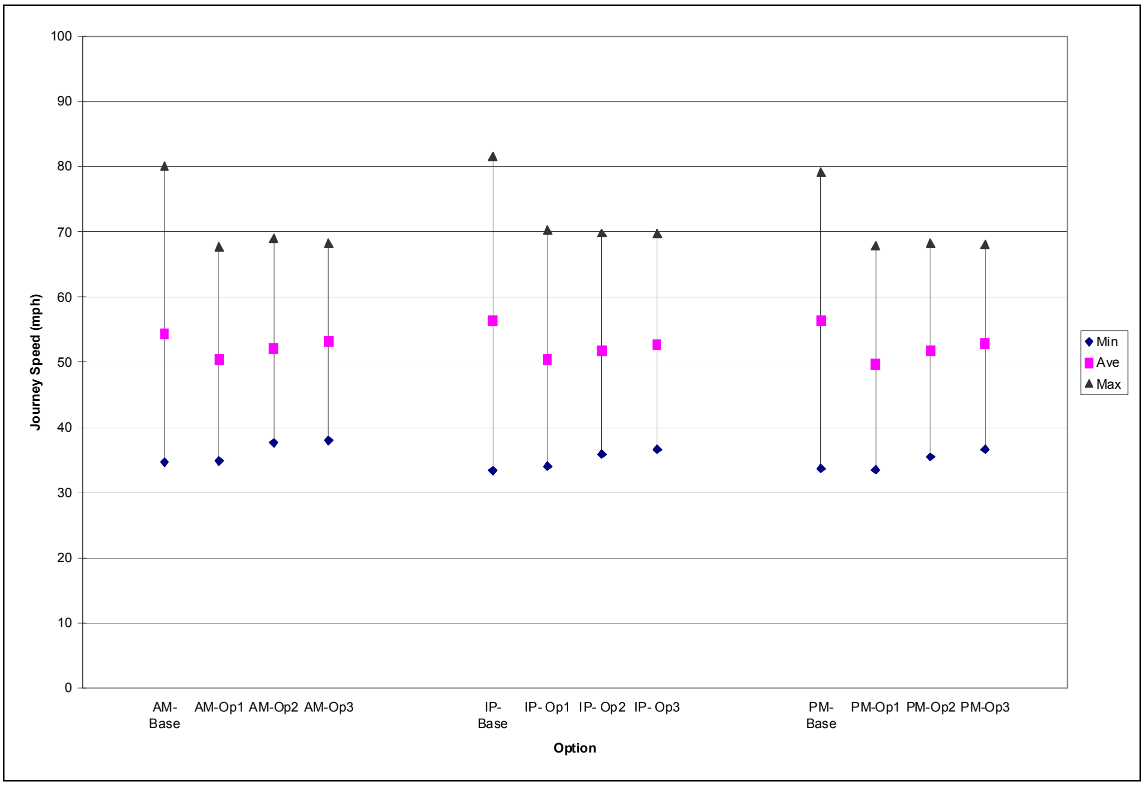

Figure E.3 : Northbound Speed Reliability (2010 Summer Month)

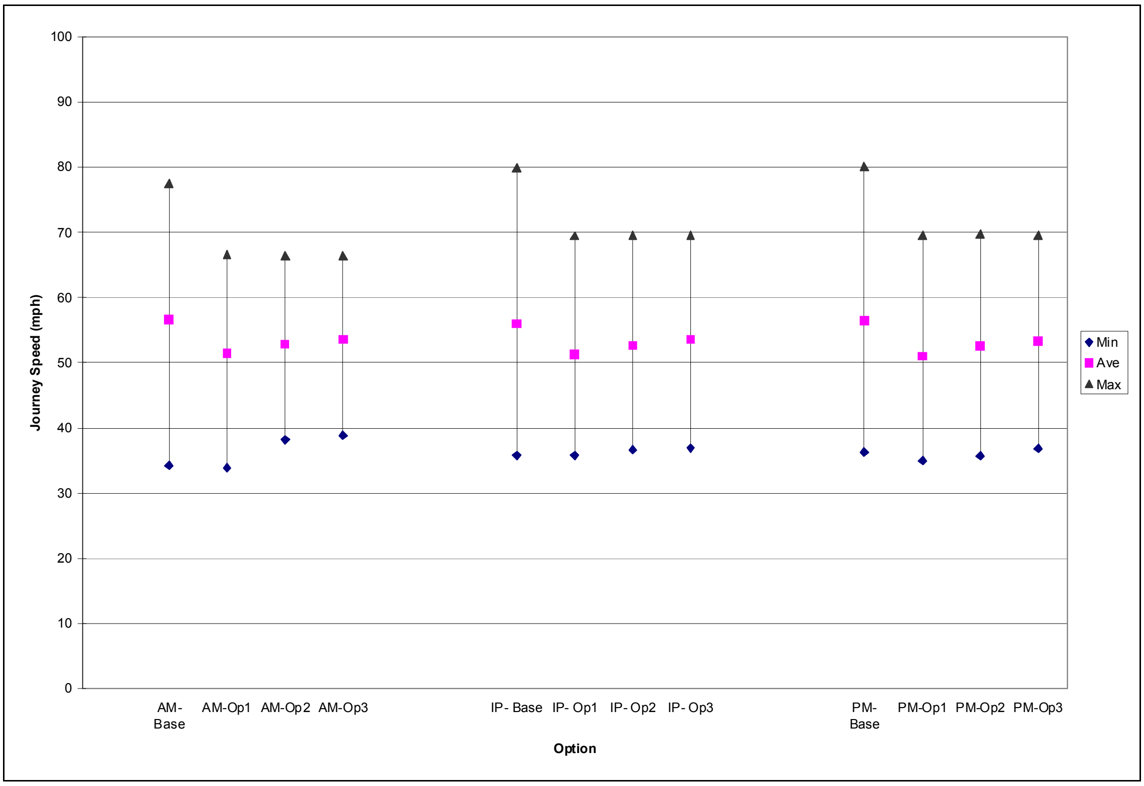

Figure E.4 : Southbound Speed Reliability (2010 Summer Month)