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Increasing the A9 HGV Speed Limit: Impact on Safety

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Executive Summary

Background

The A9 is the main trunk road linking Inverness and towns further north with central Scotland. The 170km section between Perth and Inverness is of strategic importance to industry, tourism and the development of the Scottish Highlands. It carries a substantial amount of through traffic between Perth and Inverness, including sections on which the proportion of vehicles that are heavy goods vehicles is twice the average on rural trunk 'A' roads in Scotland.

The road is mainly single carriageway with limited opportunities to overtake slower moving vehicles safely. The effects of different vehicle speeds are therefore particularly acute. The single carriageway sections are governed by national speed limits that restrict heavy goods vehicles in excess of 7.5 tonnes maximum laden weight to 40mph. This is lower than for other goods vehicles, buses and minibuses, and cars towing caravans and trailers, for which the applicable speed limit is 50mph, and is considerably lower than for cars and motorcycles, for which the applicable speed limit is 60mph. The 40mph speed limit is thought to contribute to long platoon formations, delaying other road users. This is believed to cause driver frustration which is thought to increase accident risk. Consideration is currently being given to raising the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight to 50mph on the single carriageway sections of the A9 only.

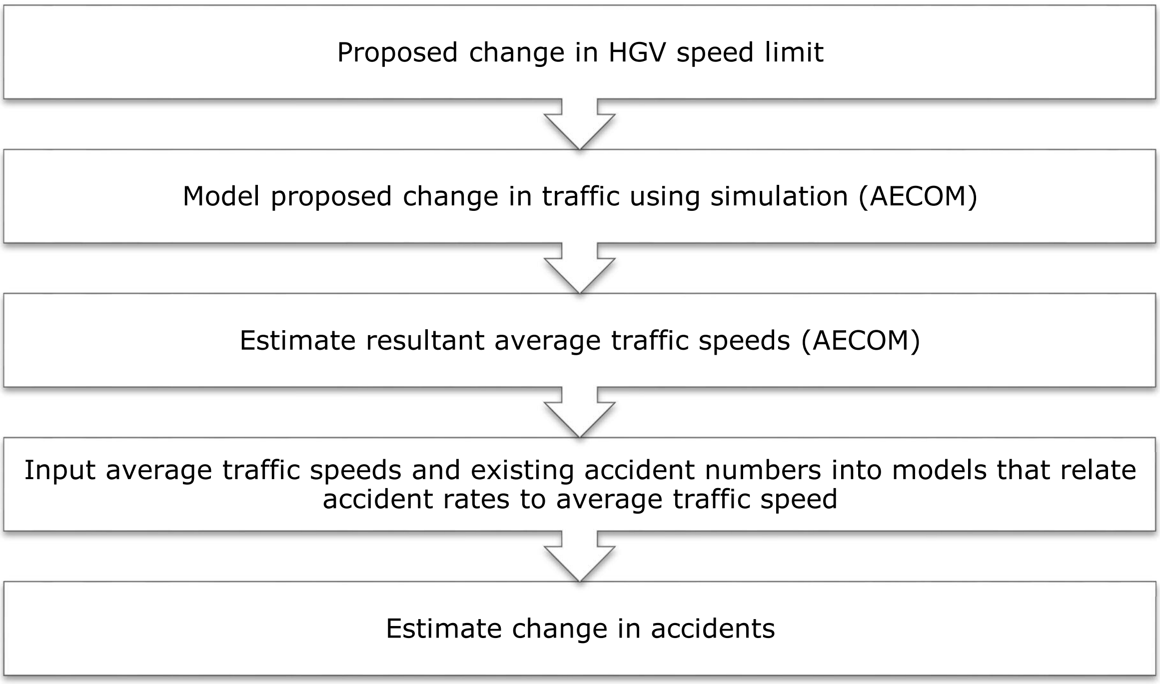
The overall injury accident rate on the A9 is lower than for major non-built-up trunk 'A' roads in Scotland, though the rate for fatal accidents appears to be higher. Accident severity on the A9 is higher than on other non-built-up trunk roads in Scotland and this is partly attributable to relatively high speeds. Average speed cameras are soon to be introduced along the entire length of the A9 between Perth and Inverness.

This report describes how the number of accidents following installation of the average speed cameras was modelled, and the results of this modelling, for two scenarios. In the first, the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight of 40mph is retained; in the second, the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight is increased to 50mph.

Methodology

A review of literature showed that average vehicle speeds are the key predictor of accidents along a route. Established relationships between average speeds and injury accidents could therefore be used to model the number of injury accidents in each scenario and each time period across the single carriageway sections.

The diagram below gives an overview of the methodology used.



AECOM conducted a study for Transport Scotland focussing on the effects on traffic behaviour relating to the introduction of average speed cameras and the possible increase in the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight from 40mph to 50mph (Transport Scotland, 2014a). As such, AECOM was able to supply vehicle speed data from output generated by the S-Paramics micro-simulation model pertaining to four single carriageway sections of the A9. Two of these sections had one lane in the direction concerned, and two of these sections had two lanes in the direction concerned. Simulated vehicle speeds were available for:

- the base case i.e. a simulation of 2012 traffic,
- Scenario 1: 'Enforced 40mph' (retain the current speed limits, i.e. including the 40mph limit applicable to heavy goods vehicles of more than 7.5 tonnes maximum laden weight, and enforce these using average speed cameras, and
- Scenario 2: 'Enforced 50mph' (raise the speed limit applicable to heavy goods vehicles of more than 7.5 tonnes maximum laden weight to 50mph, and enforce the revised speed limits using average speed cameras).

The simulated data pertained to weekdays only, and to the following time periods:

- the AM Peak (7am-10am),
- the Inter Peak (10am-4pm), and
- the PM Peak (4pm-7pm).

Assuming that the vehicle speeds provided by AECOM were representative of vehicle speeds across the route as a whole, the average speeds across all vehicles were calculated for:

- the base case and the two modelled scenarios,
- the three time periods, and

- the two different numbers of lanes (i.e. those sections of single carriageway with one lane in the direction concerned and those sections of single carriageway with two lanes in the direction concerned).

The models identified in the literature were then used to combine the historic accident data and the average vehicle speeds to estimate the number of accidents in the modelled scenarios.

Accidents

The number of accidents would be expected to fall compared with the base in both Scenario 1: 'Enforced 40mph' and Scenario 2: 'Enforced 50mph'. In Scenario 1: 'Enforced 40mph', the number of injury accidents between 7am and 7pm on weekdays was forecast to reduce by an average of between 3 and 9 a year; in Scenario 2: 'Enforced 50mph', the number of injury accidents between 7am and 7pm on weekdays was forecast to reduce by an average of between 1 and 7 a year.

Overtaking

AECOM's traffic modelling suggested that, following the introduction of average speed cameras, increasing the speed limit for heavy goods vehicles in excess of 7.5 tonnes maximum laden weight from 40mph to 50mph would reduce the number of overtaking manoeuvres. A reduction in the number of overtaking manoeuvres might be expected to reduce the number of injury accidents associated with overtaking and hence the overall injury accident risk.

The possibility of modelling the effect of a reduction in overtaking manoeuvres on injury accidents was therefore investigated. However, no reliable evidence applicable to the A9 was found that indicated how a reduction in the number of overtaking manoeuvres and a reduction in the speed differential between different vehicle types might affect the injury accident risk. Therefore, the specific effects of a reduction in number of overtaking manoeuvres and in speed differentials between different vehicle types on overall accident risk could not be modelled reliably.

Conclusion

This report describes how the number of accidents following installation of the average speed cameras was modelled, and the results of this modelling, for two scenarios. In the first, the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight of 40mph is retained; in the second, the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight is increased to 50mph.

In both scenarios, a reduction in the number of accidents would be expected: it appears that there would be a safety benefit associated with the installation of the average speed cameras whether or not the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight were increased from 40mph to 50mph. The reduction in the number of accidents is likely to be greater if this speed limit is retained at 40mph rather than increased to 50mph.

Regardless of the scenario adopted initially, it would be prudent to update the injury accident forecasts following the installation of the average speed cameras. This would enable the real world effect on driver speed choice to be incorporated into both of the modelled scenarios more accurately.

The modelling was based on average speeds, which are the key predictor of accidents along a route. However, it was not possible to model the effects of changes in the level of overtaking and the differences between different vehicle speeds. Given that there appears to be no scientifically robust research on these issues, there might be a case for conducting a carefully managed and scientifically evaluated trial on the A9 between Perth and Inverness.

Abstract

The A9 between Perth and Inverness is a route of strategic importance. It carries a substantial amount of traffic between the two towns, including a high proportion of heavy goods vehicles (HGVs). However, it is mainly single carriageway, restricting HGVs in excess of 7.5 tonnes maximum laden weight to a maximum legal speed limit of 40mph, and overtaking is severely restricted. Average speed cameras are soon to be introduced along the route, and consideration is being given to raising the speed limit applicable to these HGVs to 50mph on the single carriageway sections.

AECOM investigated the effects of the installation of the speed cameras on traffic behaviour, and provided simulated speed distributions. Scenarios included the situation in which 40mph is retained as the speed limit applicable to the relevant HGVs following the installation of the cameras, and the situation in which this limit is increased to 50mph on the A9 only.

The numbers of injury accidents in these scenarios were modelled based on established relationships between average vehicle speeds and injury accident numbers. Consideration was given to the effects on safety of reducing overtaking and reducing the speed differentials between different vehicle types. However, robust evidence was not identified that would have enabled such effects to be modelled reliably.

This accident modelling indicated that the introduction of average speed cameras is likely to reduce the future number of injury accidents. The reduction in the number of accidents is likely to be greater if the speed limit for HGVs in excess of 7.5 tonnes maximum laden weight is retained at 40mph rather than increased to 50mph.

1 Introduction

1.1 Background to the A9

The A9 is the main trunk road linking Inverness and towns further north with central Scotland. The 170km section between Perth and Inverness is of strategic importance to industry, tourism and the development of the Scottish Highlands. Although traffic flows on the A9 near both Perth and Inverness are very high, there is substantially less traffic elsewhere along the route. The percentage of heavy goods vehicles is relatively high on the A9, reaching 18% at some locations. The comparable figure for rural trunk 'A' roads is 8.9% (Transport Scotland, 2012).

About a quarter of the road's length consists of various sections of dual carriageway. In early 2004, as part of an on-going maintenance programme, two sections of the A9 near Newtonmore and Kingussie were widened to provide additional overtaking lanes in a layout known as 2+1 sections. These layouts consist of two lanes in one direction and a single lane in the other direction, and are still single carriageway sections. There are long-term plans in place to dual much more of the route by 2025.

Currently, however, the road is mainly single carriageway with limited opportunities to overtake slower moving vehicles safely. The effects of different vehicle speeds are therefore particularly acute. The single carriageway sections are governed by national speed limits that restrict heavy goods vehicles in excess of 7.5 tonnes maximum laden weight to 40mph. This is lower than for other goods vehicles, buses and minibuses, and cars towing caravans and trailers, for which the applicable speed limit is 50 mph, and is considerably lower than for cars and motorcycles, for which the applicable speed limit is 60mph. The 40mph speed limit is thought to contribute to long platoon formations, delaying other road users. This is believed to cause driver frustration which is thought to increase accident risk. Consideration is currently being given to raising the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight to 50mph on the single carriageway sections of the A9 only.

1.2 Reasons for this study

Transport Scotland previously commissioned TRL to investigate the likely effect on accidents of increasing the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight on the A9. Summersgill and Buckle (2009) used accident data up until 2007; more recently, Summersgill and Neil (2012) used accident data up until 2009.

A number of factors have changed since the previous work was completed:

1. Due to concerns that some vehicle speeds on the A9 between Perth and Inverness are excessive and might increase accident risk, it has been decided that average speed cameras will be installed along the entire length of the A9 route from Perth to Inverness.
2. AECOM conducted a study for Transport Scotland focussing on the effects on traffic behaviour relating to this change (Transport Scotland, 2014a). As such, AECOM was able to supply traffic speed data from output generated by the S-Paramics micro-simulation model.
3. More recent accident data (up until 2012) are now available.

Transport Scotland therefore wished to know the likely effect on the number of accidents of adopting either of two scenarios described in Table 1.

Table 1: Description of modelled scenarios

Scenario	Description
1. 'Enforced 40mph'	Enforce the current speed limits on the A9 using the average speed cameras, including the 40mph speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight on the single carriageway sections.
2. 'Enforced 50mph'	Raise the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight on the single carriageway sections of the A9 to 50mph and enforce the speed limits for all vehicles using average speed cameras.

This report provides an assessment of the likely effects that either of these scenarios would have on the numbers of accidents and on the associated values of prevention.

1.3 Report structure

Section 2 summarises the relationship between traffic behaviour and accidents as evidenced in literature, including both average speed and the possible effects of other changes in traffic behaviour. Section 3 presents an in-depth analysis of the accident record on the A9 over the period from 1999 to 2012. Section 4 describes the speed data output from the S-Paramics micro-simulation, and presents the average speeds for each scenario. Section 5 then describes the methodology and the results estimating the impact of adopting either scenario on accidents. Finally, Section 6 presents a summary and recommendations.

Throughout this report, the term 'accidents' refers only to injury accidents reported by the police in the STATS19 database, unless explicitly stated otherwise. Similarly, the term 'HGVs' refers only to those heavy goods vehicles in excess of 7.5 tonnes maximum laden weight.

2 Relationships between traffic behaviour and accidents

Key literature was reviewed to understand the relationships between traffic behaviour and accidents. Studies that relate average speeds to accidents were quickly identified, and the relationships between other traffic behaviours and accidents were then explored.

2.1 Average speeds

2.1.1 The Taylor model

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 different severities and types of accidents but are such that, if 'before' and 'after' refer to accident numbers and speeds before and after a change in mean speed, all have the form:

$$\text{Accidents after/Accidents before} = (\text{Mean speed after/Mean speed before})^{c}$$

where the value of *c* depends on the severity and/or accident type.

2.1.2 Nilsson's power model

Nilsson (2004) developed a relationship between speed and accidents known as the power model, which was reviewed, modified and evaluated by Elvik, Christensen and Amundsen (2004). The latter includes 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 relationship takes precisely the same form as the Taylor model above, such that the equation above holds, albeit with different values of *c* at each severity.

Elvik et al. concluded 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.

2.2 Speed differentials and overtaking frequency

AECOM's traffic modelling (Transport Scotland, 2014a) suggested that, following the introduction of average speed cameras, increasing the speed limit for heavy goods vehicles in excess of 7.5 tonnes maximum laden weight from 40mph to 50mph would reduce the number of overtaking manoeuvres. A reduction in the number of overtaking manoeuvres might be expected to reduce the number of accidents associated with overtaking and hence the overall accident risk. The possibility of modelling the effect of a reduction in overtaking manoeuvres on accidents was therefore investigated.

2.2.1 Study of English rural single carriageway roads

As reported in section 2.1.1, Taylor et al. (2002) carried out an extensive investigation of the relationship between speed and accidents on rural single carriageway roads in England and established a clear relationship between average speed and accident rate.

However, the variance of speed was not found to be statistically significant. That is to say, the extent of the differentials between the speeds of different vehicles was not found to affect the accident rate.

2.2.2 Literature reviews

Summersgill (2008, p. 30) reviewed various studies investigating the effect of having different speed limits for different vehicle types and identified that:

> *Some States in the US have differential speed limits (lower speed limits for trucks than for passenger cars) and others have uniform speed limits (the same speed limit for trucks and cars). Studies of speed and safety for these two different systems appear to have been conducted only on Interstate highways (dual carriageway roads). The most recent studies have shown no significant difference in accident rates between these two systems.*

A more recent systematic review of international literature on this subject (Kinnear, Lawton & Helman, 2012) also found that the majority of work in this field related to dual carriageway roads in the United States of America, though studies relating to single carriageway roads in Australia were also reviewed. Despite the additional scope of the review, Kinnear et al. (2012) also concluded that there is not a robust evidence base indicating a relationship between the introduction or removal of differential speed limits and changes in accident risk. That is, there is no reliable evidence showing that the overall accident risk would be affected specifically by a change to differential speed limits on a given road.

The most robust material identified in this review suggested that removing differential speed limits might affect the proportions of accidents of different types. For example, while removing differential speed limits may reduce the number of accidents that involve an overtaking manoeuvre, it is possible that other types of accidents that do not involve overtaking might increase by a comparable amount. Subsequently, even if the likelihood of an accident involving an overtaking manoeuvre were to fall, the overall accident risk may well remain unchanged.

Summersgill (2008) concluded that the effect of increasing the speed limit applicable to HGVs from 40mph to 50mph on single carriageways is unknown, and suggested that an experimental trial might be conducted on the A9 between Perth and Inverness to evaluate what the actual effect would be.

2.2.3 Dynamics of overtaking manoeuvres

Increasing the speed limit for HGVs specifically from 40mph to 50mph on the A9 could affect the number of accidents involving an overtaking manoeuvre in a number of ways, including the following:

- There would remain a speed differential between HGVs and other vehicles, meaning that drivers of other vehicles might still wish to overtake.
- Since the speed differential would be reduced, the time and distance required for a vehicle to overtake would be greater, so more time and space would be required to overtake successfully.
- Drivers might be more likely to misjudge both the need to overtake and the time and/or space required to do so.

- The average speed involved in accidents involving an overtaking manoeuvre that do occur might be higher, meaning that accidents might have a higher average severity.

Summersgill, Buckle, Robinson and Smith (2009, p. 76) specifically considered the distance and time requirements for overtaking in the context of raising the speed limits for HGVs and identified that:

> *For an increase in the speed of the overtaken vehicle of 1mph the estimated increases in distance and time were as follows: 6m to 14m (distance required to complete overtaking); 0.06 seconds to 0.56 seconds (time required to complete overtaking); and 9m to 24m (distance gap required to overtake).*

Kinnear et al. (2012) explained that it is possible that any increase in speed and distance required to complete an overtaking manoeuvre may offset any safety benefit resulting from fewer overtaking manoeuvres. Summersgill et al. (2009) even suggests that the number of accidents could increase even if the number of overtaking manoeuvres fell following a reduction in speed differentials between vehicles because each manoeuvre might carry a higher risk.

2.2.4 Potential for accident reduction

Kinnear et al. (2012) noted that, based on the data recorded systematically by the police in STATS19, the number of fatal accidents involving other vehicles overtaking HGVs appears to be small. Subsequently, the STATS19 data suggest that the assumed safety benefits of reducing overtaking by raising the speed limit applicable to HGVs may not be as substantial as expected. However, in-depth analysis of fatal accident descriptions on the A9 (Transport Scotland, 2014b) appears to highlight that overtaking and head-on collisions are more common, at least in fatal accidents, than the STATS19 data suggest. This is considered in more detail in section 3.9.

2.2.5 Speed variance

Solomon (1964) and various other studies, such as Hauer (1971), Lave (1985), and Levy and Asch (1989), were reviewed by Baruya (1997). Baruya (1997) formed the basis of the work by Taylor et al. (2002), referenced in section 2.2.1, in which speed variance was not found to be statistically significant. Although the earlier studies refer to speed variance, the focus in these tended to be on the risk associated with an individual vehicle given its speed relative to the risk associated with vehicles travelling at the average speed, rather than the risk associated with the dispersal in the speed distribution across the traffic as a whole. Solomon (1964) has also been criticised for not excluding turning manoeuvres, for example, which appear to account for much of the difference in accident rates at different speeds.

The focus of Rietveld and Shefer (1997) focus is similar, though also suggests that the rate of car accidents is linked to the number of overtaking manoeuvres, and that these are related to speed differences. While this appears to be more relevant, therefore, this work appears to have assumed that reducing overtaking necessarily reduces accident risk which, as discussed in section 2.2.3, may well not be the case. In addition, no account appears to have been taken of the changes in vehicle speeds – only the change in the overtaking frequency appears to have been considered. This is not, therefore, applicable to the A9, where the change in the frequency of overtaking manoeuvres is expected specifically as a result of changes in vehicle speeds.

More recently, Ghods, Saccomanno and Guido (2012) considered overtaking in relation to differences in car and truck speed limits on two-lane highways. Vehicle interactions were estimated using a microscopic traffic simulation model on a six kilometre section of road that was straight. Ghods et al. (2012) found that the use of differential speed limits increased car-truck overtakes but reduced car-car overtakes, and concluded that differential speed limits might therefore either increase or decrease safety.

2.2.6 Frustration

It has been suggested that increasing the speed limit applicable to HGVs might reduce driver frustration. For example, it might be logically hypothesised that the driver of a vehicle legally permitted to travel at 60mph will be more frustrated if blocked from making progress by a vehicle travelling at 40mph than by a vehicle travelling at 50mph.

It is often assumed that a reduction in driver frustration would reduce accident risk. In work commissioned by Transport Scotland in a separate but related workstream, Grayson, Kinnear and Helman (2012) established that driver frustration, and its relationship with safety, is often ill-defined and assumed rather than supported, measured or observed in scientific literature. Nevertheless, there is reasonable psychological theory that supports a model of frustration where a driver’s progress is being restricted. The relationship between frustration and accident risk, however, is less clear.

Not all drivers will overtake when frustrated on the road, and it is likely that situational variables will play a key role in driver decision making. For example, a driver’s decision to overtake a slower moving vehicle in front of them to make progress may depend on factors such as visibility, the length of the platoon or vehicle in front, oncoming traffic, and motivational factors such as time pressure (see Helman & Kinnear, 2014).

Overtaking, or at least the acceptance of risky overtaking, is often considered to result from driver frustration. A concurrent experimental study of the relationship between driver frustration and overtaking commissioned by Transport Scotland suggests that the relationship is not as clear as often assumed (Helman & Kinnear, 2014). Road users were shown a series of video clips depicting various scenarios and asked how they would feel if encountering the scenario in real life. While frustration and the intention to overtake both reduced overall as speed increased (from 40mph to 56mph), it was not to the same magnitude. Frustration reduced much more than the intention to overtake, and in some situations the intention to overtake at the higher speed (56mph) was the same or even higher than at the lower speed (40mph). This suggests that, while the raising of the HGV speed limits may reduce driver frustration, in certain situations it may not have the same effect on overtaking behaviour.

Even if frustration is reduced, there is a possibility of unintended consequences. For example, the study reported by Transport Scotland (2014a) suggested that convoys will be shorter if the speed limit applicable to HGVs is 50mph rather than 40mph. It could be that a driver encountering shorter convoys of vehicles might be more likely to want to overtake the convoy than were he or she to encounter a longer convoy (Helman & Kinnear, 2014).

While research has started to identify the relationship between frustration and overtaking behaviour, and the situational variables that affect frustration, ultimately the effect that frustration has on safety following changes to differential speed limits on the A9 remains uncertain.

2.3 Summary

There are established relationships between average vehicle speeds and accidents. These were used to model the effects of the changes on the A9 as described in section 5.

However, no evidence was found that identified how a reduction in the speed differential between different vehicle types and a reduction in the number of overtaking manoeuvres would affect the overall accident risk. The specific effect of a reduction in speed differentials between different vehicle types and a reduction in overtaking on overall accident risk could not therefore be modelled reliably.

3 Accidents on the A9

This section provides a detailed analysis and breakdown of accident data for the A9 up to 2012 and includes analysis of:

- Accidents
- Accident rates
- Vehicles
- Casualties
- Contributory factors
- Accident types

The analyses were based on accidents on single carriageway sections of the A9 from immediately north of the roundabout near Perth (OSGR: NN 096 263) to a location immediately south of the junction with the A96 near Inverness (OSGR: NH 687 454).

3.1 Data sources

The numbers of accidents used in the following analysis are based on STATS19 records of injury accidents on the A9 and on all non-built-up A-roads in Scotland. Accident rates for non-built-up trunk A-roads in Scotland are sourced from Road Casualties Scotland (Transport Scotland, 2013), which is also based on STATS19 data.

The STATS19 database is based on injury accidents reported to and by the police, based on a long-established protocol. The data are collected by the police at the scene of an accident or in some cases reported by a member of the public at a police station The data include details of the attendant circumstances, details of the vehicle(s) involved, the resulting casualties and the factors which, in the opinion of the reporting police officer, contributed to the accident (data from 2005), giving at least 50 data items for each accident. Research has shown that very few, if any, road accident fatalities are not reported to the police. However, a considerable proportion of non-fatal casualties are not known to the police, indicating that a higher total number of casualties than police accident data would suggest. Police data on road accidents remain the most detailed, complete and reliable single source of information on road casualties in Great Britain. The analysis of STATS19 used the coded fields, and used multiple data fields to identify key accident types. In a separate analysis, Transport Scotland investigated the text descriptions contained in the files relating to the 23 fatal accidents on the single carriageway sections of the A9 between 2008 and 2012, which provides more reliable details about the accidents concerned (Transport Scotland, 2014b). Such analysis is more time consuming, and thus is restricted to a smaller number of cases, but allows for more detailed considerations of the circumstances of each accident.

The following criteria were used to select accidents on the route from within the STATS19 database:

- Grid references within the ranges identified by the co-ordinates above
- 1st road class and number or 2nd road class and number recorded as the A9

- Road type is recorded as single carriageway (this includes single carriageway sections with two lanes in one direction and one lane in the other, i.e. 2+1 roads; these were identified by grid references)

The AADT traffic flow information was obtained from DfT counter sites (Department for Transport, 2013), 13 of which are located on the 170.4km route between Perth and Inverness. Table 2 sets out the sections of route to which the data from each counter site were allocated.

Table 2: Section of route to which the AADT flow from each counter site was allocated

Census Point	From grid reference		From description	To grid reference		To description	Length (km)
CP 10723	309600	726300	Immediately north of roundabout, north of Perth, start of dual carriageway	302500	742100	Junction of A9 with A822 and A923/A984 at Dunkeld (single carriageway)	18.2
CP 30729	302500	742100	Junction of A9 with A822 and A923/A984 at Dunkeld (single carriageway)	297600	752500	Junction of A9 with A827 at Ballinluig (dual carriageway)	12.6
CP 722	297600	752500	Junction of A9 with A827 at Ballinluig (dual carriageway)	295500	756600	Junction of A9 with A924 south of Pitlochry, end of dual carriageway and start of single carriageway	4.6
CP 20728	295500	756600	Junction of A9 with A924 south of Pitlochry, end of dual carriageway and start of single carriageway	292600	759000	Junction of A9 with A924 north of Pitlochry (single carriageway)	4.0
Average of CP 40725 & CP 50748	292600	759000	Junction of A9 with A924 north of Pitlochry (single carriageway)	264000	782900	Junction of A9 with A889 (single carriageway)	43.9
CP 30824	264000	782900	Junction of A9 with A889 (single carriageway)	268350	792400	Junction with the B9150	10.8
CP 50741	268350	792400	Junction with the B9150	276600	801100	Junction of A9 with A86, near Kingussie (single carriageway)	13.2
CP 20727	276600	801100	Junction of A9 with A86, near Kingussie (single carriageway)	288500	810800	Junction of A9 with B9152, south of Aviemore (single carriageway)	15.8
CP 40821	288500	810800	Junction of A9 with B9152, south of Aviemore (single carriageway)	290000	815300	Junction of A9 with A95, north of Aviemore (single carriageway)	5.4
CP 10808	290000	815300	Junction of A9 with A95, north of Aviemore (single carriageway)	287475	824050	Junction of A9 with A938, north of Carrbridge (single carriageway)	10.6
CP 20726	287475	824050	Junction of A9 with A938, north of Carrbridge (single carriageway)	271925	838450	Junction of A9 with B9154, south of Daviot (dual carriageway)	23.2
CP 10809	271925	838450	Junction of A9 with B9154, south of Daviot (dual carriageway)	268800	845350	End point in Inverness, south of A96 junction (dual carriageway)	8.1

3.2 Accidents

In the fourteen-year period between 1999 and 2012 there were 583 accidents on the single carriageway sections of the A9 between Perth and Inverness. 65 of these accidents were fatal and 144 were serious. Table 3 presents the number of accidents at each severity for each year from 1999 to 2012.

Table 3: Number of accidents on the A9 by severity and year

Year	Fatal	Serious	Slight	Total	% Fatal and Serious
1999	6	16	24	46	48%
2000	4	17	25	46	46%
2001	7	11	23	41	44%
2002	3	10	29	42	31%
2003	4	11	31	46	33%
2004	4	10	32	46	30%
2005	1	12	19	32	41%
2006	6	8	33	47	30%
2007	6	9	29	44	34%
2008	5	8	28	41	32%
2009	3	12	29	44	34%
2010	7	9	23	39	41%
2011	5	5	25	35	29%
2012	4	6	24	34	29%
Total	**65**	**144**	**374**	**583**	**36%**

There has been a reduction in the number of serious accidents over the period, whilst the number of slight accidents has remained approximately constant. There were too few fatal accidents to be able to discern any meaningful change over the period.

Figure 1 compares the accident severities on the A9 (single carriageway) with those for accidents on all non-built-up trunk A-roads in Scotland (Transport Scotland, 2013; Transport Scotland, 2010). It should be noted that the latter includes both dual and single carriageway routes, but this is the best comparator for which the relevant data are easily available. Between 1999 and 2012 on these routes, 5% of recorded accidents were fatal and 22% were serious. Accidents on the A9 were of greater severity, on average: 11% of accidents were fatal and 25% were serious in the same period.

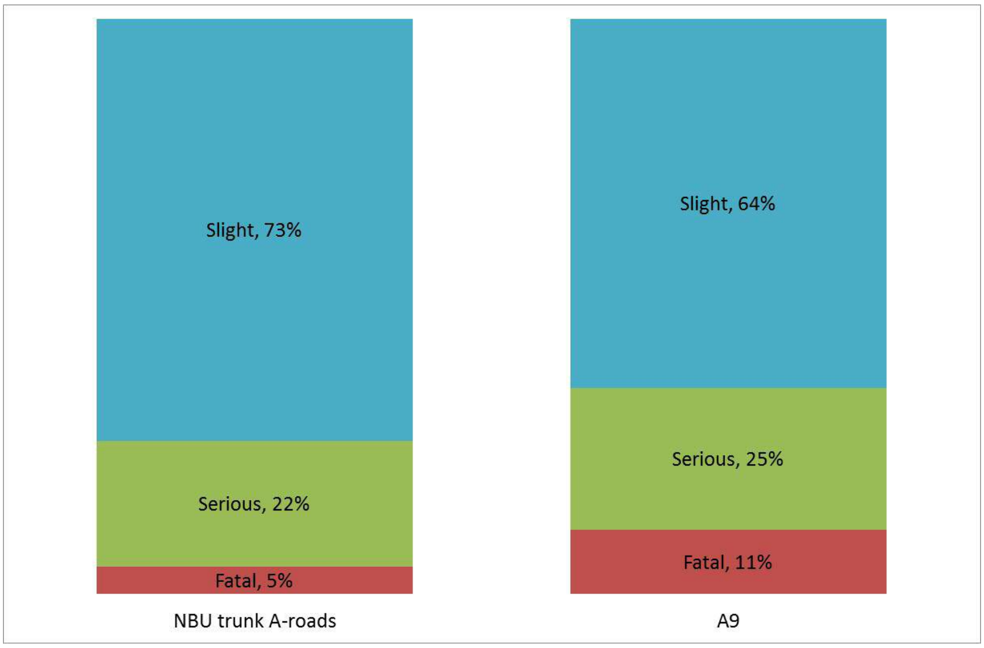


Figure 1: Accident severities on the A9 compared with all non-built-up (NBU) trunk A-roads in Scotland (1999-2012)

Summersgill and Buckle (2009) considered whether the higher percentage of fatal accidents on the A9 might be attributable to the relatively high speed of the traffic. Nilsson's accident-speed relationships (see section 5.1.2 for details) were used to investigate the extent to which a higher mean speed might be expected to increase the percentage of fatal accidents. The results suggested that the relatively high percentage of fatal accidents on the A9 was not wholly attributable to the higher mean speed.

3.3 Accident rates

The accident rates, in terms of accidents per vehicle-kilometre, identify the risk to an individual road user and can be used to compare routes of different lengths and with different traffic volumes.

Table 4 shows the accident rates for the A9 (single carriageways) compared with all non-built-up (NBU) trunk A-roads in Scotland (dual and single carriageway).

Table 4: 1999-2012 average accident rate (accidents per 100 million vehicle kilometres)

Route	Fatal	Serious	Fatal and Serious	All severities
A9	1.09	2.45	3.54	9.86
NBU trunk A-roads Scotland	0.69	3.22	3.91	14.56

Overall, the accident rate on the A9 is lower than for the comparison routes, and the combined fatal and serious rate is similar. However, the fatal accident rate is higher on the A9.

Figure 2 shows the trends in fatal and serious accident rates on the A9 and for non-built-up trunk A-roads in Scotland, showing similarities in the fatal and serious accident rates over several years, which has declined on both the A9 and on all non-built-up trunk A-roads. The fatal accident rate on the A9 is more variable due to the small number of fatal accidents, but appears to be similar in the early part of the period and to be slightly higher in the last few years.

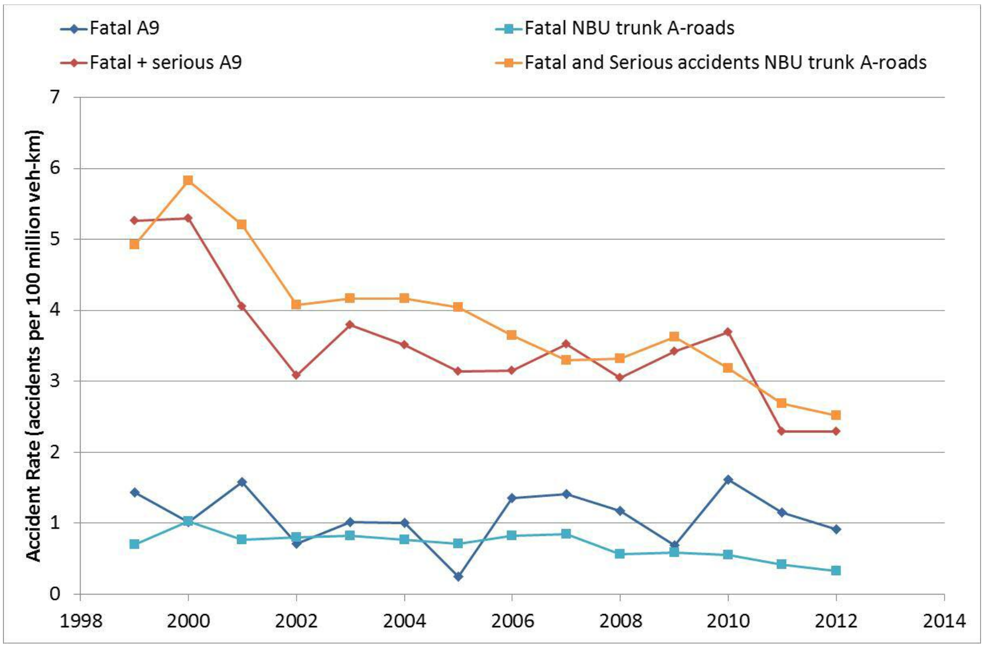


Figure 2: Fatal and serious accident rates on the A9 and on all non-built-up (NBU) trunk A-roads in Scotland

Figure 3 shows that the total accident rate on the A9 has been consistently lower than for all non-built-up trunk A-roads in Scotland, and has been on a decreasing trend.

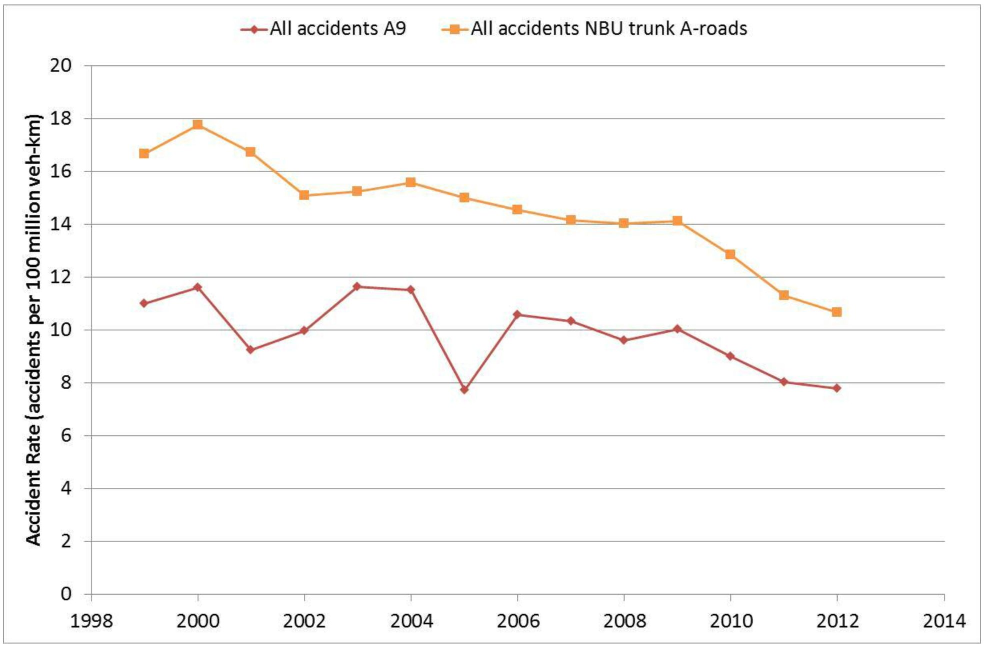


Figure 3: Accident rates on the A9 and on all non-built-up (NBU) trunk A-roads in Scotland

Table 5 presents the accident rates for the sections of road spanned by each traffic census point over the 14-year period between 1999 and 2012. Some of the traffic census points covered both single and dual carriageway sections. The AADT for these links was used together with the length of single carriageway sections to estimate the traffic volumes on the single carriageway sections.

Table 5: Accident rates (1999-2012) by section of the A9

Census Point	From	To	Fatal	Serious	Slight	Total	% Fatal and Serious	Single Carriageway Length	Average AADT	Average Accident Rate	Fatal and Serious Accident Rate
10723	A912	A822	7	25	47	79	41%	15.3	12,082	8.4	3.4
30729	A923	A827	11	18	44	73	40%	11.2	11,734	10.9	4.3
Dual section (CP722)											
20728	A924 (south)	A924 (north)	4	5	25	34	26%	4.2	8,149	19.4	5.1
40725	A924 (north)	LA Boundary	13	33	56	102	45%	29.2	8,148	8.4	3.8
50748	LA Boundary	A889	3	10	24	37	35%	7.3	6,575	15.1	5.3
30824	A889	B9150	7	15	36	58	38%	15	6,961	10.9	4.1
50741	B9150	A86	3	4	26	33	21%	8	6,230	13.0	2.7
20727	A86	B9152	9	13	37	59	37%	15.3	7,677	9.8	3.7
40821	B9152	A95	1	4	20	25	20%	5.6	6,543	13.4	2.7
10808	A95	A938	3	5	29	37	22%	10.5	6,632	10.4	2.2
20726	A938	B9154	4	12	30	46	35%	16.4	8,917	6.2	2.1
Dual section (CP10809)											
Total			**65**	**144**	**374**	**583**	**36%**	**138**	**8,411**	**9.8**	**3.5**

The average accident rate is variable along the route. The highest accident rate (19.4) was north of the dual carriageway section near Pitlochry, the shortest section. The lowest accident rate (6.2) was the last section of single carriageway near Moy before the dual carriageway on the approach to Inverness.

3.4 Vehicles involved

There were 1,166 vehicles involved in the 583 accidents between 1999 and 2012. Cars accounted for almost three-quarters (73%) of the vehicles involved. Goods vehicles accounted for 19% of the vehicles involved in these accidents, with the majority of these being HGVs (11% of the total). The involvement of these HGVs was much higher on the A9 than on all non-built-up (NBU) A-roads in Scotland (4%). This is likely to be, at least in part, due to differences in the traffic volumes.

Table 6: Number of vehicles in accidents by vehicle types (1999-2012)

Vehicle type	Number of vehicles in accidents on the A9 single carriageways	% for the A9 single carriageway	% for NBU A-roads in Scotland
Pedal cycle	4	0%	1%
Motorcycle	43	4%	6%
Car	850	73%	78%
Bus/coach	12	1%	1%
LGV	63	5%	5%
Heavy goods ≤ 7.5 tonnes	32	3%	1%
Heavy goods > 7.5 tonnes	127	11%	4%
Other/unknown	35	3%	2%
Total	**1,166**	**100%**	**100%**

3.5 Casualties

1,147 people were injured in the accidents on the A9, including 87 people who were killed. The majority of the casualties were car occupants (as would be expected given that the majority of accident-involved vehicles were cars).

Table 7: Number of casualties in accidents by casualty injury (1999-2012)

Road user type	Killed	Seriously Injured	Slightly Injured	Total	%
Pedestrian	5	1	5	11	1%
Pedal cyclist	0	0	3	3	0%
Motorcyclist	7	18	22	47	4%
Car occupant	63	221	596	880	77%
Bus/coach occupant	0	10	79	89	8%
LGV occupants	6	6	31	43	4%
Heavy goods ≤ 7.5 tonnes occupant	0	7	7	14	1%
Heavy goods > 7.5 tonnes occupant	6	11	24	41	4%
Other/unknown	0	2	17	19	2%
Total	**87**	**276**	**784**	1,147	**100%**

3.6 Accidents involving HGVs

11% of accident-involved vehicles were HGVs. However, 105 accidents involved such vehicles, as shown below, representing some 18% of the accidents. The mass of these vehicles means these accidents are, on average, of higher severity: 28% of accidents resulting in a fatality involved these HGVs.

Table 8: Accidents involving HGVs

	Fatal	Serious	Slight	Total
HGV in accident	18	36	51	105
Other accidents	47	108	323	478
Total	**65**	**144**	**374**	**583**

3.7 Contributory factors

The contributory factors to accidents have been reported in STATS19 since 2005. They give an indication of what actions contributed to the accident. Only accidents where a police officer attended the scene are included in this analysis. Table 9 shows the most commonly reported contributory factors in the accidents on the single carriageway sections of the A9. (Note that several contributory factors can be recorded for each accident so the sum of the frequencies of the individual contributory factors is far greater than the number of accidents.)

Table 9: Most commonly reported 20 contributory factors in accidents on the A9 single carriageway sections (2005-2012)

Contributory Factor		Fatal	Serious	Slight	Total
410	Loss of control	13	15	54	82
405	Failed to look properly	12	21	48	81
103	Slippery road (weather)	3	9	52	64
406	Failed to judge other's path or speed	3	16	37	56
403	Poor turn or manoeuvre	7	13	29	49
409	Swerved	5	12	22	39
503	Fatigue	10	7	17	34
602	Careless, reckless or in a hurry	7	8	17	32
308	Following too close	1	12	18	31
307	Travelling too fast for conditions	1	4	23	28
408	Sudden braking	1	3	19	23
509	Distraction in vehicle	5	3	8	16
707	Vision affected by rain, sleet, snow or fog	0	3	11	14
109	Animal or object in carriageway	0	3	10	13
505	Illness or disability, mental or physical	6	1	5	12
706	Vision affected by dazzling sun	0	0	11	11
501	Impaired by alcohol	2	1	8	11
302	Disobeyed give way or stop sign or markings	0	4	6	10
306	Exceeding speed limit	4	4	2	10
605	Learner or inexperienced driver or rider	2	3	3	8
All accidents with CFs with police attended		**37**	**68**	**207**	**312**

The most commonly reported factors were 'loss of control' and 'failed to look properly', each recorded in 26% of accidents. These were also the most common factors in fatal accidents, with 'fatigue' the third-most common factor, recorded in 10 out of the 37 accidents which resulted in a fatality. The two main speed-related contributory factors, 'travelling too fast for conditions' and 'exceeding speed limit', were recorded in 9% and 3% of accidents respectively. Note that 'overtaking' is not recorded as a contributory factor; however, the manoeuvre variable, in which overtaking is recorded, is analysed in the following sections.

3.8 Accident types

The accident and vehicle details in accidents were examined in order to categorise the accidents into accident types. The following groups were identified:

- Single vehicle accidents
- Junction accidents
- Overtaking accidents
- Head-on accidents

- Shunt accidents

Note that each accident could belong to more than one group.

3.8.1 Single vehicle accidents

31% of accidents involved a single vehicle. Note that single vehicle accidents include accidents which involve a pedestrian if only one vehicle is involved.

Table 10: Single vehicle accidents (1999-2012)

Number of vehicles	Fatal	Serious	Slight	Total	% for the A9 single carriageway	% for NBU A-roads in Scotland
Single vehicle	9	28	146	183	31%	42%
Multiple vehicles	56	116	228	400	69%	58%
Total	**65**	**144**	**374**	**583**	**100%**	**100%**

Single vehicle accidents were of relatively low severity: 20% were fatal or serious compared with 43% of multiple vehicle accidents. On all Scottish non-built-up A-roads, 42% of accidents involved only a single vehicle and 58% involved multiple vehicles. The severities were much more similar; 26% of single vehicle accidents and 28% of multiple vehicle accidents resulted in a fatality or serious injury. This suggests that the multiple vehicle accidents are different in nature on A9 to the comparator routes.

Single vehicle accidents on the A9 were over-represented at night: 40% were between 7pm and 7am, as opposed to 19% of multi-vehicle accidents.

Motorcyclists were more likely to be involved in single vehicle accidents: these represented 10% of the vehicles in single vehicle accidents, compared with less than 3% of the vehicles in accidents involving multiple vehicles.

Table 11: Type of vehicles involved in accidents (1999-2012)

Vehicle type	Single vehicle accidents	Multiple vehicle accidents	Total
Pedal cycle	1	3	4
Motorcycle	18	25	43
Car	131	719	850
Bus/coach	1	11	12
LGV	10	53	63
Heavy goods < 7.5 tonnes	5	27	32
Heavy goods > 7.5 tonnes	16	111	127
Other/unknown	1	34	35
Total	**183**	**983**	**1,166**

The most common contributory factors in single vehicle accidents were:

- Loss of control (46%)

- Slippery road (weather) (38%)
- Swerved (19%)
- Travelling too fast for conditions (16%)
- Animal or object in carriageway (11%)

3.8.2 Junction accidents

32% of accidents on the A9 were at or within 20 metres of a junction. This is a very similar proportion to those on non-built-up A-roads in Scotland.

Table 12: Junction accidents (1999-2012)

Junction detail	Fatal	Serious	Slight	Total	% for the A9 single carriageway	% for NBU A-roads in Scotland
Junction	10	49	128	187	32%	31%
Non-junction	55	95	246	396	68%	69%
Total	**65**	**144**	**374**	**583**	**100%**	**100%**

27 of the accidents at junctions were single vehicle accidents.

3.8.3 Overtaking accidents

Overtaking accidents were defined as accidents where any vehicle involved was 'overtaking moving vehicle on its offside', 'overtaking stationary vehicle on its offside' or 'overtaking on nearside'. The overtaken vehicle may not have been recorded in STATS19 if there was no contact between the vehicles and there were no injuries to the occupants of the overtaken vehicle.

Using this approach, the STATS19 data suggested that 13% of all accidents on the A9 between 1999 and 2012 involved overtaking, compared with 9% on all non-built-up A-roads in Scotland.

Table 13: Overtaking accidents (1999-2012)

Overtaking	Fatal	Serious	Slight	Total	% for the A9 single carriageway	% for NBU A-roads in Scotland
Overtaking	12	25	40	77	13%	9%
Not overtaking	53	119	334	506	87%	91%
Total	**65**	**144**	**374**	**583**	**100%**	**100%**

15 of the 77 overtaking accidents were at a junction, 12 involved a single vehicle, 34 involved two vehicles and 31 involved three or more vehicles.

191 vehicles were involved in the 77 overtaking accidents, of which 82 vehicles were overtaking. 58 of the overtaking vehicles were cars, seven were motorcycles, seven

were LGVs, and eight were heavy goods vehicles, including four of more than 7.5 tonnes maximum laden weight.

Of those that were recorded, the vehicles that were overtaken most commonly had a frontal impact, whilst other vehicles in the accident were most commonly hit on the front or offside. 21 of the 77 accidents resulted in a head-on collision and a further seven resulted in a shunt. There were 37 overtaking accidents between 2005 and 2012 where contributory factors were recorded. The most common were:

- Failed to look properly (16 accidents)
- Poor turn or manoeuvre (12 accidents)
- Careless, reckless or in a hurry (11 accidents)
- Loss of control (10 accidents)
- Failed to judge other person's path or speed (10 accidents)

As described in section 3.1, a study analysed the text descriptions of fatal accidents (Transport Scotland 2014b) on the single carriageway sections of the A9 between 2008 and 2012. This found that 8 of the 23 fatal accidents (35%) involved overtaking, a higher proportion than estimated from the STATS19 data shown above. These 8 accidents resulted in 15 of the 37 fatalities.

3.8.4 Head-on accidents

Head-on accidents are not directly extractable as an accident type from the STATS19 data. This accident type was derived using the first point of impact and the vehicle movement 'from' and 'to' compass points.

Using this approach, the STATS19 data suggested that 20% of all accidents and about half of the fatal accidents were head-on accidents – they were of high severity. On all non-built-up A-roads in Scotland, 11% of accidents were head-on.

Table 14: Head-on accidents (1999-2012)

Head-on	Fatal	Serious	Slight	Total	% for A9 single carriageway	% for NBU A-roads in Scotland
Head-on	32	41	44	117	20%	11%
Not head-on	33	103	330	466	80%	89%
Total	**65**	**144**	**374**	**583**	**100%**	**100%**

27 of the 117 head-on accidents occurred at a junction.

There were 67 head-on accidents between 2005 and 2012 where contributory factors were recorded. The most common factors were:

- Fatigue (18 accidents)
- Poor turn or manoeuvre (16 accidents)
- Failed to look properly (16 accidents)
- Swerved (14 accidents)

- Loss of control (13 accidents)
- Failed to judge other person's path or speed (12 accidents)

A study analysed the text descriptions of fatal accidents (Transport Scotland 2014b) on the single carriageway sections of the A9 between 2008 and 2012. This found that 14 of the 23 fatal accidents (61%) involved a head-on collision.

3.8.5 Shunt accidents

Shunt accidents are not directly extractable as an accident type from the STATS19 data. This accident type was derived using the first point of impact and the vehicle movement 'from' and 'to' compass points.

15% of accidents on the A9 single carriageway were shunt accidents, a similar figure to all NBU A-roads in Scotland (17%).

Table 15: Shunt accidents (1999-2012)

Shunt	Fatal	Serious	Slight	Total	% for A9 single carriageway	% for NBU A-roads in Scotland
Shunt	5	19	62	86	15%	17%
Not shunt	60	125	312	497	85%	83%
Total	**65**	**144**	**374**	**583**	**100%**	**100%**

There were 47 accidents with contributory factors reported (2005-2012). The most commonly reported contributory factors were:

- Following too close (21 accidents)
- Failed to judge other person's path or speed (20 accidents)
- Failed to look properly (17 accidents)
- Sudden braking (21%)

3.8.6 Hierarchy of accident types

There is some overlap between some of the accident types above, especially head-on accidents and overtaking accidents as shown in Table 16.

Table 16: Overtaking and head-on accidents (1999-2012)

Accident type	Head-on	Non-head-on	Total
Overtaking	21	56	77
Non-overtaking	96	410	506
Total	**117**	**466**	**583**

117 of the 583 accidents (20%) were head-on accidents, of which 21 (18%) were overtaking accidents. 77 accidents (13%) were overtaking accidents, of which 21 (27%) were head-on accidents.

These groups can be assigned in the order in Table 17 so that each accident is only classed as one accident type; that is, an accident which involved both a vehicle overtaking and a head-on collision would be classed as an overtaking accident. Using this approach, the number of accidents of each type is shown in Table 17.

Table 17: Accident types (hierarchy) by severity

Accident type	Fatal	Serious	Slight	Total	% Fatal and Serious	% of accidents on the A9 single carriageway	% of accidents on NBU A-roads in Scotland
Single vehicle	9	28	146	183	20%	31%	42%
Junction	9	45	106	160	34%	27%	25%
Overtaking	11	21	19	51	63%	9%	5%
Head-on	22	22	27	71	62%	12%	7%
Shunt	1	12	38	51	25%	9%	9%
Other	13	16	38	67	43%	11%	11%
Total	**65**	**144**	**374**	**583**	**36%**	**100%**	**100%**

Compared with all non-built-up Scottish A-roads, accidents on the A9 were more likely to be overtaking or head-on accidents, which are both high severity accident types. This is unsurprising given non-built-up A-roads include both dual carriageway and single carriageway sections.

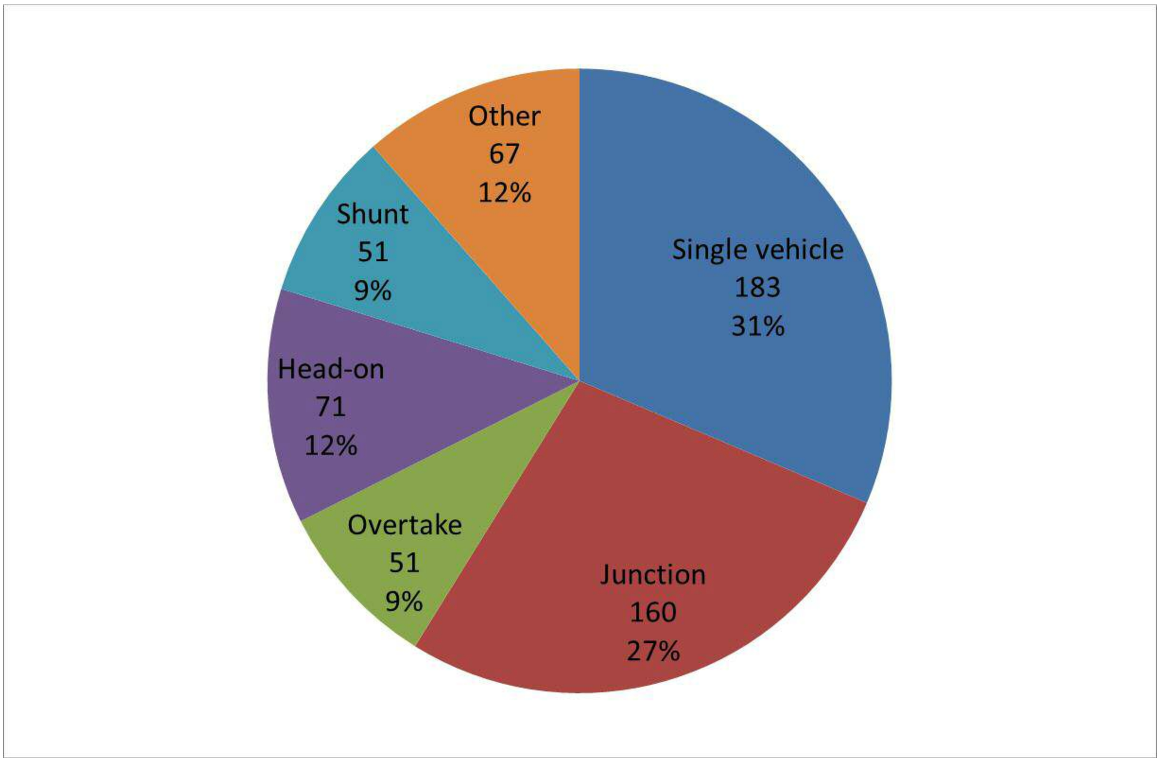


Figure 4: Distribution of accident types (in hierarchy)

Figure 5: Accident severities for accident types (hierarchy)

Further accident data analysis is provided in Appendix A.

3.9 Accident data for modelling

A micro-simulation model was used by AECOM to estimate the effect of changing the speed limit on vehicle speeds, specifically considering weekday periods between 7am and 7pm. Accident figures for these periods are presented below.

296 of the 583 accidents (51%) on the A9 between 1999 and 2012 occurred between 7am and 7pm on a weekday. 30% of these resulted in a fatality or serious injury compared with 36% of all accidents in the period.

Table 18: Accident by time period (1999-2012)

Time	Day	Fatal	Serious	Slight	Total	% Fatal and Serious
7pm-7am	Weekend	3	10	34	47	28%
	Weekday	16	30	55	101	46%
7am-7pm	Weekend	18	24	97	139	30%
	Weekday	28	80	188	296	36%
Total		**65**	**144**	**374**	**583**	**36%**

There were 193 accidents between 2008 and 2012, 33% of which resulted in a fatality or serious injury. 112 of these accidents were between 7am and 7pm on weekdays.

Table 19: Accidents by time period (2008-2012)

Time	Day	Fatal	Serious	Slight	Total	% F+S
7pm-7am	Weekend	0	2	9	11	18%
	Weekday	6	8	17	31	45%
7am-7pm	Weekend	6	2	31	39	21%
	Weekday	12	28	72	112	36%
Total		**24**	**40**	**129**	**193**	**33%**

Examining the accident types by time and day indicates that 62% of overtaking accidents, 57% of head-on accidents and 65% of shunt accidents occurred between 7am and 7pm on weekdays. On the other hand, just 37% of single vehicle accidents occurred in this time period.

Table 20: Accident types by period (1999-2012)

		Single vehicle	Junction	Overtake	Head-on	Shunt	Other	Total
7pm-7am	Weekend	33	9	3	2	3	6	47
	Weekday	42	51	13	25	19	20	139
7am-7pm	Weekend	40	23	13	23	8	13	101
	Weekday	68	104	48	67	56	28	296
Total		**183**	**187**	**77**	**117**	**86**	**67**	**583**

In section 2.2.4, it was noted that, in general, there are relatively few accidents on single carriageways recorded in STATS19 that appear to involve an HGV and in which a vehicle was identified as overtaking. The benefit of reducing the frequency of overtaking manoeuvres might subsequently be more limited than would be expected. The number of such accidents on the A9 as recorded in STATS19 was therefore investigated.

There were 296 accidents on the single carriageway sections of the A9 in the 14 year period, between 7am and 7pm on weekdays, from 1999 to 2012 inclusive, recorded in STATS19. 14 of these (5%) were recorded as having involved both an HGV and an overtaking manoeuvre. However, as described in section 3.8.3, details of overtaken vehicles would not necessarily have been recorded if no one in the overtaken vehicle was injured.

48 of the 296 accidents (16%) were recorded as having involved overtaking, and 67 (23%) appear to have been head-on accidents. There is some overlap between these accident types, since some head-on accidents involved overtaking, and the total of the two types is 105 (35%). There were also 48 shunt accidents (16%) (that were not also head on or overtaking) which might have come about in part because of the platooning effects caused by slower moving vehicles. The STATS19 data therefore appear to suggest that, even if there were to be a reduction in the risk associated specifically with overtaking manoeuvres on the A9, there is limited potential for a reduction in the total accident risk.

However, the analysis of the STATS19 data is likely to underestimate the number of accidents involving overtaking for the reasons described above. This was confirmed by the text description analysis (Transport Scotland, 2014b) which showed that higher proportions of the fatal accidents involved overtaking than the STATS19 data analysis indicated.

4 Vehicle speeds on the A9

4.1 Introduction

AECOM on behalf of Transport Scotland (2014a) studied the effects of increasing the speed limit for HGVs from the current 40mph to 50mph on the A9 between Perth and Inverness using the S-Paramics micro-simulation model. The micro-simulation model was calibrated by comparing speed distributions for various types of vehicle with direct observations obtained from traffic counter sites.

This traffic modelling identified that there are likely to be a number of changes in traffic behaviour following the installation of average speed cameras, and following the possible increase in the speed limit applicable to HGVs on the A9. For example, this modelling suggested that the introduction of average speed cameras will reduce average vehicle speeds, reduce the frequency of overtaking manoeuvres, reduce the speed differentials between the fastest and slowest moving vehicles, and reduce the lengths of platoons that form behind slower moving vehicles.

While the literature review considered all of these factors, no evidence was found that identified how a reduction in the speed differential between different vehicle types and a reduction in the number of overtaking manoeuvres would affect the overall accident risk. However, established relationships between average vehicle speeds and accidents were identified. Unlike the other factors, average speed can therefore be used to model the effects of the changes on the A9.

This section describes the analysis of AECOM’s detailed speed distributions in order to calculate the relevant average vehicle speeds, to input into the accident modelling.

4.2 Vehicle speed data

AECOM’s modelling was of 2012 traffic on weekdays (Mondays – Fridays), between 7am and 7pm, at four different single carriageway locations on the A9. Two of these were on the two lane side of the ‘2+1’ single carriageway sections and two were on sections where there was only one lane in the direction concerned. The speed data were classified into the following time periods:

- the AM Peak (7am-10am),
- the Inter Peak (10am-4pm), and
- the PM Peak (4pm-7pm).

Each simulation was repeated ten times. To test the sensitivity of the results, AECOM modelled vehicle speeds using two different ‘aggression’ options: ‘low aggression’ and ‘default aggression’ for both scenarios described in the introduction. Details of these two aggression options are available in Transport Scotland (2014a). Vehicle speeds were output for each of the ten simulations for each of the following:

- the base case i.e. a simulation of 2012 traffic,
- Scenario 1: ‘Enforced 40mph’ with ‘low aggression’,
- Scenario 2: ‘Enforced 50mph’ with ‘low aggression’,
- Scenario 1: 'Enforced 40mph' with 'default aggression', and

- Scenario 2: 'Enforced 50mph' with 'default aggression'.

4.3 Average speed calculations

Using the data provided by AECOM, TRL calculated the average speeds for all vehicles in all ten simulations for:

- the base case and each of the four combinations of enforcement speeds and aggression options,
- the three time periods, and
- the two different numbers of lanes (i.e. those sections of single carriageway with one lane in the direction concerned and those sections of single carriageway with two lanes in the direction concerned).

In addition, the weighted averages of the vehicle speeds across all single carriageway sections were calculated, taking account of the relative lengths of those sections with one lane and those sections with two lanes. These average speeds are presented in Table 21, where 'All' refers to the weighted average across all the single carriageway sections.

Table 21: Average vehicle speeds (mph) on the A9 split by aggression option, scenario, number of lanes and time of day (Weekdays only)

Scenario and aggression option		Number of lanes	AM Peak	Inter Peak	PM Peak
Base		1	56.5	54.0	54.9
		2	64.0	62.1	62.4
		All	56.6	54.1	55.0
Low aggression	Scenario 1: Enforced 40mph	1	47.0	44.5	45.0
		2	51.2	49.5	49.9
		All	47.1	44.6	45.1
	Scenario 2: Enforced 50mph	1	49.0	47.4	47.5
		2	52.7	51.5	51.8
		All	49.0	47.5	47.6
Default aggression	Scenario 1: Enforced 40mph	1	51.6	49.1	49.6
		2	54.8	53.0	53.5
		All	51.7	49.1	49.7
	Scenario 2: Enforced 50mph	1	53.2	51.6	51.9
		2	56.3	55.0	55.3
		All	53.2	51.7	51.9

For the purposes of the accident modelling, it was assumed that the vehicle speeds on the one lane sides of the sections with one lane in the direction concerned were representative of all the single lane sections, including the single lane on the 2+1 sections. Similarly, the vehicle speeds on the two lane sides of the sections with two lanes in the direction concerned were assumed to be representative of all the single carriageway sections with two lanes in the direction concerned. Treating the 2+1 sections in this way gives a total two lane length of 4km and a single lane length of 254.4km (comprising 125.2km of S2 in each direction plus 4km of single lane from the 2+1 section).

5 Accident modelling

5.1 Models used

5.1.1 The Taylor model

The prediction of accidents from the speed distributions provided by AECOM was based on established relationships between mean traffic speed and accidents, as described in section 2.3. The Taylor models used here are those for:

- all injury accidents,
- fatal and serious injury accidents, and
- slight injury accidents.

Level 1 models had the same form which was:

$$A = k\, Q^a\, L^b\, V^c\, G$$

where A is the accident frequency, 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, G is a category variable which depends on the group to which each link was allocated, and k, a, b and c are parameters calculated by the model. (G 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:

$$A = k\, Q^a\, L^b\, V^c\, G\, exp(d_1 D_1 + d_2 D_2 + \ldots)$$

where D_1 and D_2 represent these additional variables and d_1 and d_2 are parameters determined by the model

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 22. For all injury accidents the models reduce to:

$A = k_1\, V^{2.479}$ (Taylor level 1) and

$A = k_2\, V^{2.431}$ (Taylor level 2)

where k_1 and k_2 are constants for a particular route with a given flow, length and characteristics.

If 'before' and 'after' refer to accident numbers and speeds before and after a change in mean speed, the constants in the models are unchanged and therefore are such that:

$$\text{Accidents after/Accidents before} = (\text{Mean speed after/Mean speed before})^c$$

Table 22: 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
All injury	2.479	2.431

5.1.2 *Nilsson's power model*

Nilsson (2004) developed a relationship between speed and accidents known as the power model, which was reviewed, modified and evaluated by Elvik, Christensen and Amundsen (2004). The latter includes 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 relationship takes precisely the same form as the Taylor model above, such that the equation above holds, albeit with different values of *c* at each severity. The values of *c* (exponent of mean speed) reported in Elvik et al. for different severities of accident are presented in Table 23.

Elvik et al. concluded 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 23: The effect of mean speed on accidents (Nilsson)

Type of accident	Value of c
Fatal	3.6
Serious injury	2.4
Slight injury	1.2
All injury	2.0

5.2 Methodology

The analysis reported here used both levels of the Taylor model and the Nilsson model. These were used to combine the historic accident data, presented in section 3, and the average vehicle speeds, presented in section 4, to estimate the number of accidents for:

- each of the four combinations of enforcement speeds and aggression options:
  - 'Enforced 40mph' with 'low aggression',
  - 'Enforced 50mph' with 'low aggression',
  - 'Enforced 40mph' with 'default aggression',
  - 'Enforced 50mph' with 'default aggression',
- each of the three time periods:
  - the AM Peak (7am-10am),
  - the Inter Peak (10am-4pm),
  - the PM Peak (4pm-7pm), and

- the two different numbers of lanes:
    - o those sections of single carriageway with one lane in the direction concerned, and
    - o those sections of single carriageway with two lanes in the direction concerned.

All of these estimates were calculated using two sets of historic accident data: 1999-2012 and 2008-2012. The shorter period (2008-2012) has the advantage of being less susceptible to natural statistical variation, while the longer period (1999-2012) gives a more accurate picture of the current situation – there may have been significant changes in the characteristics of the route since 1999. There is an argument for using each time period or any period in between. In reality, the differences between the two were not substantial: the annual number of accidents between 7am and 7pm on weekdays on the sections of the A9 that are single carriageway remained remarkably stable throughout the period. However, as would be expected, there was some variation in the number of accidents at any given injury severity.

Each of the models considers accidents at different severities and also the overall number of accidents. The total number of accidents was therefore estimated both by:

- summing the results at each severity, and
- using the all injury number alone.

Similarly, the numbers of accidents was forecast both by:

- summing the results from each model for the two different numbers of lanes, and
- modelling the numbers of accidents using the weighted average vehicle speeds.

This approach provided four different estimates for both levels of the Taylor model and for the Nilsson model, i.e. a total of twelve different estimates for:

- each of the three time periods, and
- each of the four combinations of enforcement speeds and aggression options,
- using each of the two sets of historic accident data.

The twelve different estimates in each case effectively identified ranges for the numbers of accidents in each one.

The outputs from the models were then summed across the three time periods, producing ranges for the likely changes in the annual number of accidents on the single carriageway sections of the A9 between 7am and 7pm on weekdays. This approach provided a different range for each of the four enforcement speed and aggression options combinations, and for both sets of historic accident data.

5.3 Results

The findings are summarised in Table 24 (1999-2012 base, low aggression), Table 25 (2008-2012 base, low aggression), Table 26 (1999-2012 base, default aggression) and Table 27 (2008-2012 base, default aggression).

The financial values that follow each table are based on the values of prevention provided for trunk roads in Reported Road Casualties Scotland 2012, and are based on 2012 values at 2012 prices.

5.3.1 *1999-2012 base, low aggression*

Table 24: Forecasts of the number of accidents per year on the A9, based on accident data from 1999-2012 with low aggression (Single carriageway sections, weekdays, 7am-7pm only)

Accidents per Year	Fatal and Serious		Slight		Total	
Base	7.7		13.4		21.1	
	Range of estimates		**Range of estimates**		**Range of estimates**	
Scenario 1: 'Enforced 40mph'	4.5	5.0	8.4	11.0	13.0	16.0
Scenario 2: 'Enforced 50mph'	5.2	5.7	9.2	12.2	14.5	17.9
Change from Base to Scenario 1	-3.2	-2.8	-5.0	-2.4	-8.1	-5.2
Change from Base to Scenario 2	-2.5	-2.0	-4.3	-1.2	-6.6	-3.2
Change from Scenario 1 to Scenario 2	0.8	0.8	0.7	1.2	1.5	2.0

In the last 14 years (1999-2012), there were an average of 21.1 accidents per year on the single carriageway sections of the A9 between 7am and 7pm on weekdays. An average of 2.0 of resulted in a fatality and an average of a further 5.7 resulted in a serious injury.

In Scenario 1: 'Enforced 40mph', the number of accidents per year between 7am and 7pm on weekdays on single carriageway sections would be expected to fall from the base scenario by between 5.2 and 8.1.

In Scenario 2: 'Enforced 50mph', the number of accidents per year between 7am and 7pm on weekdays on single carriageway sections would be expected to fall by between 3.2 and 6.6.

5.3.2 2008-2012 base, low aggression

Table 25: Forecasts of the number of accidents per year on the A9, based on accident data from 2008-2012 with low aggression (Single carriageway sections, weekdays, 7am-7pm only)

Accidents per Year	Fatal and Serious		Slight		Total	
Base	8.0		14.4		22.4	
	Range of estimates		**Range of estimates**		**Range of estimates**	
Scenario 1: 'Enforced 40mph'	4.7	5.0	9.0	11.9	13.8	16.9
Scenario 2: 'Enforced 50mph'	5.5	5.9	9.8	13.2	15.4	19.0
Change from Base to Scenario 1	-3.3	-3.0	-5.4	-2.5	-8.6	-5.5
Change from Base to Scenario 2	-2.5	-2.1	-4.6	-1.2	-7.0	-3.4
Change from Scenario 1 to Scenario 2	0.8	0.8	0.8	1.3	1.6	2.1

In the last five years (2008-2012), there were an average of 22.4 accidents per year on the single carriageway sections of the A9 between 7am and 7pm on weekdays. An average of 2.4 resulted in a fatality and an average of a further 5.6 resulted in a serious injury.

In Scenario 1: 'Enforced 40mph', the number of accidents per year between 7am and 7pm on weekdays on single carriageway sections would be expected to fall from the base scenario by between 5.5 and 8.6.

In Scenario 2: 'Enforced 50mph', the number of accidents per year between 7am and 7pm on weekdays on single carriageway sections would be expected to fall by between 3.4 and 7.0.

5.3.3 1999-2012 base, default aggression

Table 26: Forecasts of the number of accidents per year on the A9, based on accident data from 1999-2012 with default aggression (Single carriageway sections, weekdays, 7am-7pm only)

Accidents per Year	Fatal and Serious		Slight		Total	
Base	7.7		13.4		21.1	
	Range of estimates		**Range of estimates**		**Range of estimates**	
Scenario 1: 'Enforced 40mph'	5.9	6.0	10.6	12.0	16.6	17.9
Scenario 2: 'Enforced 50mph'	6.6	6.8	11.3	13.1	18.0	19.8
Change from Base to Scenario 1	-1.8	-1.8	-2.8	-1.5	-4.6	-3.2
Change from Base to Scenario 2	-1.1	-1.0	-2.2	-0.3	-3.1	-1.3
Change from Scenario 1 to Scenario 2	0.8	0.8	0.6	1.2	1.4	1.9

In the last 14 years (1999-2012), there were an average of 21.1 accidents per year on the single carriageway sections of the A9 between 7am and 7pm on weekdays. An average of 2.0 of resulted in a fatality and an average of a further 5.7 resulted in a serious injury.

In Scenario 1: 'Enforced 40mph', the number of accidents per year between 7am and 7pm on weekdays on single carriageway sections would be expected to fall from the base scenario by between 3.2 and 4.6.

In Scenario 2, 'Enforced 50mph', the number of accidents per year between 7am and 7pm on weekdays on single carriageway sections would be expected to fall by between 1.3 and 3.1.

5.3.4 2008-2012 base, default aggression

Table 27: Forecasts of the number of accidents per year on the A9, based on accident data from 2008-2012 with default aggression (Single carriageway sections, weekdays, 7am-7pm only)

Accidents per Year	Fatal and Serious		Slight		Total	
Base	7.7		13.4		21.1	
	Range of estimates		**Range of estimates**		**Range of estimates**	
Scenario 1: 'Enforced 40mph'	6.1	6.2	11.4	12.8	17.6	19.0
Scenario 2: 'Enforced 50mph'	6.9	7.0	12.1	14.1	19.1	21.0
Change from Base to Scenario 1	-1.9	-1.8	-3.0	-1.6	-4.8	-3.4
Change from Base to Scenario 2	-1.1	-1.0	-2.3	-0.3	-3.3	-1.4
Change from Scenario 1 to Scenario 2	0.8	0.9	0.7	1.3	1.5	2.1

In the last five years (2008-2012), there were an average of 22.4 accidents per year on the single carriageway sections of the A9 between 7am and 7pm on weekdays. An average of 2.4 resulted in a fatality and an average of a further 5.6 resulted in a serious injury.

In Scenario 1: 'Enforced 40mph', the number of accidents per year between 7am and 7pm on weekdays on single carriageway sections would be expected to fall from the base scenario by between 3.4 and 4.8.

In Scenario 2: 'Enforced 50mph', the number of accidents per year between 7am and 7pm on weekdays on single carriageway sections would be expected to fall by between 1.4 and 3.3.

5.4 Summary

This traffic modelling identified that there are likely to be a number of changes in traffic behaviour following the installation of average speed cameras, and following the possible increase in the speed limit applicable to HGVs on the A9. For example, this modelling suggested that the introduction of average speed cameras will reduce average vehicle speeds, reduce the frequency of overtaking manoeuvres, and reduce the speed differentials between the fastest and slowest moving vehicles.

Established relationships between average speeds and accidents were identified but no other robust relationships between changes in traffic behaviour and accidents could be found. Therefore, accident modelling was based on the changes in average speeds alone.

The accident modelling forecast the possible changes in accident numbers, between 7am and 7pm on weekdays, as a result of adopting either Scenario 1: 'Enforced 40mph' or Scenario 2: 'Enforced 50mph'.

The number of accidents expected in either of these scenarios would be expected to be lower than the current number of accidents. That is, both scenarios appear to be safer than maintaining the status quo.

When the vehicle speeds were modelled using the 'low aggression' option, the number of accidents was forecast to reduce by between 3 and 9 accidents a year, on average; when the 'default aggression' option was used, the number was forecast to reduce by between 1 and 5 accidents a year, on average. These figures, applicable to the period between 7am and 7pm on weekdays, were quite consistent regardless of the years used for the base period.

Regardless of the scenario adopted initially, it would be prudent to update these forecasts following the installation of the average speed cameras. This would enable the real world effect on driver speed choice to be incorporated into both of the modelled scenarios more accurately.

6 Summary and conclusion

6.1 Background

The A9 is the main trunk road linking Inverness and towns further north with central Scotland. The 170km section between Perth and Inverness is of strategic importance to industry, tourism and the development of the Scottish Highlands. It carries a substantial amount of through traffic between Perth and Inverness, including sections on which the proportion of vehicles that are heavy goods vehicles is twice the average on rural trunk 'A' roads in Scotland.

The road is mainly single carriageway with limited opportunities to overtake slower moving vehicles safely. The effects of different vehicle speeds are therefore particularly acute. The single carriageway sections are governed by national speed limits that restrict heavy goods vehicles in excess of 7.5 tonnes maximum laden weight to 40mph. This is lower than for other goods vehicles, buses and minibuses, and cars towing caravans and trailers, for which the applicable speed limit is 50mph, and is considerably lower than for cars and motorcycles, for which the applicable speed limit is 60mph. The 40mph speed limit is thought to contribute to long platoon formations, delaying other road users. This is believed to cause driver frustration which is thought to increase accident risk. Consideration is currently being given to raising the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight to 50mph on the single carriageway sections of the A9 only.

The overall injury accident rate on the A9 is lower than for major non-built-up trunk 'A' roads in Scotland, though the rate for fatal accidents appears to be higher. Accident severity on the A9 is higher than on other non-built-up trunk roads in Scotland and this is partly attributable to relatively high speeds. Average speed cameras are soon to be introduced along the entire length of the A9 between Perth and Inverness.

This report describes how the number of accidents following installation of the average speed cameras was modelled, and the results of this modelling, for two scenarios. In the first, the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight of 40mph is retained; in the second, the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight is increased to 50mph.

6.2 Methodology

A review of literature showed that average vehicle speeds are the key predictor of accidents along a route. Established relationships between average speeds and injury accidents could therefore be used to model the number of injury accidents in each scenario and each time period across the single carriageway sections.

The diagram below gives an overview of the methodology used.

Proposed change in HGV speed limit

↓

Model proposed change in traffic using simulation (AECOM)

↓

Estimate resultant average traffic speeds (AECOM)

↓

Input average traffic speeds and existing accident numbers into models that relate accident rates to average traffic speed

↓

Estimate change in accidents

AECOM conducted a study for Transport Scotland focussing on the effects on traffic behaviour relating to the introduction of average speed cameras and the possible increase in the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight from 40mph to 50mph (Transport Scotland, 2014a). As such, AECOM was able to supply vehicle speed data from output generated by the S-Paramics micro-simulation model pertaining to four single carriageway sections of the A9. Two of these sections had one lane in the direction concerned, and two of these sections had two lanes in the direction concerned. Simulated vehicle speeds were available for:

- the base case i.e. a simulation of 2012 traffic,
- Scenario 1: 'Enforced 40mph' (retain the current speed limits, i.e. including the 40mph limit applicable to heavy goods vehicles of more than 7.5 tonnes maximum laden weight, and enforce these using average speed cameras, and
- Scenario 2: 'Enforced 50mph' (raise the speed limit applicable to heavy goods vehicles of more than 7.5 tonnes maximum laden weight to 50mph, and enforce the revised speed limits using average speed cameras).

The simulated data pertained to weekdays only, and to the following time periods:

- the AM Peak (7am-10am),
- the Inter Peak (10am-4pm), and
- the PM Peak (4pm-7pm).

Assuming that the vehicle speeds provided by AECOM were representative of vehicle speeds across the route as a whole, the average speeds across all vehicles were calculated for:

- the base case and the two modelled scenarios,
- the three time periods, and

- the two different numbers of lanes (i.e. those sections of single carriageway with one lane in the direction concerned and those sections of single carriageway with two lanes in the direction concerned).

The models identified in the literature were then used to combine the historic accident data and the average vehicle speeds to estimate the number of accidents in the modelled scenarios.

6.3 Accidents

The number of accidents would be expected to fall compared with the base in both Scenario 1: 'Enforced 40mph' and Scenario 2: 'Enforced 50mph'. In Scenario 1: 'Enforced 40mph', the number of injury accidents between 7am and 7pm on weekdays was forecast to reduce by an average of between 3 and 9 a year; in Scenario 2: 'Enforced 50mph', the number of injury accidents between 7am and 7pm on weekdays was forecast to reduce by an average of between 1 and 7 a year.

6.4 Overtaking

AECOM's traffic modelling suggested that, following the introduction of average speed cameras, increasing the speed limit for heavy goods vehicles in excess of 7.5 tonnes maximum laden weight from 40mph to 50mph would reduce the number of overtaking manoeuvres. A reduction in the number of overtaking manoeuvres might be expected to reduce the number of injury accidents associated with overtaking and hence the overall injury accident risk.

The possibility of modelling the effect of a reduction in overtaking manoeuvres on injury accidents was therefore investigated. However, no reliable evidence applicable to the A9 was found that indicated how a reduction in the number of overtaking manoeuvres and a reduction in the speed differential between different vehicle types might affect the injury accident risk. Therefore, the specific effects of a reduction in number of overtaking manoeuvres and in speed differentials between different vehicle types on overall accident risk could not be modelled reliably.

6.5 Conclusion

This report describes how the number of accidents following installation of the average speed cameras was modelled, and the results of this modelling, for two scenarios. In the first, the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight of 40mph is retained; in the second, the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight is increased to 50mph.

In both scenarios, a reduction in the number of accidents would be expected: it appears that there would be a safety benefit associated with the installation of the average speed cameras whether or not the speed limit applicable to heavy goods vehicles in excess of 7.5 tonnes maximum laden weight were increased from 40mph to 50mph. The reduction in the number of accidents is likely to be greater if this speed limit is retained at 40mph rather than increased to 50mph.

Regardless of the scenario adopted initially, it would be prudent to update the injury accident forecasts following the installation of the average speed cameras. This would enable the real world effect on driver speed choice to be incorporated into both of the modelled scenarios more accurately.

The modelling was based on average speeds, which are the key predictor of accidents along a route. However, it was not possible to model the effects of changes in the level of overtaking and the differences between different vehicle speeds. Given that there appears to be no scientifically robust research on these issues, there might be a case for conducting a carefully managed and scientifically evaluated trial on the A9 between Perth and Inverness.

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References

Baruya A (1997). A Review of Speed-Accident Relationship for European Roads. Project Report PR/TT/029/97. Crowthorne: TRL.

Department for Transport. 2013. Traffic Counts. [Online]. [Accessed 16 December 2013]. Available from: http://www.dft.gov.uk/traffic-counts/

Elvik R, Christensen P and Amundsen A (2004). Speed and road accidents: an evaluation of the power model. TOI Report 740/2004. Oslo: The Institute of Transport Economics.

Ghods A, Saccomanno F and Guido G (2012). Effect of Car/Truck Differential Speed Limits on Two-Lane Highways Safety Operation using Microscopic Simulation. Canada: University of Waterloo.

Grayson, G., Kinnear, N. and Helman, S. (In press). A review of the effects of frustration on driving behaviour and the propensity to overtake. Published Project Report. Crowthorne: TRL.

Helman, S. and Kinnear, N. (In press). Factors associated with driving frustration and overtaking intentions. Published Project Report. Crowthorne: TRL.

Hauer E (1971). Accidents, Overtaking and Speed Control. Israel: Israel Institute of Technology.

Kinnear N, Lawton B and Helman S (In press). A Review of Differential Speed Limits for HGVs and their Impact on Road Safety. Published Project Report. Crowthorne: TRL.

Lave, C (1985). Speeding coordination and the 55-mph limit. American Economic Review, Vol 75 (dec), pp 1159-1164.

Levy, D and Asch (1989). Speeding, coordination, and the 55-mph limit: Comment. American Economic Review, Vol 79 (Sep), pp 913-915.

Nilsson G (2004). Traffic safety dimensions and the power model to describe the effect of speed on safety. Lund Institute of Technology Bulletin 221. Lund: Lund Institute of Technology.

Rietveld P and Shefer D (1997). Speed Choice, Speed Variance, and Speed Limits. Amsterdam: Vrije University.

Solomon D (1964). Accidents on main rural highways related to speed, driver and vehicle. Washington D.C.: Bureau of Public Roads, U.S. Department of Commerce.

Summersgill I (2008). Estimation of the effect on accidents of changing the HGV speed limit on rural single carriageway roads in Scotland. TRL Unpublished Project Report UPR/SSI/217/08. Crowthorne: TRL.

Summersgill I and Buckle G (2009). Estimation of the effect on accidents of increasing the HGV speed limit on A9. TRL Draft Project Report RPN874. Crowthorne: TRL.

Summersgill I and Neil M (2012). The Impact of Speed Enforcement and Increasing the HGV Speed Limit on the A9(T). Microsimulation Modelling and Accident Assessment.

Summersgill I, Buckle G, Robinson T and Smith S (2009). HGV Speed Limit Increase Evaluation: Final Report. Published Project Report PPR576. Crowthorne: TRL.

Taylor M C, Baruya A and Kennedy J V (2002). The relationship between speed and accidents on rural single carriageway roads. TRL Report TRL511. Crowthorne: TRL.

Transport Scotland (2010). Reported Road Casualties Scotland 2009. Edinburgh: The Scottish Government.

Transport Scotland (2012). Scottish Transport Statistics No 31 2012 Edition. Edinburgh: The Scottish Government. Available at http://www.transportscotland.gov.uk/strategy-and-research/publications-and-consultations/j251205-000.htm (accessed November 2013)

Transport Scotland (2013). Reported Road Casualties Scotland 2012. Edinburgh: The Scottish Government.

Transport Scotland (2014a). A9 Average Speed Cameras – Traffic Modelling and Analysis. Edinburgh: AECOM Limited.

Transport Scotland (2014b). Transport Scotland plain text review and analysis of fatal accident reports. Available at www.A9Road.info (accessed January 2014)

Appendix A Additional accident data

A.1.1 Accidents

Table 28: Number of accidents on A9 by number of vehicles (1999-2012)

Number of vehicle	Fatal	Serious	Slight	Total	% F&S
1	9	28	146	183	20%
2	31	73	172	276	38%
3	17	31	32	80	60%
>3	8	12	24	44	45%
Total	65	144	374	583	36%
% single vehicle	**14%**	**19%**	**39%**	**31%**	

Over two-thirds (68%) of accidents, including 55 of the 65 fatal accidents occurred away from a junction.

Table 29: Number of accidents on A9 by junction detail (1999-2012)

Junction detail	Fatal	Serious	Slight	Total	% F&S
Non-junction	55	95	246	396	38%
T or staggered	7	29	83	119	30%
Slip road	1	6	13	20	35%
Crossroads	0	0	1	1	0%
Private drive	2	9	15	26	42%
Other junction	0	5	16	21	24%
Total	**65**	**144**	**374**	**583**	**36%**

Figure 6 shows the pattern of accidents thorough the week. On each day the greatest number of accidents was between noon and 6pm, and the least between midnight and 6am. The highest total number of accidents occurred on Saturdays and Fridays.

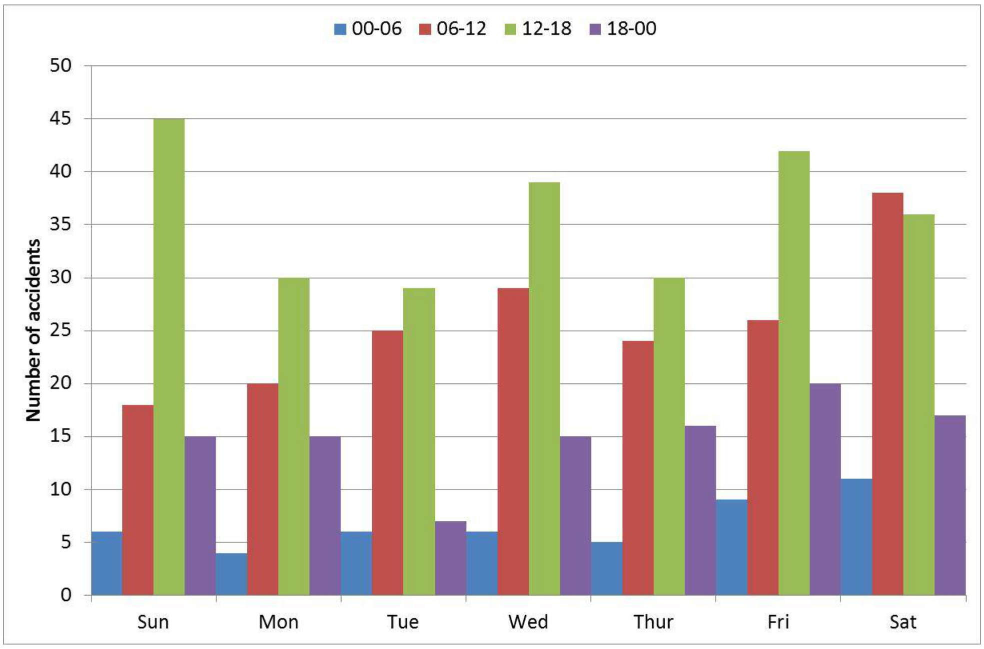

Figure 6: Accident numbers by day of week and time period (1999-2012)

Table 30: Number of accidents by month (1999-2012)

Month	Fatal	Serious	Slight	Total
Jan	4	13	31	48
Feb	6	10	31	47
Mar	5	11	34	50
Apr	8	8	21	37
May	4	6	32	42
Jun	5	11	33	49
Jul	7	14	41	62
Aug	6	20	41	67
Sep	3	19	24	46
Oct	6	13	19	38
Nov	6	11	26	43
Dec	5	8	41	54
Total	**65**	**144**	**374**	**583**

Table 31: Number of accidents by day of week (1999-2012)

Day	Fatal	Serious	Slight	Total
Sun	7	18	59	84
Mon	6	20	43	69
Tues	4	18	45	67
Wed	14	25	50	89
Thur	10	20	45	75
Fri	10	27	60	97
Sat	14	16	72	102
Total	**65**	**144**	**374**	**583**

Table 32: Number of accidents by time period (1999-2012)

hour	Fatal	Serious	Slight	Total	%F&S
00-06	9	8	30	47	36%
06-12	18	45	117	180	35%
12-18	25	56	170	251	32%
18-00	13	35	57	105	46%
Total	**65**	**144**	**374**	**583**	**36%**

A.1.2 Data for comparison

Table 33: Accident severity and year Trunk non-built-up Scotland (Transport Scotland, 2013 (Table5a))

Year	Fatal	Serious	All Severities
2002	70	285	1,315
2003	72	295	1,345
2004	68	305	1,393
2005	63	294	1,327
2006	74	254	1,311
2007	76	223	1,278
2008	50	245	1,247
2009	52	272	1,267
2010	48	231	1,127
2011	37	200	995
2012	28	191	926
2002-2012	**638**	**2,795**	**13,531**

Table 34: Accident rates on A9 single and A-Trunk non-built-up Scotland (Transport Scotland, 2013 Table 5b)

				A9	Scotland NBU trunk A-roads		
Year	**fatal**	**serious**	**slight**	**Total**	**Fatal**	**serious**	**Total**
1999	1.4	3.8	5.7	11.0	0.7	4.2	16.7
2000	1.0	4.3	6.3	11.6	1.0	4.8	17.8
2001	1.6	2.5	5.2	9.2	0.8	4.4	16.7
2002	0.7	2.4	6.9	10.0	0.8	3.3	15.1
2003	1.0	2.8	7.8	11.6	0.8	3.3	15.2
2004	1.0	2.5	8.0	11.5	0.8	3.4	15.6
2005	0.2	2.9	4.6	7.7	0.7	3.3	15.0
2006	1.4	1.8	7.4	10.6	0.8	2.8	14.5
2007	1.4	2.1	6.8	10.3	0.8	2.5	14.2
2008	1.2	1.9	6.6	9.6	0.6	2.8	14.1
2009	0.7	2.7	6.6	10.0	0.6	3.0	14.1
2010	1.6	2.1	5.3	9.0	0.6	2.6	12.9
2011	1.1	1.1	5.7	8.0	0.4	2.3	11.3
2012	0.9	1.4	5.5	7.8	0.3	2.2	10.7

1. Traffic estimates are based on an "urban/rural" split which differs slightly from the "built-up/non-built-up" classification used for the number of accidents. Therefore, these rates are approximations: the "non-built-up" rate is the number of accidents on "non-built-up" roads divided by the estimated volume of traffic on "rural" roads, for example. The figures given in this table take account of any revisions to the traffic estimates for previous years.

A.1.3 Vehicles

The majority of vehicles (62%) involved in accidents were 'going ahead'.

10% of vehicles were turning right or waiting to turn right.

Table 35: Number of vehicles by vehicle manoeuvres

Vehicle manoeuvre	Total	%
Reversing, parked, stopping, starting, U-turn	66	6%
Waiting to go ahead, but held up	75	6%
TurnL or waiting to TurnL	15	1%
TurnR or waiting to turn R	116	10%
Changing lane	12	1%
Overtaking	82	7%
Going ahead on a bend	73	6%
Going ahead	727	62%
Total	**1,166**	**100%**

A.1.4 Accidents involving an HGV

In the 105 accidents which involved an HGV, 41 of the resulting 210 casualties were occupants of that vehicle.

Table 36: Casualties in accidents involving an HGV

Road user group	Killed	Seriously injured	Slightly injured	Total
Pedestrian	2	1	0	3
Pedal cycle	0	0	1	1
motorcycle	0	0	2	2
Car	11	35	56	102
Bus/coach	0	7	37	44
LGV	0	5	8	13
20	0	1	1	2
21	6	11	24	41
Other/unknown	0	0	2	2
Total	19	60	131	210

Table 37: Accidents types by involvement of an HGV

Accident type (hierarchy)	HGV	No HGV	Total	%HGV
Single vehicle	16	167	183	9%
Junction	20	140	160	13%
Overtake	18	33	51	35%
Head-on	21	50	71	30%
Shunt	10	41	51	20%
Other	20	47	67	30%
Total	**105**	**478**	**583**	**18%**

A.1.5 Single vehicle accidents

Table 38: Contributory factors in single vehicle accidents

Factor		Fatal	Serious	Slight	Total	% of total
410	Loss of control	2	6	37	45	46%
103	Slippery road (weather)	1	3	33	37	38%
409	Swerved	1	2	15	18	19%
307	Travelling too fast for conditions	0	1	15	16	16%
109	Animal or object in carriageway	0	2	9	11	11%
503	Fatigue	0	1	7	8	8%
501	Impaired by alcohol	1	1	6	8	8%
403	Poor turn or manoeuvre	0	1	5	6	6%
809	Pedestrian wearing dark clothing at night	3	0	1	4	4%
706	Vision impaired by dazzling sun	0	0	4	4	4%
All accidents with contributory factors		**7**	**10**	**80**	**97**	**100%**

A.1.6 Overlap of accident types

Table 39 shows the complete overlap of the accident types above. For example, there were 145 accidents that involved a single vehicle, were not at a junction, did not involve overtaking, and were not head-on or shunt accidents.

Table 39: Overlap of accident types

Number of vehicles	Junction accident	Overtaking accident	Head-on accident	Shunt accident	Number of accidents
Single vehicle	Junction accident	Overtaking	Not head-on	Not shunt	1
		Not overtaking			26
	Non-junction accident	Overtaking			11
		Not overtaking			145
Multiple vehicle	Junction accident	Overtaking	Head-on	Not shunt	2
			Not head-on	Shunt	1
				Not shunt	11
		Not overtaking	Head-on	Shunt	1
				Not shunt	24
			Not head-on	Shunt	22
				Not shunt	99
	Non-junction accident	Overtaking	Head-on	Not shunt	19
			Not head-on	Shunt	6
				Not shunt	26
		Not overtaking	Head-on	Shunt	5
				Not shunt	66
			Not head-on	Shunt	51
				Not shunt	67
Total					**583**

Table 40 shows the overlap between pairs of accident types; for example, there were 24 shunt accidents at a junction.

Table 40: Multiple accident types (1999-2012)

Accident type	Total	Single vehicle	Junction	Overtake	Head-on	Shunt	None of above
Single vehicle	**183**	**183**	27	12	0	0	-
Junction	**187**	27	**187**	15	27	24	-
Overtake	**77**	12	15	**77**	21	7	-
Head-on	**117**	0	27	21	**117**	6	-
Shunt	**86**	0	24	7	6	**86**	-
None of above	**67**	-	-	-	-	-	**67**