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Development of Scotland's 2030 Road Safety Casualty Targets and Key Performance Indicators

Contents

Executive summary

The numbers of those killed or seriously injured on the road network in Great Britain have not reduced significantly in the last decade. Evidence from collisions reported to the police show that in the most recent five years (2014 – 2018) killed or seriously injured (KSI) casualties have increased by 2.9% compared to the preceding five year period. The picture in Scotland is better however, with a 16% reduction in the same period.

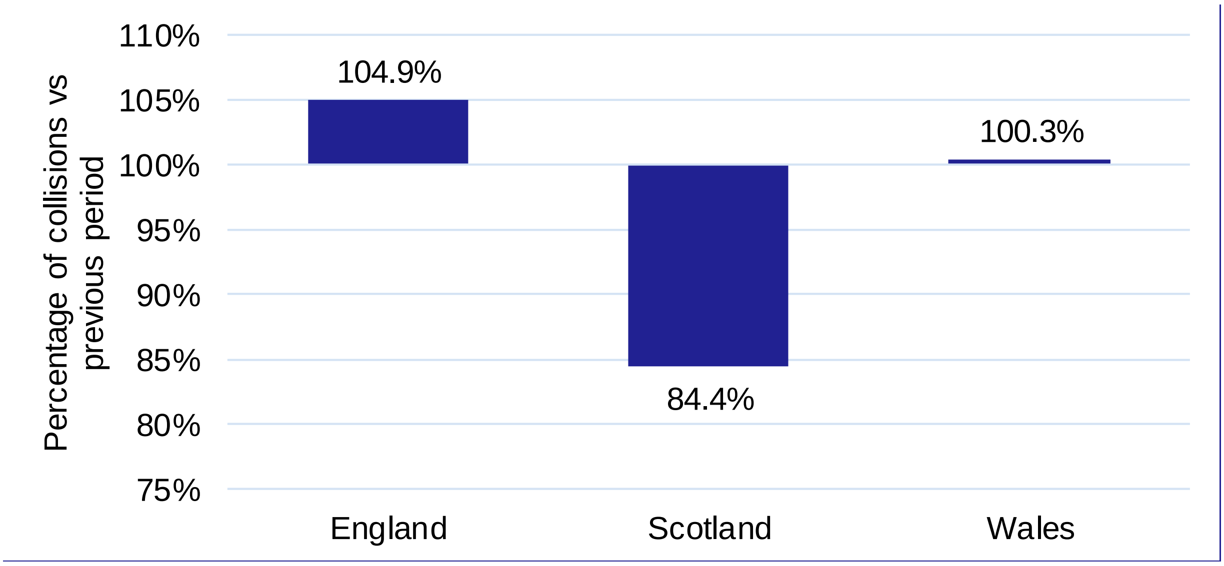


Figure 1 Change in Killed or Seriously Injured Casualties – 2009-2013 vs 2014-2018

Although the UK government has not chosen to set targets for road safety performance, including casualty reduction, the Scottish Government has adopted targets against defined baselines. The current targets to 2020 form part of the current road safety framework and include four separate measures focussing on fatal and seriously injured casualties.

The purpose of this study is to review and define new targets to the year 2030, using the evidence currently available. The four targets for consideration are:

- people killed
- people seriously injured
- children (aged <16) killed
- children (aged <16) seriously injured

This study carries out the modelling and prediction of casualty numbers, a review of interim casualty targets and potential key performance indicators (KPIs), the impact of external factors - notably vehicle safety improvements, and a final discussion of the evidence and provision of recommendations for Scotland's Road Safety Framework to 2030.

Forecasting casualty numbers

Simply taking previous performance and taking a straight-line prediction of trends through to 2030 would be a rather crude exercise, ignoring a wealth of information available to produce a better-informed forecast. The study has considered information from other models that forecast likely traffic levels, changes in vehicle use, population growth and a shift to demographic with a larger proportion of older people.

The first analysis considered how changes in traffic and vehicle use may result in changes to the number and type of road users injured in fatal and serious collisions on Scotland's roads. At the same time, models developed by the Department for Transport and Office for National Statistics were used to 'correct' for changes in the way injury severity is recorded by police officers.

The following baseline figure for killed and seriously injured casualties (adjusted for severity reporting changes) was established using the period 2014-2018, from which forecasts were made to the year 2030:

Reported killed, average per annum	172
Adjusted seriously injured, average per annum	2003

Traffic growth by vehicle type was taken from Transport Scotland forecasts for five groups of vehicles, including pedal cycles. This allowed for separate calculations to demonstrate which types of vehicle may become more or less involved in collisions in the next decade.

Forecasting the number of fatalities by class was not possible due to the small numbers in each cohort which made forecasting unreliable, although combined KSI figures were revealed. This initial analysis showed that, based on recent casualty performance and predicted traffic growth, pedal cyclists casualties as well as those in light goods vehicles were due to rise, with reductions in motorcycle casualties, pedestrians, cars and taxis, and other vehicles.

A similar approach was taken to the profiling of future casualties by age group, this time using a combination of predicted population changes, plus the traffic growth scenario. The population-only models produced slightly lower forecasts than the traffic-only models and the final outputs were scaled to ensure casualty forecasts matched for both road user groups and age groups.

All age groups, with the exception of the 65-74 and 85+ years old group showed a decrease against the baseline figures, before traffic growth was taken into account. There are stark differences in forecasted numbers for each age band with child casualties and those under the age of 25 much less likely to make up a significant proportion of killed or seriously injured casualty numbers.

An attempt was made to combine all of the datasets in an artificial neural network model to allow for a combination of factors in many dimensions. The results of this exercise are included in the report, although the outputs were not reliable enough to use in the final forecasts.

One final stage was required to take the modelled predictions and produce estimated of casualty numbers through to 2030, namely estimating the impact of planned road safety improvements on casualty numbers. Gradual improvements seen over the last decade, such as changes in vehicle safety, road infrastructure and road user behaviour will already have contributed to the model through the historic casualty figures.

If a step-change is made in one of these areas then it would be reasonable to expect that this would influence future casualty numbers beyond the improvement rates already seen. The introduction of new vehicle safety regulations by the European Union will significantly influence safety features for fitment in new vehicles from 2022 onwards. Technologies to avoid collisions, such as autonomous emergency braking, have a great potential to reduce the severity of injuries resulting from collisions, and may even stop the collision occurring altogether. This measure, along with over a dozen other vehicle improvements, were adopted based on a previous analysis of their potential benefit for reducing casualties.

This report takes the evidence submitted to the EU and estimates the impact improved vehicle safety will have on road user and casualty age groups in Scotland through to 2030. The impact will take several years to significantly influence casualty numbers due to the rate of new vehicles entering the fleet. By 2030 however, these improvements are anticipated to improve casualty reduction as follows:

Killed casualties	
Baseline	172
Forecast model in 2030	136
Forecast model plus vehicle improvements in 2030	109
Seriously injured casualties	
Baseline	2003
Forecast model in 2030	1459
Forecast model plus vehicle improvements in 2030	1255

Forecasts were provided for each age group and road user type, based on vehicle class, assuming a neutral impacts of these technologies across age groups and road user types. Based on these forecasts the following recommendations have been made for Scotland’s 2030 casualty reduction targets:

Target	Percent Reduction
People killed	40%
People seriously injured	40%
Children (aged <16) killed	100% (Vision Zero)
Children (aged <16) seriously injured	60%

Table 1 – Recommended casualty reduction targets for Scotland to 2030

The information provided on forecasted trends for individual groups will assist in prioritising future activities and an understanding of where the greatest capacity for casualty reduction beyond these forecasts lie. It should be noted here that the target for children killed in road accidents by 2030 has been set at zero. This vision is the first stage in achieving a long-term goal of no deaths or serious injuries on Scotland's roads.

Key Performance Indicators (KPI) and Intermediate Measures

In order to assess performance over the next decade it is essential to establish a performance management framework that reviews evidence surrounding road use, including behaviours that are known to lead to collisions and injuries. Further consideration was given to measures that may reduce collision involvement of young drivers, as well as those who drive for work.

Speed compliance is one of the key factors in predicting collision rates and as a part of this report compliance on different roads by vehicle class was reviewed. Across Great Britain compliance is poorest in 20mph limits, and although the sample size involved is small, in free-flowing conditions the vast majority of drivers do not stick to the limit. Compliance is best on national speed-limit rural roads. In considering a KPI for speeding it was decided that the length of roads be taken into consideration to assess where the greatest amount of non-compliance is to be experienced.

There is good evidence regarding seatbelt use and distraction due to hand-help mobile phones. It is essential that these behaviours are regularly monitored and appropriate action taken to improve compliance. Sober driving by avoiding drugs and alcohol is more difficult to assess independently without a truly random program of police checks. Using evidence from self-reported behaviour through surveys, as well as failure rates for roadside checks will help to guide understanding of this issue on Scotland's roads.

This report recommends KPIs for all of the above categories of speed, distraction, seatbelt use, drink driving and drug driving. Further consideration should be made of other KPIs which could reveal the overall safety levels of vehicles on the roads, road infrastructure safety ratings, emergency service response times, and safety schemes implemented for those who drive for work.

The matter of graduated driver licensing was also considered and modelled for young drivers in Scotland under a specific set of circumstances. The resulting analysis for Scotland showed that the introduction of a passenger restriction where no more than one 15-19 year old passenger would be allowed, unless accompanied by a 25+ year old, would result in 13 fewer KSI casualties per year.

A full set of intermediate progress measures has been produced for road user and casualty age groups which can be used to measure progress and compare future performance against the modelled predictions. Should future performance not match these estimates then further investigation would be warranted to evaluate the road safety scenarios present in the future.

Introduction

Transport Scotland Analytical Services have commissioned Agilysis Limited to carry out research to help inform measures to be used for Scotland's Road Safety Framework to 2030.

The task is split into two elements. Firstly, to recommend 2030 casualty targets for road casualties in Scotland including development of a methodology to project anticipated reductions across the three casualty severity categories within sub-population and road-user groups. Secondly, to recommend key performance indicators (KPIs) to help accurately monitor progress against the Road Safety Framework to 2030 outcomes.

These targets should be understood in the wider context of progress towards Scotland's long-term Safe System goal: eliminating death and serious injury on Scotland's roads by 2050.

The current targets to 2020 form part of the current framework[1] and include four separate measures focussing on fatal and seriously injured casualties as shown in *Table 2* below.

Target	Percent Reduction
People killed	40%
People seriously injured	55%
Children (aged <16) killed	50%
Children (aged <16) seriously injured	65%

Table 2 – 2020 Scottish Road Safety Targets

Reviewing progress to these targets is not within the scope of this research project, although it is noted that in Scotland and much of Europe, casualty reduction progress has slowed relative to that seen in the previous decade.

This report comprises four major sections; the modelling and prediction of casualty numbers through to 2030, the review of interim targets and KPIs, the impact of external factors, notable vehicle safety improvements, and a final discussion of the evidence and recommendations for the 2030 framework.

Before proceeding to the first report element it is worth outlining how the performance management elements of a road safety framework can be constructed. In *Figure 2* the long-term goal, or vision, is shown to be at the top of the pyramid representing a desire to achieve zero fatal or seriously injured casualties. On the path to this ambitious goal lie interim targets, such as the ones this report is considering. These align with the long-term goal, addressing fatal and seriously injured casualties, and setting defined targets along which progress can be measured as each target date approaches. Supporting and informing these targets

[1] https://www.transport.gov.scot/media/29622/j243698.pdf

lie a number of metrics that either detail casualty progress (intermediate measures) or assess safety improvements as assessed for roads, road users or vehicles (KPIs). It is possible to further measure outputs, such as number of breath-tests carried out, and we will consider the usefulness of output measures later in the report. All of these can be used in combination to assess progress and impact as the journey to 2030 continues.

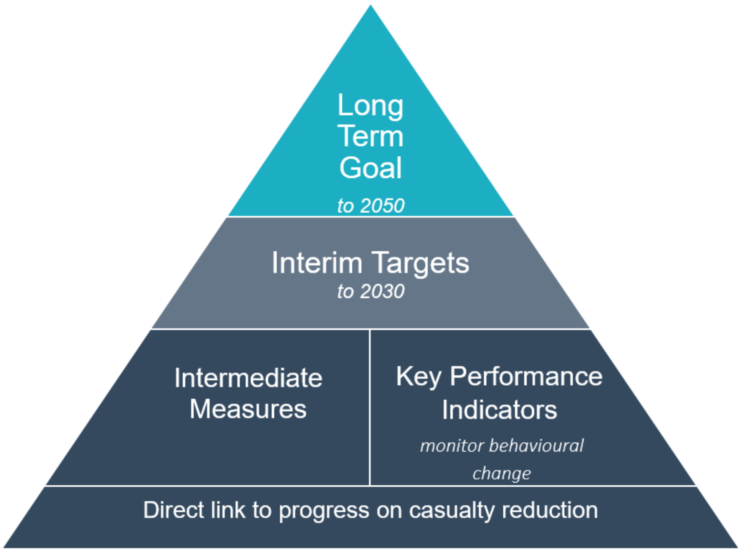


Figure 2 – Illustration of the key elements of the performance management element of a road safety framework

Forecasting casualty numbers

The aforementioned 2020 casualty reductions targets were informed by research undertaken by TRL[2]. This used an established statistical approach developed in the late-1990s to help the UK Government to set national casualty reduction targets for the year 2010[3]. A review of the methodology[4] in 2008 showed that most of these original forecasts had proved sufficiently reliable. Road safety trends to 2019 are not however exhibiting continued, reliable reductions and we will consider how this may influence predictions to 2030.

One key element of the Broughton et al methodology is the inclusion of an estimation of safety improvements. These so called DESS measures (Drink/driving, Engineering, Secondary Safety) were chosen as their influence on future safety performance could be reliably estimated. Twenty years on from this original assessment we know much more about the potential influence of individual safety measures, most notably following the release of research by TRL for the European Commission[5].

As a result of this our approach to forecasting casualty numbers is following a two-stage approach: firstly, to use known and modelled data for changes to traffic and populations; and secondly to consider the individual impact of the EU General Safety and Pedestrian Safety Regulations. This will allow Transport Scotland to consider the likely reductions, should no safety improvements be implemented, and how the forecasts could be adapted to ambitious targets by improving safety levels of vehicles.

Advances in statistical techniques, notably in the field of machine learning, allow researchers to use new approaches to understanding relationships in large, complicated datasets. We have chosen to explore the usefulness of this new approach, alongside an adapted version of the Broughton et al methodology and will present the results separately within this section of the report. We will return to the options for inclusion within the Framework to 2030 in the discussion section.

Data sources

The data used in this report was gathered from multiple sources.

Transport Scotland's LATIS (Land-use And Transport Integration in Scotland) service has provided both historic data and forecasts[6]. Modelled data from three

[2] Casualty forecasts for Scotland for the year 2020, TRL, J Broughton 2009
[3] Broughton J, Allsop R E, Lynam D A and McMahon C M (2000). The numerical context for setting national casualty reduction targets. TRL Report TRL382. Wokingham: TRL.
[4] Broughton J and Buckle G (2008). Monitoring progress towards the 2010 casualty reduction target – 2006 data. TRL Report TRL668. Wokingham: TRL.
[5] Cost-effectiveness analysis of Policy Options for the mandatory implementation of different sets of vehicle safety measures – Review of the General Safety and Pedestrian Safety Regulations Technical Annex to GSR2 report SI2.733025. M Seidl, R Khatry, J Carroll, D Hynd, C Wallbank, and J Kent (TRL Ltd.) March – 2018
[6] http://transport.gov.scot/latis

different scenarios developed by LATIS (the Primary scenario, and Low and High population and economic growth scenarios) were used. Data was accessed by TELMoS (Transport, Economic and Land-use Model of Scotland) zone[7] or region and aggregated as necessary. Metrics used included:

- population by age and employment status, by TELMoS zone
- car ownership by TELMoS zone
- congestion, road distance and delay times by TELMoS region

Observed traffic data used for the development of the Transport Model for Scotland (TMfS) provided detailed historic data at road link level. Metrics used included:

Traffic flow in passenger car units, by vehicle type and journey purpose

- average vehicle speeds
- link capacity
- rurality

STATS19 collision and casualty data from Transport Scotland provided historic road safety data. Collisions were matched spatially to LATIS TELMoS zones based on grid reference. The following metrics were derived:

Casualty home location and deprivation (spatially matched on population weighted centroid of postcode)

Casualties resulting from specific collision types, including shunts and vulnerable road users struck by motor vehicles, by vehicle type (derived analytically)

Historic STATS19 severity data was adjusted in line with record level estimates published by the Department for Transport and the Office of National Statistics and matched in MAST Online[8]. This adjustment was made to account for likely increases in casualties recorded as seriously injured, as a result of Police Scotland's adoption of the CRaSH system which uses injury-based reporting. The section titled 'NRS single age population data' briefly explains why we are using severity-adjusted data in this analysis.

[7] 'Zones' are areas smaller than traditional local authority districts that are used for more granular analysis
[8] MAST Online is a web data portal which connects STATS19 collision and casualty data provided by DfT and Transport Scotland to other data sets and exposes it for analysis See https://roadsafetyanalysis.org/mast-online/ for details.

NRS single age population data[9]

The systems for collecting statistics about road casualties has been well-established for many years and even though these systems are managed by individual police forces the level of consistency has traditionally be considered suitable for inclusion in national statistics. However, the introduction of Injury Based Reporting Systems (IBRS) appears to have led to a change in the reported severity of road casualties. This can be explained by the change of reporting systems from Non-Injury-Based Reporting Systems (NIBRS), where judgment of the casualty severity is made by the reporting police officer, to IBRS, where the severity of the injury is determined automatically from the most severe type of injury suffered. It appears that some casualties that would have been categorised as 'slight' on NIBRS are recorded as 'serious' in IBRS. This became apparent from initial analysis of high level data suggesting that switching to CRaSH and COPA added between 5 and 15% to the Great Britain total for 'serious' injuries[12].

The Office for National Statistics (ONS) Methodology Advisory Service have completed analysis to quantify the effect of the introduction of new injury based reporting systems (CRaSH and COPA) on the number of slight and serious injuries reported to the police, and to estimate the level of slight and serious injuries as if all police forces were using injury-based reporting systems. The Department for Transport have now used this methodology and calculated estimated injury severities at record-level which is published in the open dataset[10]. Although there is a caveat regarding the use of user or age-level analysis in small areas, we consider this to be appropriate for this exercise covering the whole of Scotland.

Scotland has adopted the CRASH system in 2019 which means that future severity reporting is likely to be higher, hence the need to use adjusted pre-2019 data in projecting future casualty numbers.

For this report and the associated analysis, we will use data from 2009 to 2018 to model trend. Adjusted figures will be used for serious casualties and a five-year baseline between 2014 and 2018 is used as the benchmark for the casualty reduction targets.

Table 3 shows the figures for killed and serious casualties together with the adjusted serious numbers and also includes Reported Road Casualties Scotland (RRCS) figures for comparison. Casualty reductions will be estimated in terms of percentages which can then be applied to the RRCS data at a later stage. Similar tables will be produced later in the report for other road user groups and casualty ages. The baseline average for fatal casualties is therefore 172 and for serious casualties 2,003. The KSI casualty baseline is 2,175. Because adjusted casualty figures based on RRCGB are used for serious and KSI casualties throughout this

[9] https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/population/population-estimates/mid-year-population-estimates/population-estimates-time-series-data

[10] https://data.gov.uk/dataset/cb7ae6f0-4be6-4935-9277-47e5ce24a11f/road-safety-data

document, killed casualty figures published in RRCGB rather than RRCS have also been used for consistency's sake. The underlying adjusted figures are probability calculations rounded to integers for convenience of presentation. This may result in small apparent discrepancies due to rounding errors.

	Reported RRCS Killed	Reported RCGB Killed	Reported RRCS Serious	Adjusted RCGB Serious	Adjusted RCGB KSI
2014	203	200	1,701	2,111	2,311
2015	168	162	1,602	2,006	2,168
2016	191	191	1,697	2,091	2,282
2017	145	146	1,594	1,925	2,071
2018	161	160	1,582	1,883	2,043
Baseline		*172*		*2,003*	*2,175*

Table 3 – Baseline data for the period 2014 – 2018

Methodology 1 – Regression Model

Our initial approach adapts that of Broughton et al to provide a baseline projection of casualty numbers to 2030. This approach assumes that the rate of casualties per vehicle kilometre of traffic decays exponentially over time. In the previous analysis for Transport Scotland, this was undertaken separately for five classes of casualty:

- car occupants
- motorcyclists
- pedestrians
- pedal cyclists
- others

In the previous analysis, traffic exposure for car occupant casualties was taken as vehicle kilometres travelled by cars; exposure for motorcyclists was taken as vehicle kilometres travelled by motorcycles; and exposure was taken as vehicle kilometres travelled by all motor vehicles for the remaining three casualty classes.

As more granular flow data was available to us, our version of this methodology used vehicle kilometres travelled by pedal cycles as exposure for pedal cyclist casualties, and vehicle kilometres travelled by the remaining vehicle types was used as exposure for other casualties. Furthermore, small goods vehicles under 3 tonnes mgw (SGV) occupants were introduced as a sixth casualty class, separate from other casualties, and SGV traffic was separated from other traffic for use as exposure. The decision to use this naming convention rather than 'Light Goods Vehicle (LGV) avoids confusion with "Large Goods Vehicle".

Traffic data was taken from the Department for Transport Road Traffic Statistics[11] from 2009 to 2018, whilst casualty data was taken from the Great Britain version of the STATS19 dataset over the same 10-year period. The decision to use this, instead of the official Scottish collision dataset, was made to allow the use of severity adjusted numbers[12] for casualties that were seriously injured.

Projected traffic data was provided by the TMfS14[13] model, part of the LATIS dataset, which has future traffic flows for three scenarios: the Primary Scenario; the High Population/Higher Economic Growth/Low Fuel Scenario; and the Low Population/Lower Economic Growth/High Fuel Scenario. These are explained further in *Box 1*.

This report focusses on the Primary Scenario which includes figures for population growth, economic success and crucially an increase in vehicle miles travelled by 37% to 2037. Increasing vehicle miles travelled results in increased exposure to the possibility of a collision taking place, hence its importance for this work.

There are three projections into the future for each model. As the TMfS14 data did not have projected vehicle traffic broken down to the same granularity as the DfT Road Traffic Statistics, the modal breakdown of projected traffic flow was modelled using historic DfT traffic data. It was assumed that, for each vehicle type (cars and taxis, two wheeled motor vehicles, LGVs, pedal cycles, and other vehicles), proportional traffic flow would continue with the same exponential growth or decay as seen between 2009 and 2018. *Figure 3* below illustrates this historic data provided for Scotland.

Box 1 Traffic Forecasts and Alternative Scenarios

The Primary Scenario assumes certain trends in the period 2014 to 2037, notably a 37% increase in vehicle miles. There are separate predictions for cars, good vehicles, and bus travel.

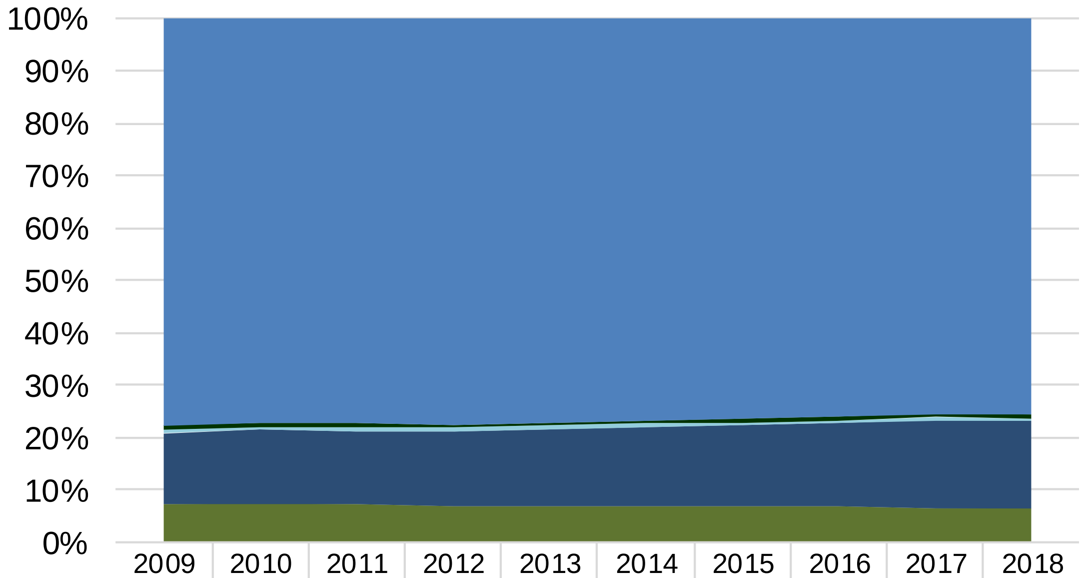
The alternative scenarios allow for difference in population growth (+3.8% to +12.3%), economic growth (+38% to +73%), and fuel prices (+56% to -2%).

The impact on vehicle miles, which is the key consideration in this report, is a variance in growth of between 26 and 51 percent.

[11] https://roadtraffic.dft.gov.uk/regions/3

[12] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/833813/annex-update-severity-adjustments-methodology.pdf

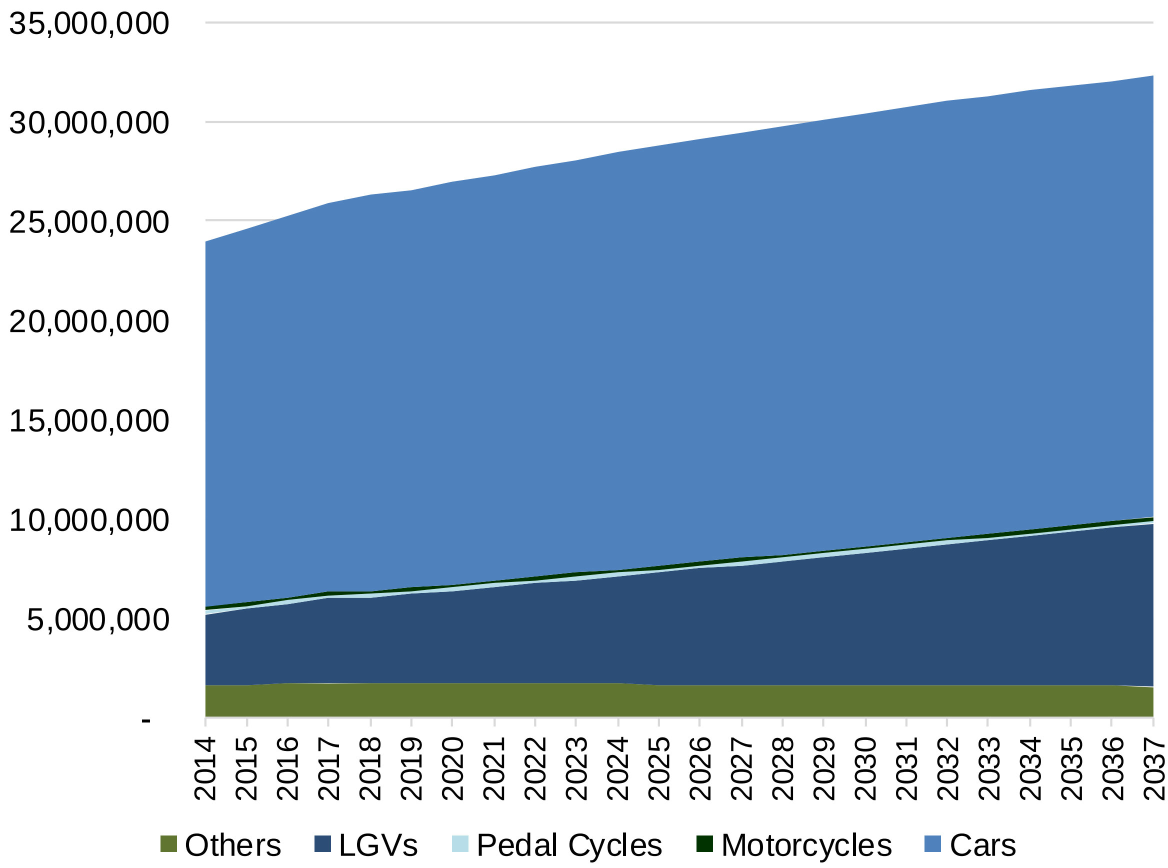
[13] https://www.transport.gov.scot/our-approach/industry-guidance/land-use-and-transport-integrations-in-scotland-latis/#42984



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cars	78.3%	77.8%	77.9%	78.1%	77.7%	77.4%	77.0%	76.5%	75.9%	76.1%
Motorcycles	0.73%	0.67%	0.68%	0.67%	0.66%	0.67%	0.65%	0.63%	0.64%	0.64%
Pedal Cycles	0.65%	0.69%	0.71%	0.72%	0.76%	0.83%	0.76%	0.62%	0.61%	0.65%
LGVs	13.7%	14.1%	14.2%	14.2%	14.5%	15.0%	15.5%	16.1%	16.8%	16.7%
Others	7.27%	7.41%	7.17%	7.06%	7.11%	6.93%	6.87%	6.72%	6.66%	6.49%

Figure 3 – Proportional traffic flow by vehicle type from TMfS14 data

This proportional flow was then used to break the TMfS14 projected flow data down by vehicle type. *Figure 4* below shows this projected flow by vehicle type for the Primary scenario. The charts for the other two scenarios are provided in the appendix as *Figure 33.*



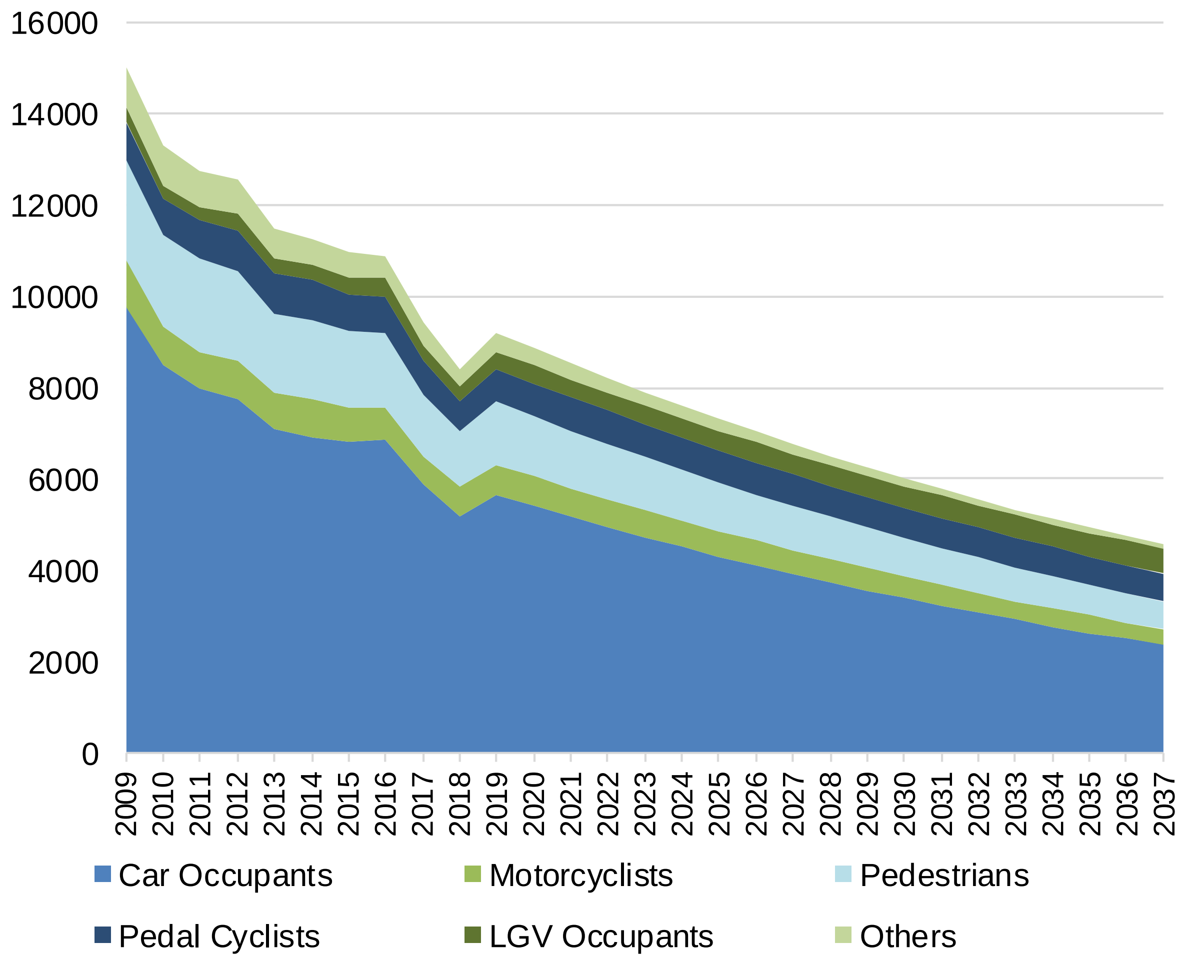
	2020	2025	2030
Cars	20,441,498	21,153,137	21,812,272
LGVs	4,689,424	5,616,861	6,632,502
Pedal Cycles	172,262	176,437	178,155
Motorcycles	167,697	167,735	165,398
Others	1,691,320	1,683,871	1,652,727

Figure 4 – Forecasted traffic growth in Scotland using the primary scenario

Two separate models were created: one for all casualties, regardless of severity; and one for casualties that were killed or seriously injured (KSI). The detailed explanation and notation for these models are included in section 1 of the appendix.

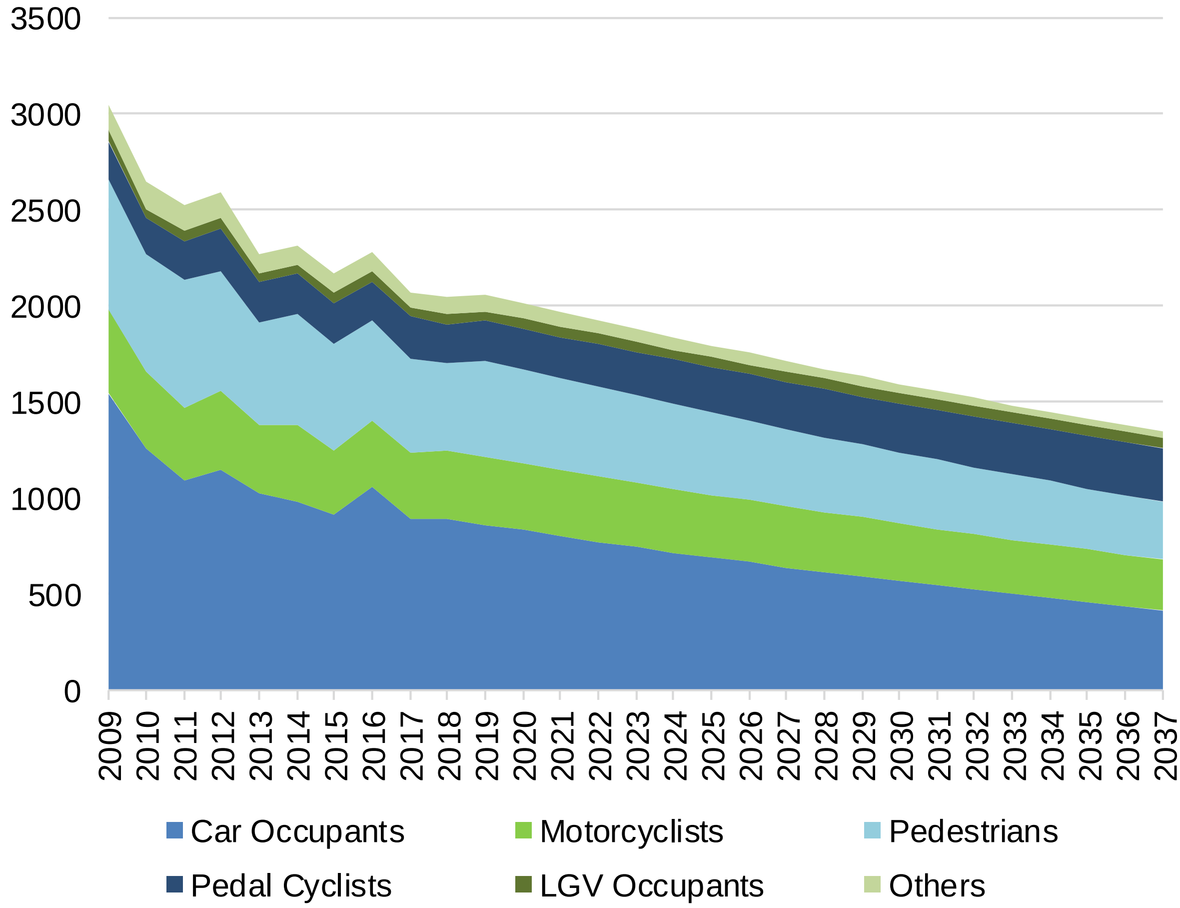
Although there is not a desire to include a target of all casualties, it has been modelled to allow us to review the reliability of the model with a larger dataset. It also allows figures for the three individual severity classifications to be pulled out. This is particularly useful in light of the number of casualties recorded as slight which have been statistically adjusted to serious for reasons described in 0 above.

Figure 5 below, and *Figure 34* in the appendix show the resulting projections for primary flow scenario and the other two from models for all casualties. *Figure 6* repeats this for KSI casualties with the two alternative flow projection analyses included as *Figure 35* in the appendix.



	2020	2025	2030
Car Occupants	5,401	4,311	3,392
Motorcyclists	645	549	460
Pedestrians	1,321	1,064	848
Pedal Cyclists	731	706	672
LGV Occupants	387	432	475
Others	363	244	162

Figure 5 – Primary flow scenario for all casualties to 2037



	2020	2025	2030
Car Occupants	803	664	542
Motorcyclists	346	324	299
Pedestrians	471	414	360
Pedal Cyclists	221	241	260
LGV Occupants	52	53	53
Others	74	58	45

Figure 6 – Primary flow scenario for KSI casualties to 2037

A more basic model was used to project fatality numbers up to 2037, where all fatalities were treated as a single class of casualty with all vehicle flow as exposure. This simplified model was used for projecting fatalities as the number of killed casualties became too small to provide reliable trends once subdivided further. This is something found consistently throughout this report. *Figure 7* illustrates this issue. The predictions for road user groups with larger numbers e.g. car occupants, works well, but as 'others' constituted a small but growing number of fatalities, the exponential trend fit to this small amount of data grew to large projected values very quickly.

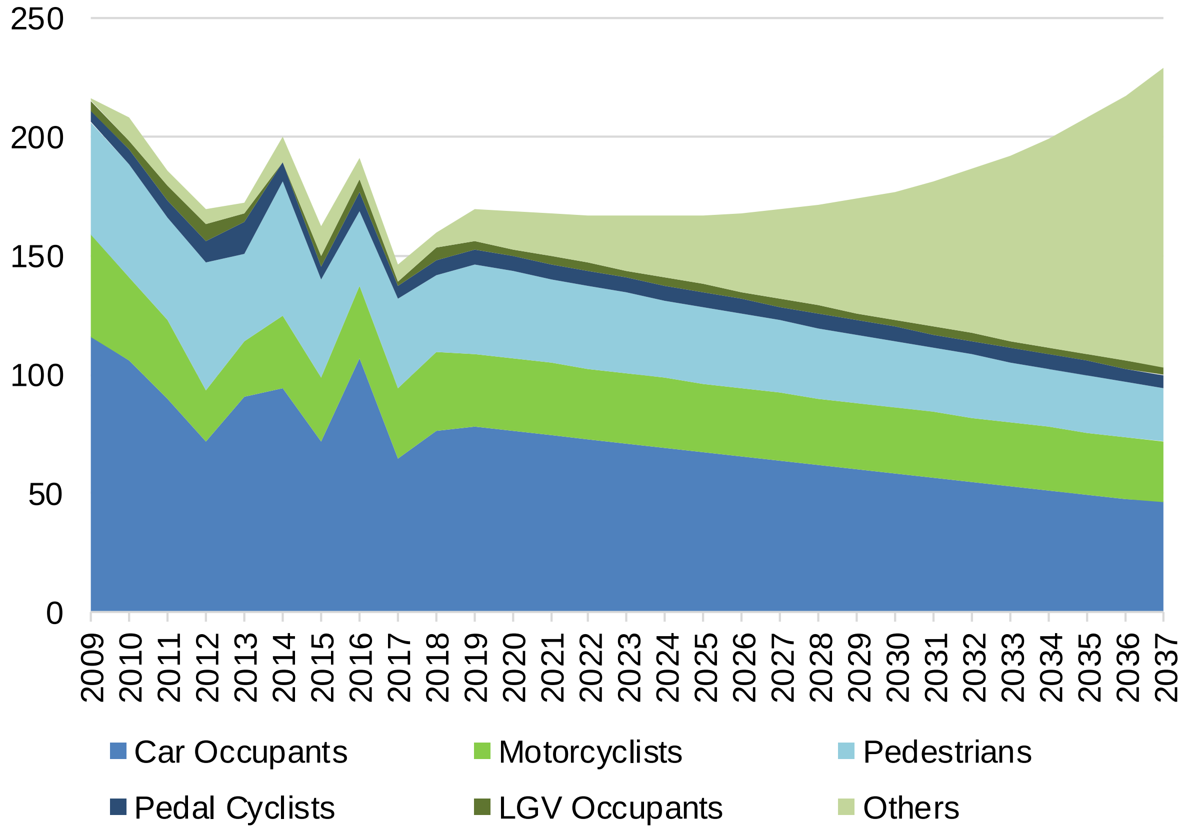


Figure 7 – Primary flow scenario for killed casualties, by road user group, to 2037

The charts and tables showing the projections resulting from the simple model for the primary flow scenario is included as *Figure 8*. The charts for the other two flow scenarios can be found in the appendix as *Figure 36.*

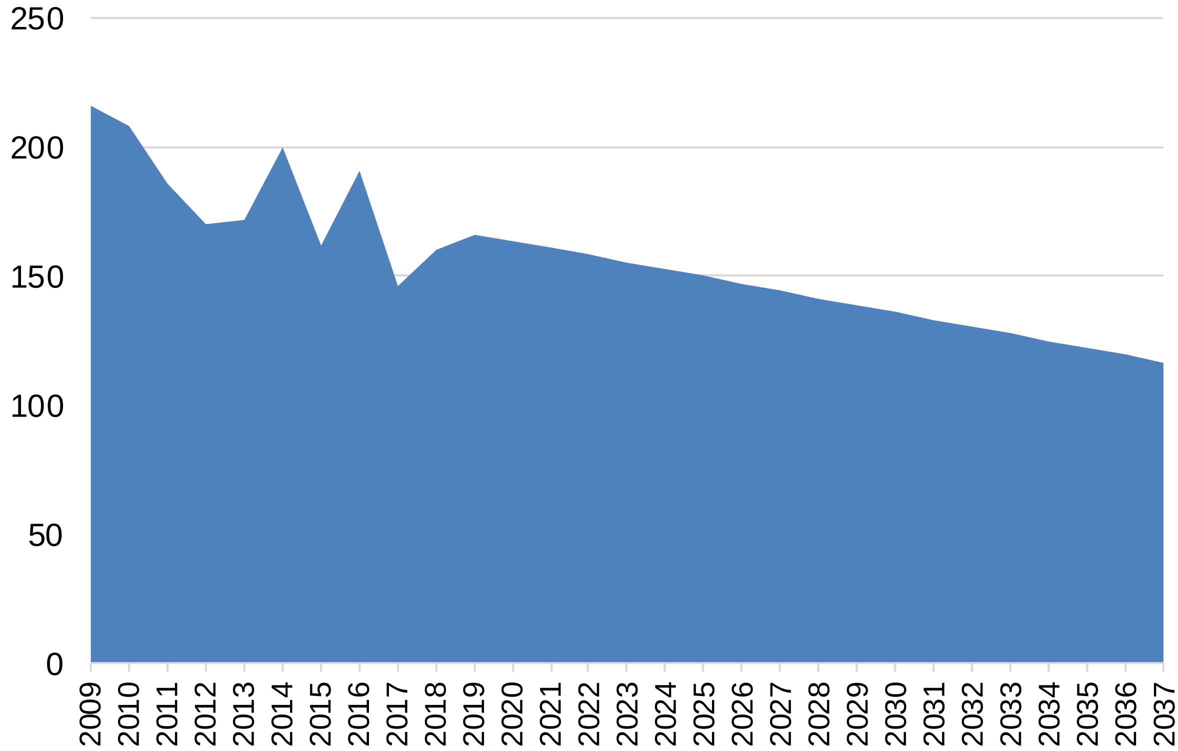


Figure 8 – Primary flow scenario for killed casualties to 2037

The results based on flow changes within the individual vehicle types plus pedestrians (road user types) indicate a probable 20.8 percent reduction in fatal casualties (136 in 2030) and 27.2 percent reduction in serious casualties. We also modelled slight casualties which are expected to fall by 43.7% to 2030. These results are illustrated in *Table 4*.

	Killed	Serious (adj.)	Slight (adj.)
Baseline	172	2,003	7,839
2030	136	1,459	4,414
Reduction	20.8%	27.2%	43.7%

Table 4 – Casualty forecasts to 2030 for all road user severities using the primary flow scenario

The primary scenario for traffic flow uses central estimates of population changes, economic growth, and fuel prices. The two 'High' and 'Low' estimates are based on the extreme combinations of these three factors. This means that overall casualty projections would vary by -7.23% or +7.16% compared to the Primary Scenario. These variations and the resulting changes in casualty projections are shown as *Table 5*. When compared to the five-year baseline this would mean casualty reduction projections varying between 15 and 27 percent for fatalities, and 22 to 32 percent for serious casualties.

	Low Pop/Lower Econ Growth/High Fuel	Primary Scenario	High Pop/Higher Econ Growth/Low Fuel
Killed	126	136	146
Serious	1,354	1,459	1,564

Table 5 – Alternative casualty forecasts to 2030 for all road user Killed and Serious severities using the High and Low scenarios

As the model for KSI casualties includes figures for different road user casualty groups it is possible to examine how trends are expected to change and where variation may occur. It has not been possible to carry this out for killed casualties on their own, hence the decision to model KSI casualties in this instance.

There is a predicted increase in pedal cycle casualties which reflects both the recent trend in bicycle trips and casualty number, plus projected growth. The model does not take into account the potential benefit of 'safety in numbers' which explains that as cyclist densities increase, collision rates fall i.e. cycling becomes safer per mile travelled. It also does not take into account any plans for increased segregation of motorised traffic and cyclists.

Year	Cars and Taxis	Pedestrians	TWMV	Pedal Cycles	Other Vehicles	LGVs
Baseline	948	524	354	206	93	50
2030	565	370	304	256	47	53
Change	-40%	-29%	-14%	25%	-49%	5%

Table 6 – Variation in predicted KSI casualty reductions for different road user casualty groups to 2030

Child casualties

In addition, a model was created using a similar methodology to project the number of child casualties that were killed or seriously injured. This model used three classes of casualty: vehicle occupants; pedestrians; and pedal cyclists. The exposure used for vehicle occupants was traffic flow of all motor vehicles, and hence excluded pedal cycle flow, whilst the exposure for pedestrians was the traffic flow of all vehicles, including pedal cyclists.

Figure 9 shows the projections resulting from this model for the primary scenario. The charts for the other two scenarios are provided in the appendix as *Figure 37*. Due to the difficulty in modelling small numbers we have not separated out child fatalities. In the baseline period there were 6 child fatalities per year (29 in five years) and 192 adjusted serious casualties per year (775 reported in five years, plus a total adjustment of 186).

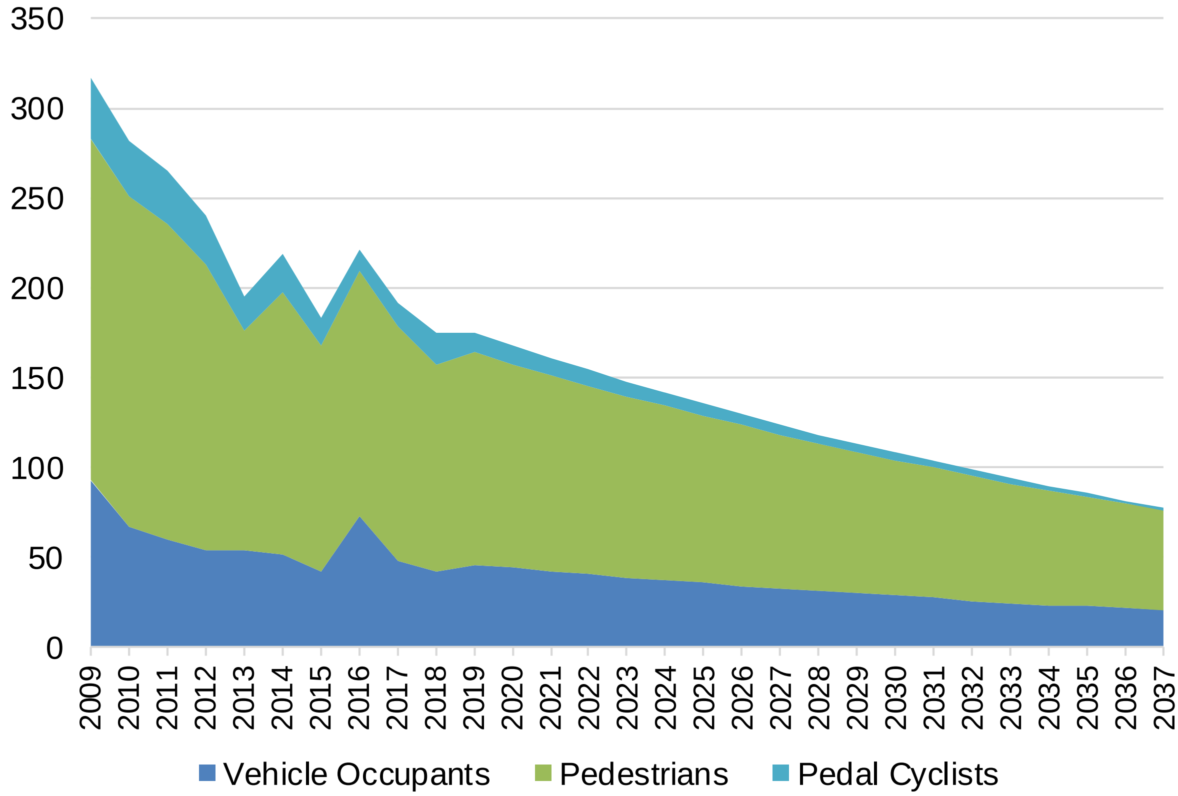


Figure 9 – Primary flow scenario for child KSI casualties to 2037

Projected casualty reductions for child KSI casualties are better than for all ages of road user with the primary scenario delivering a 46% reduction against the five-year baseline. Variance with the High and Low models is between 42 and 49 percent respectively, as seen in *Table 7*.

	Low Pop/Lower Econ Growth/High Fuel	Primary Scenario	High Pop/Higher Econ Growth/Low Fuel
Baseline	198	198	198
2030	100	108	116

Table 7 – Modelled child KSI casualties to 2030 and five-year baselines for three flow scenarios

Population age-band analysis

Although population growth is taken into account in the projected traffic flow data that influences the base model above, it does not directly impact casualty projections. Neither does it reflect expected changes in age group populations. It is expected that with an aging population, those at-risk proportions will change by 2030. In order to account for this, a similar methodology to the flow-based approach was applied that relies more heavily on population data. It is assumed that casualty rates per population count also decay exponentially over time. The notation is included in section 1 of the appendix.

National Records of Scotland (NRS) Population Estimates Data, whilst projected population data was taken from the NRS Population Projections Data.

It is worth noting here that although casualties have been matched to the age profile of Scotland's residents, it does not account for casualties from elsewhere which may have a different age profile. Analysis of casualty residency from MAST Online[14] indicates that in the baseline period 5.5% of killed casualties were from outside Scotland and this was also the case for 3.8% of seriously injured casualties.

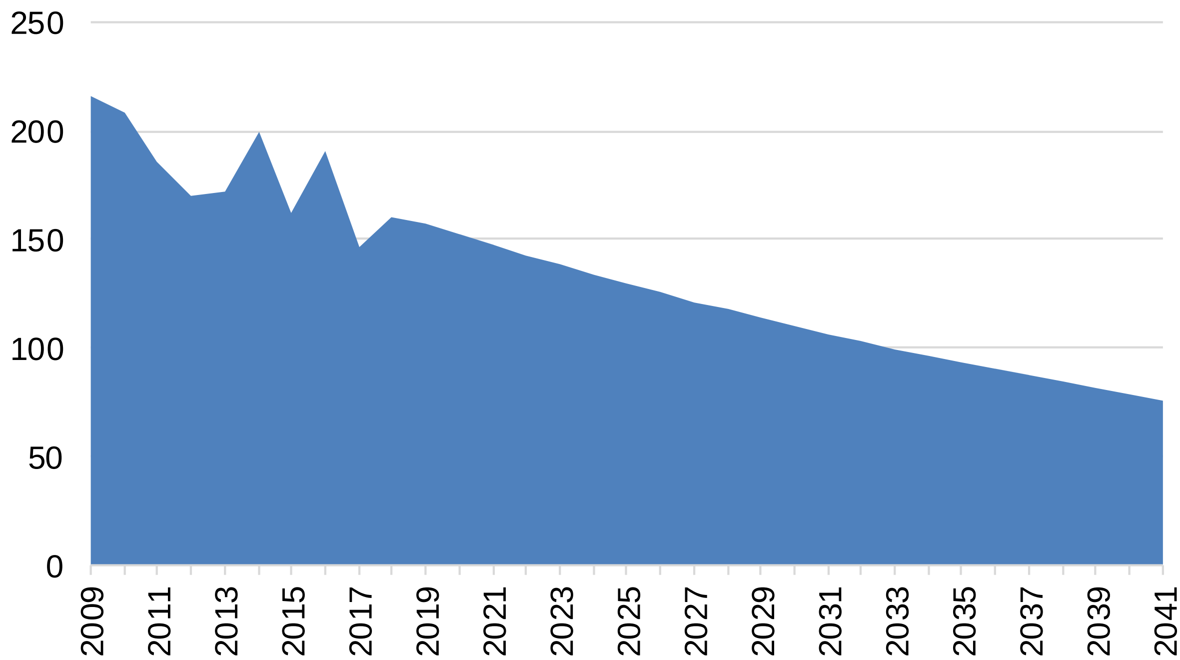


Figure 10 – Killed casualties using the population model projected to 2041

[14] https://roadsafetyanalysis.org/

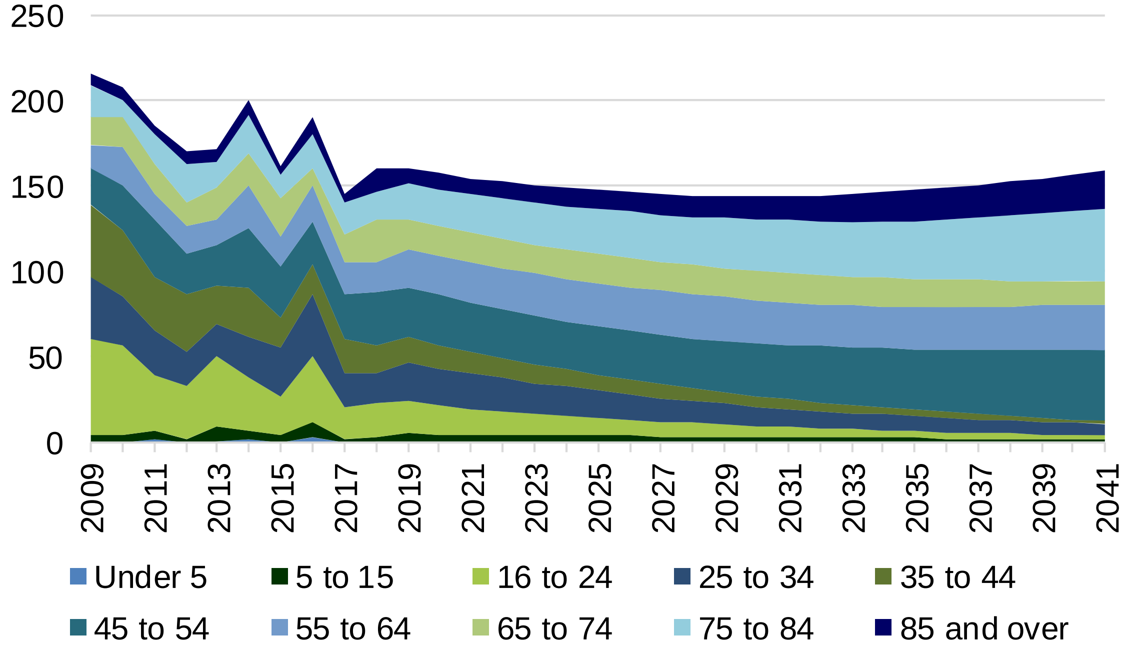


Figure 11 – Killed casualties by age band projected to 2041

As for the traffic projections, models were created for all casualties (*Figure 12*), KSI casualties (*Figure 13*), and killed casualties (*Figure 10*). As with the road-user fatality analysis, breaking down age groups within the model does not produce a reliable output. This report will not therefore consider fatality trends within age groups and will instead focus on the KSI casualty projections.

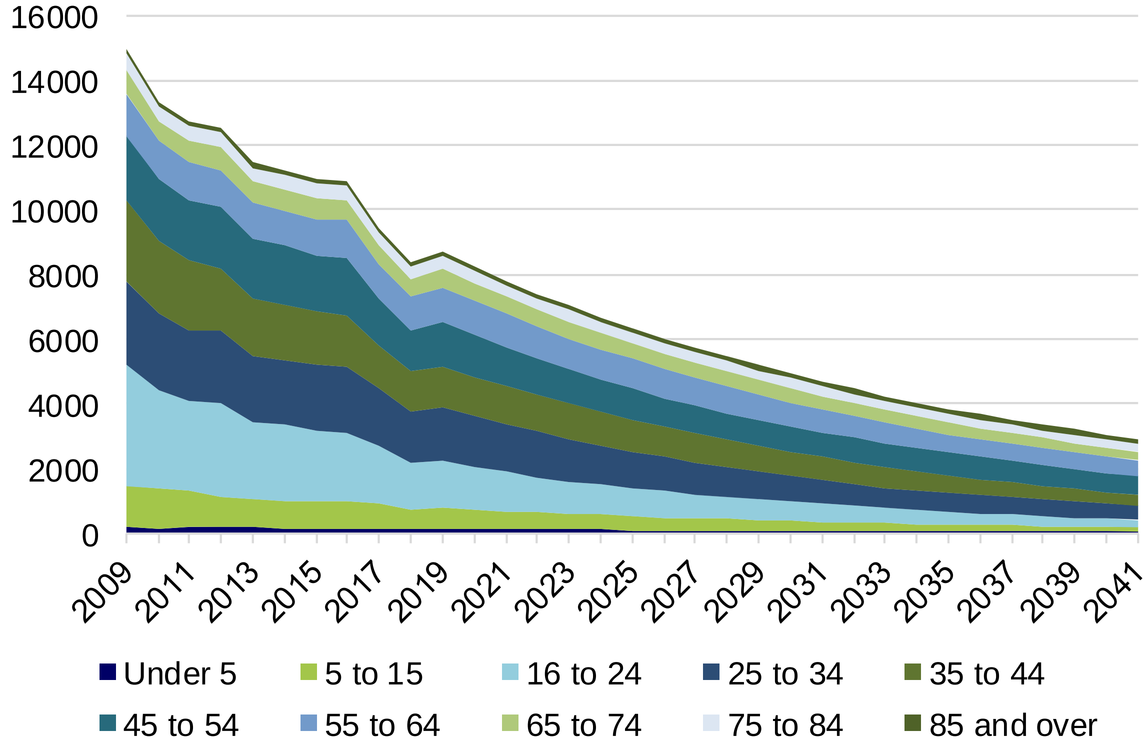


Figure 12 – All casualties by age band projected to 2041

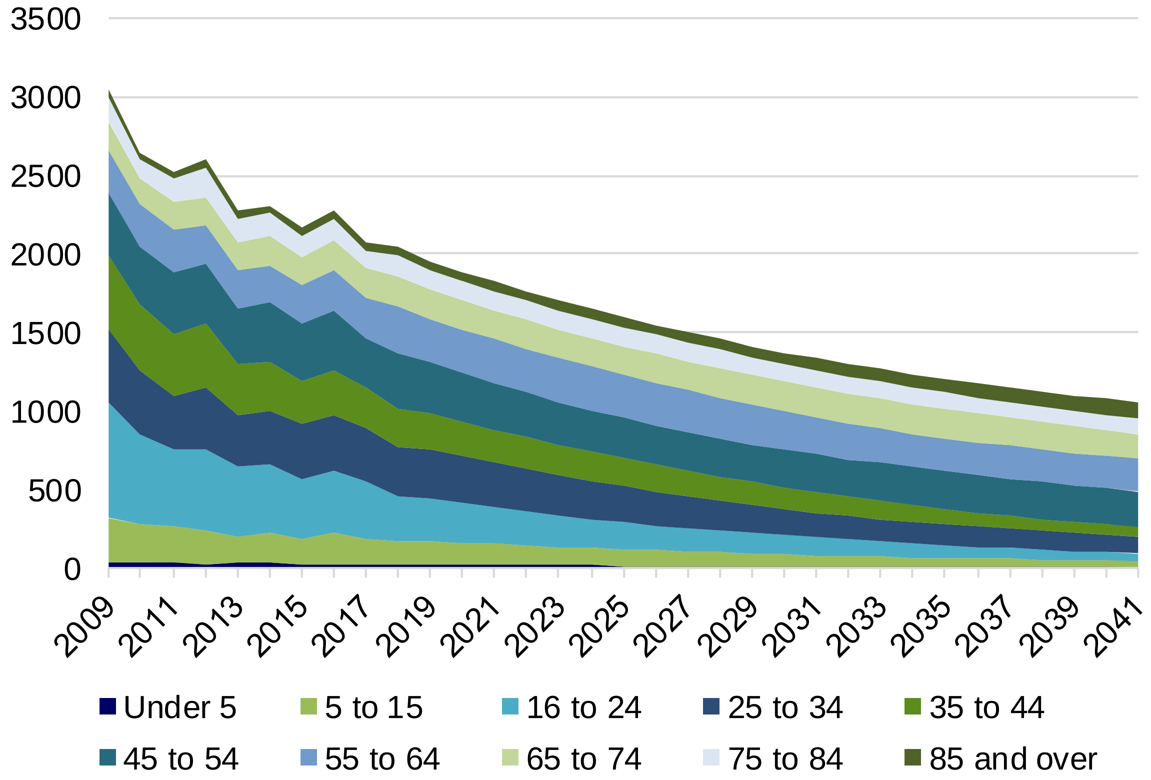


Figure 13 – KSI casualties by age band projected to 2041

The overall casualty reductions using this model are slightly greater than those predicted using the primary flow model. A comparison is shown in Table 8 for each of the three injury severities. The largest variance is for fatalities which are predicted to be 110 using population-only data, versus 136 when increased traffic flow is taken into consideration (19% difference). Serious casualties are predicted to be 1263 versus 1459 in the flow model (13% difference).

	Killed	Serious (adj)	Slight (adj)
Baseline	171.8	2,003	7,839
Primary Flow Model	136	1,459	4,415
Reduction	20.8%	32.9%	43.7%
Population Model	110	1,263	3,672
Reduction	35.9%	37%	53.2%

Table 8 – Modelled casualty reductions using flow and population models against baseline casualty figures

As with road user casualty groups it is then possible to review where casualty numbers may vary in the future between the different age groups. This exercise can only be calculated for KSI casualties and is therefore an indication, rather than a specific target. *Table 9* illustrates the changes visible in *Figure 13* and compares them to the five-year baseline KSI casualties for each age band. These projections do not take account of any changes in traffic flow and assume only demographic change. Nevertheless, they do illustrate clearly the expected reductions in younger age groups alongside a slight rise for those over 65 years of age (+1.3%).

	Baseline	2030	Change
Under 5	24	11	-56%
5 to 15	173	76	-56%
16 to 24	371	121	-67%
25 to 34	343	167	-51%
35 to 44	272	138	-49%
45 to 54	360	241	-33%
55 to 64	259	243	-6%
65 to 74	185	190	2%
75 to 84	135	116	-14%
85 and over	51	70	37%

Table 9 – Modelled casualty reductions using population age bands versus baseline casualty figures

Alongside the primary projections, a series of variant population projections were published in the NRS Projected Population of Scotland[15] for the following scenarios: high fertility; high migration; high life expectancy; low fertility; low migration; low life expectancy; high population; low population; and natural change only. Using this data, a variety of casualty projections have been made, which are displayed in the appendix as *Figure 38*. Variance is relatively low compared to the changes expected at the extreme ends of the flow modelling with estimates varying between 96.7% (Low Population) and 103.3% (High Population) of the primary projection. As such we have not included a separate analysis of these and their impacts on casualty predictions in any detail.

Methodology 2 – Artificial Neural Network

The original TRL methodology from Broughton et al assumes that the coefficient $\boldsymbol{\alpha}$ depends only on the chosen casualty class. As a result, the casualty forecasts depend only the historic casualty numbers and the volume of traffic, both historic and projected. Although projected traffic data does take a lot of other variables such as fuel prices, economic growth and population change into account, it would greatly enhance the methodology to allow for the inclusion of additional trend data that will undoubtedly impact on the future trends in casualty rates.

Several attempts were made to model the function $\boldsymbol{\alpha}$ by fitting an artificial neural network to both contextual and historic trend data. An artificial neural network (ANN)

[15] https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/population/population-projections/population-projections-scotland/2016-based/variant-projections

is a series of stacked layers, each built from a network of artificial neurons. Using a combination of linear transformations of the input data and non-linear perturbations of the data, they are theoretically capable of approximating any sufficiently smooth function to any degree of accuracy. Given a set of training input data and known output data, a sophisticated back-propagation algorithm efficiently fits the neural network as closely as possible to the given data. However, the successful approximation of a function such as $\boldsymbol{\alpha}$ using a neural network relies on two things. Firstly, it requires that such a function exists. That is, we need to assume a priori that it is possible to accurately predict the values of $\boldsymbol{\alpha}$ using the variables in the input data alone. Secondly, it requires that both the input data and known output data are accurate and reflective of the situation which is being modelled.

The full details of this work are included in section 2 of the appendix. Due to the failure to reliably predict $\boldsymbol{\alpha}$ we are not able to produce casualty predictions using the ANN technique and the results cannot be used further in this report.

Key Performance Indicators and Intermediate Measures

Within the original ITT document mention was given to the following KPIs:

- speed
- vulnerable road users (pedestrians, cyclists and motorcyclists)
- age (pre-drivers, drivers aged between 17-25 and older drivers)

There was also a request to consider what other KPIs may be appropriate. Following consultation with Transport Scotland a decision was made to split the review of KPIs into two sections:

- Intermediate Measures: Tracking performance of casualty figures for specific user groups using the STATS19 dataset e.g. *17-25 year old drivers killed or seriously injured in a collisions.*
- Key Performance Indicators: Alternative measures of observed road safety behaviours, the quality of vehicles, and road infrastructure e.g. *percentage of drivers complying with the speed limit.*

Intermediate Measures are useful for monitoring progress against a casualty reduction target as they allow variances in specific groups to be monitored, notably if they are a key priority or at-risk group. These would normally relate to casualties associated with specific vehicle types or pedestrians, and to the age of the casualty. There will be some overlap between individual Intermediate Measures.

KPIs are to be defined as evidence pointing toward the intrinsic level of safety within the system and are always aligned to a *safe system* approach. Compliant motorists using vehicles with good occupant protection and active safety features travelling on high-quality roads is the key to a successful safe system.

Intermediate measures

The intermediate measures considered as a part of this project are related to groups traditionally known to be at higher risk of death or serious injury, or those that are more vulnerable. This includes the following age bands:

- 0 – 15 years old
- 16 – 25 years old
- 65 years old and greater

These age bands correspond to all casualties, not just driver or vehicle occupants. It may be desirable to only measure *drivers* in the *17-25* years old category. The starting age band for older road users has historically been aligned to the retirement age, although it could easily be changed to match the age at which driving license renewal is required (70).

The remaining at-risk groups will overlap age bands and relate to modes of transport including:

- pedestrians
- cyclists (including pedal cycle pillion passenger casualties)
- motorcyclists (Two Wheeled Motor Vehicles abbreviated to TWMV, including pillion passenger casualties)

Casualty numbers can be calculated as a rate using either population data or vehicle traffic / distance walked. For the purpose of this study we use the appropriate calculations from the regression model in Section 2.

The analysis of casualties is undertaken using combined KSI measure rather than attempt to identify projections and measures for fatalities on their own. Similarly, slight casualties are removed as they do not align with a safe system approach which only the most serious injuries are prioritised.

The data model used for populations does not take into account changes in traffic using any of the associated models. *Figure 14* shows the predicted KSI trends based on combining age groups modelled previously. It is likely that both the child and older road user groups may produce slightly different results if modelled as a grouped range e.g. over 65 years old, versus the combination of the three separate age bands seen in *Table 9*.

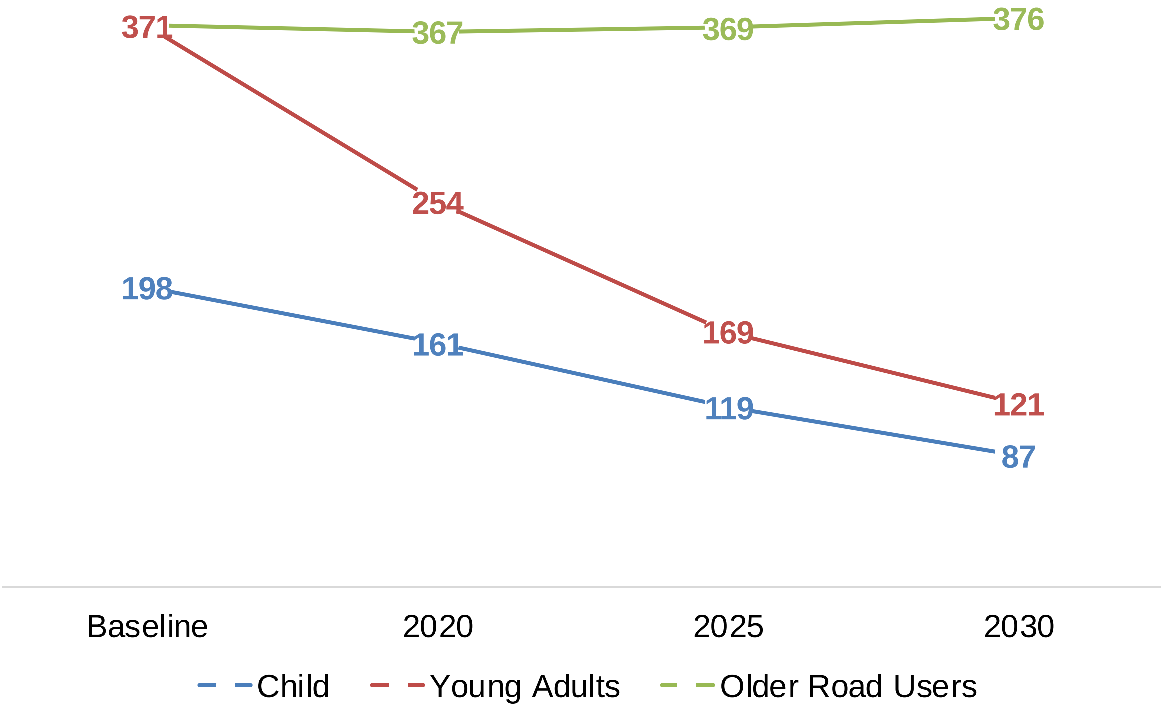


Figure 14 – Predicted KSI casualty trends by age-related road user group

To provide a prediction that aligns more closely with the trend shown using the primary scenario for transport growth we have re-scaled the age band analysis to match the modelled trends and shown this in *Figure 15*. This still predicts significant reductions in child and young person KSI casualties, but older road users KSIs now increase more significantly.

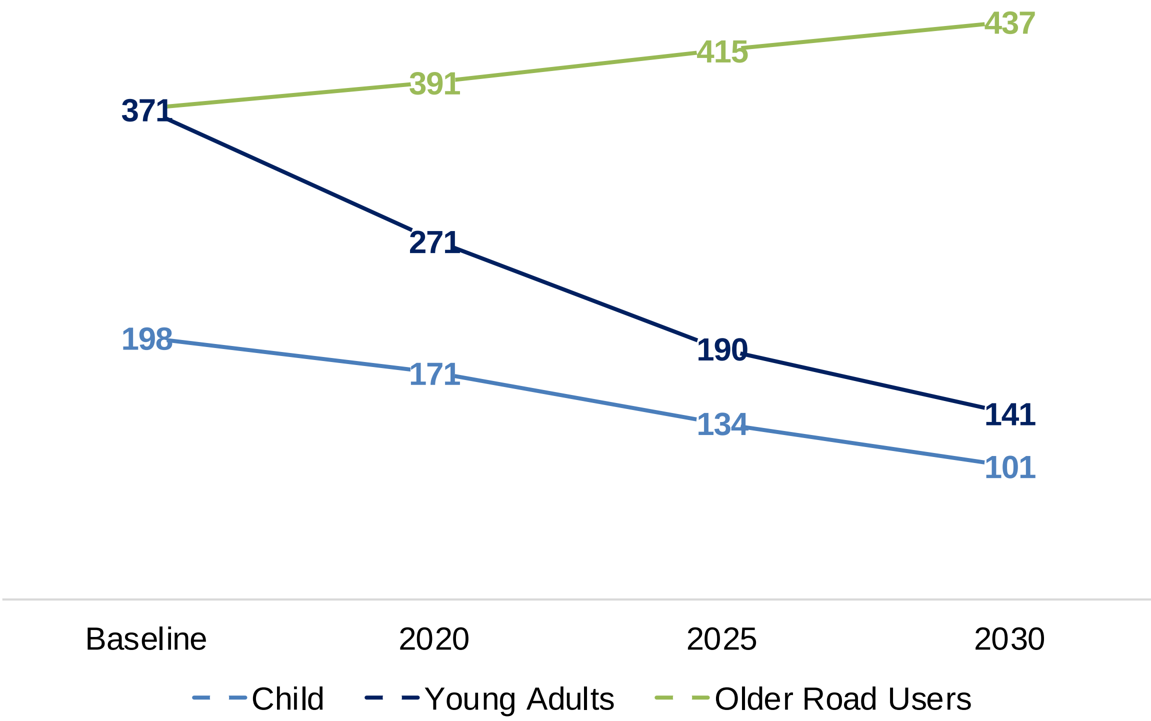


Figure 15 – Predicted KSI casualty trends by age-related road user group, rescaled by traffic growth

This modelling demonstrates clearly how intermediate measures for individual age groups needs careful consideration and is something we will revisit later in the report.

Intermediate measures for the three most significant road user groups; pedestrians, cyclists, and TWMVs, have been reviewed already and illustrated in *Figure 6* and *Table 6*. For comparison with the age groups, *Figure 16* shows the trends these three groups have in terms of total KSI casualties in around 2030.

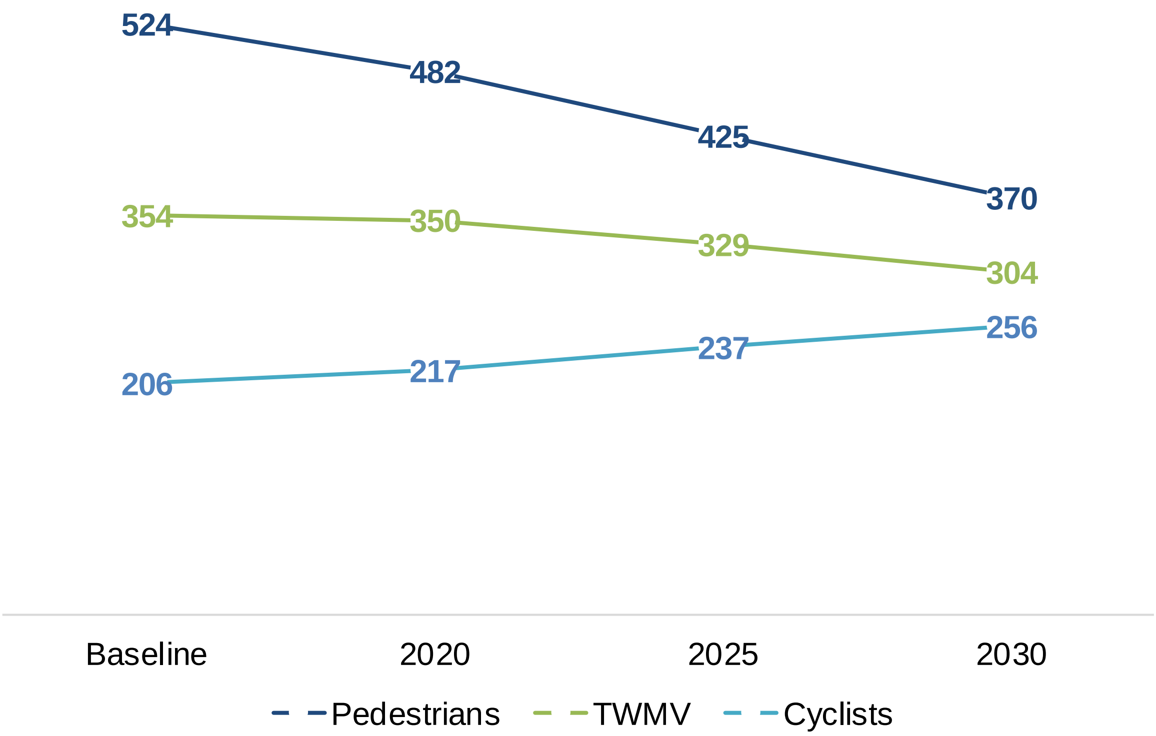


Figure 16 – Predicted KSI casualty trends by road user group

KPIs

A priority for measuring a KPI based on vehicle speeds was noted in the original research specification and this is one of the potential KPIs that has the most existing evidence available. Within the European Commission report[16] on developing an EU road safety framework the proposed KPI for speed is 'Percentage of vehicles travelling within the speed limit'. This is important as evidence from the European Transport Safety Council (ETSC) has calculated that if mean speeds were to drop by only 1 km/h on all roads across the EU, more than 2200 road deaths could be prevented every year.

Speed compliance data has been collected by the Department for Transport in a continuous time series since 2011[17] and provides for a breakdown by vehicle type and four different road categories. The data is based upon around 100 different Automatic Traffic Counters (ATCs) operated by the DfT. These ATC sites count traffic continuously as well as recording the speed at which the vehicles travel and the physical properties of passing vehicles, which are used to classify traffic.

[16] https://ec.europa.eu/transport/sites/transport/files/legislation/swd20190283-roadsafety-vision-zero.pdf

[17] https://www.gov.uk/government/statistical-data-sets/vehicle-speed-compliance-statistics-data-tables-spe

Although not an estimate of average speed across the network they do provide insight into the speeds at which drivers choose to travel when free to do so as they are based on 'free flow' traffic. Of the sites used by the DfT only seven are in Scotland (three on motorways, three on A roads and a single B road site). As this would provide too small a sample size we have chosen to use the entire dataset for our analysis.

The DfT use the classification LCV for *Light Commercial Vehicles* which is based on axle length, not weight. This is similar to the classification for LGVs based on weight which is used earlier in the casualty analysis.

Establishing a KPI for speed compliance will be based on the percentage of drivers complying with the speed limit. This will vary by road type and speed limit and also by vehicle type. The DfT data show that between 2014 and 2018 compliance is best for HGVs on Motorways (better than 99% compliance), and worst for TWMVs in 20 mph limits (11.32% compliance). *Figure 17* to *Figure 20* illustrate compliance levels by vehicle type on the four different road types.

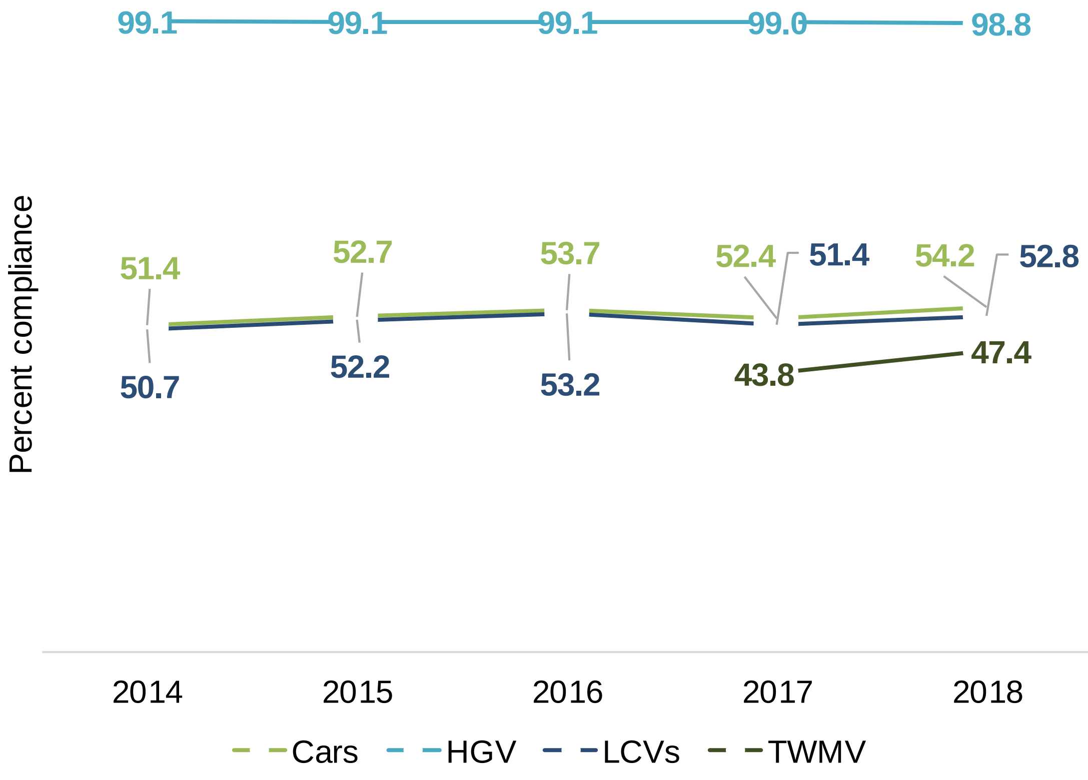


Figure 17 - Speed limit compliance by vehicle type – Motorways

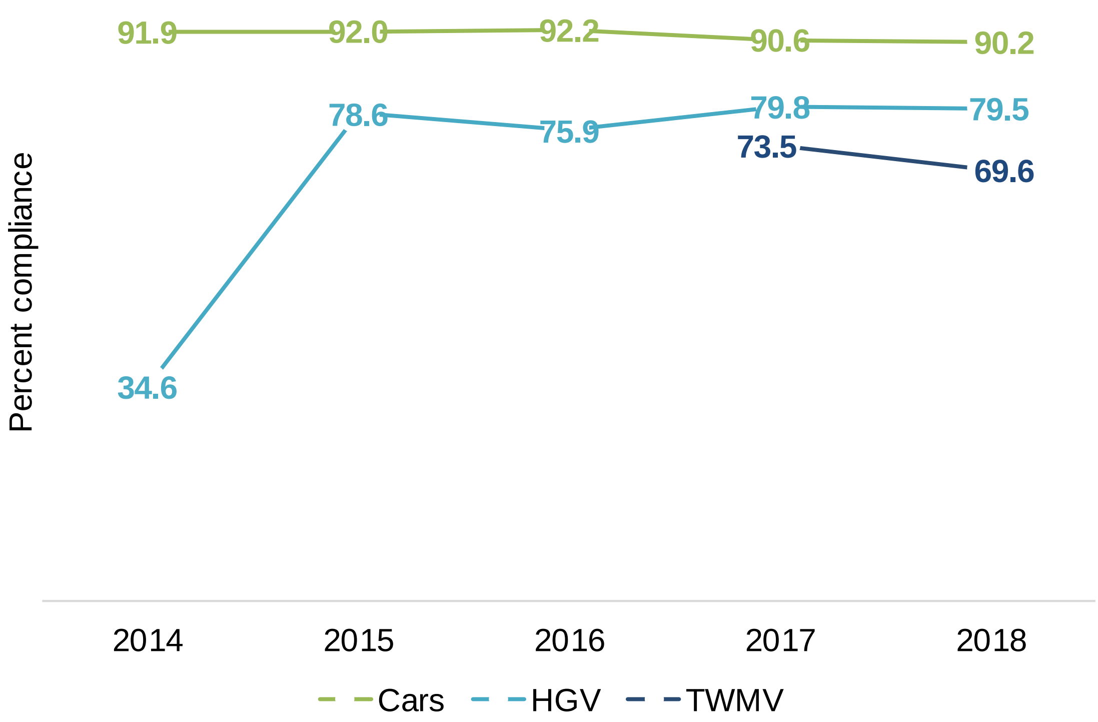


Figure 18 - Speed limit compliance by vehicle type – National Speed Limit, Single Carriageways

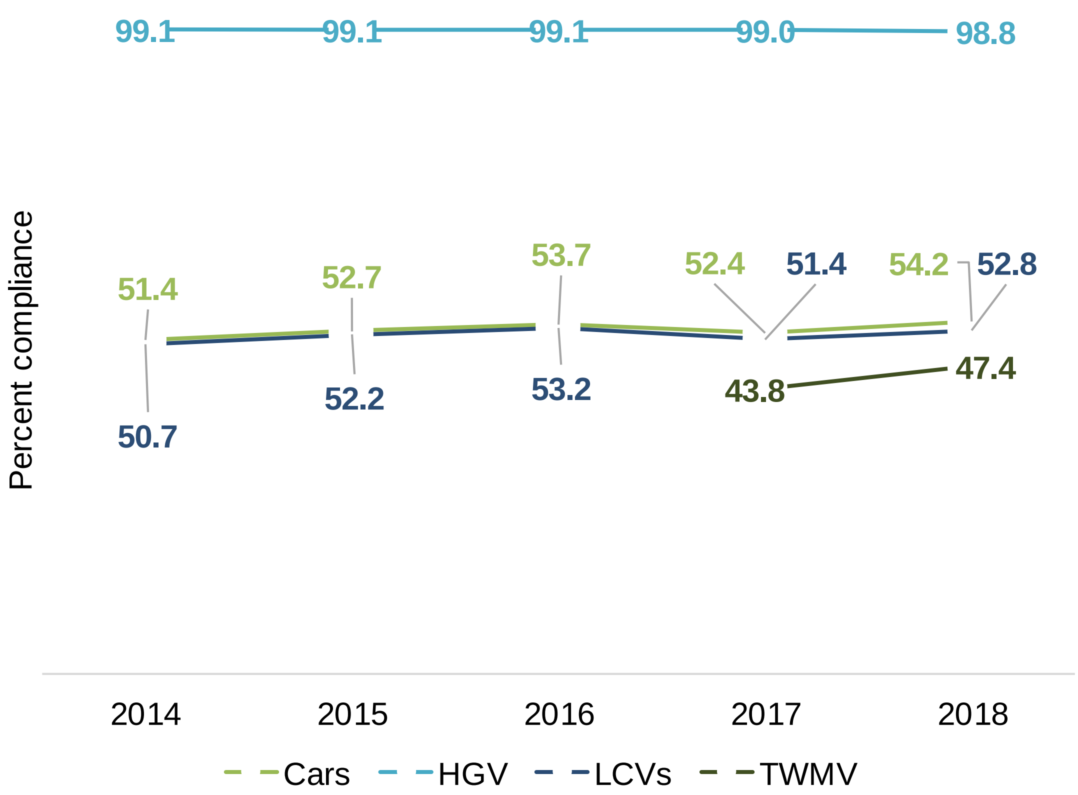


Figure 19 - Speed limit compliance by vehicle type – 30 Mph Limits

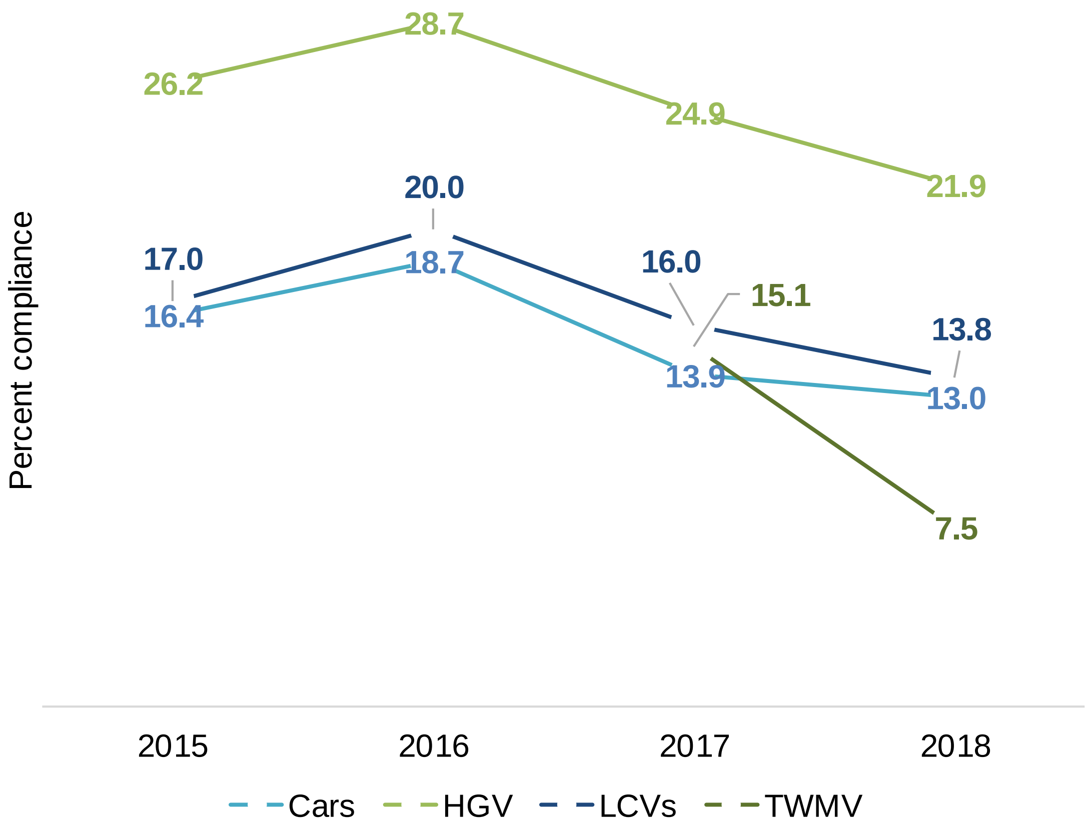


Figure 20 - Speed limit compliance by vehicle type – 20 Mph Limits

To produce an estimate of the level of non-compliance across the Scottish road network at any point in time requires an understanding of the length of road by speed limit as well as the amount of traffic on each of these roads. This would allow a weighting of each of the four analyses according to the amount of traffic per mile of road. It would however assume that all roads were free-flowing which is unrealistic. If levels of free-flow traffic changed over time this would also under or over-estimate the percentage of cars speeding.

For the purpose of this report an analysis has been undertaken using information about speed limit road lengths provided by Insight Warehouse[18]. For the four road types used by the DfT road lengths in Scotland are shown in *Table 10*. Road lengths are shown in the first column with columns two and three showing the total levels of compliance with speed limit for all vehicle types for the five year period. The final two columns show the percentage of non-compliance and compliance respectively weighted for road length in each of the limits. The weakness of this analysis is that it doesn't take into account traffic per km, which will be higher on motorways, and doesn't allow for congestion which suppresses the ability to speed.

[18] www.speedmap.co.uk

	Road length (km)	Compliant count	Non-compliant count	Weighted non-compliance by road length	Weighted compliance by road length
20 Mph	2151	11488	61693	1.7%	0.3%
30 Mph	31352	171321	195637	15.9%	13.9%
60 Mph single carriageway	69782	198878	19871	6.0%	60.3%
70 Mph motorway	1988	1345640	1040789	0.8%	1.1%

Table 10 – Speed compliance estimate for Scottish roads

The analysis above indicates that it is difficult to create a national speed compliance KPI that accurately assesses the true level of compliance. It is perhaps more acceptable to create separate KPIs for each speed limit, or road 'type'. Of course, with further data it may be possible to more accurately predict the true level of non-compliance on a given day.

Further considerations regarding the specification of counters, site locations and separation of vehicle types is included within the aforementioned European Commission document[16].

Future levels of speed compliance are likely to be affected by three main factors; any changes in speed limit, increased enforcement, increases in vehicle technologies including warning devices. It is also possible that an uptake in telematics-based insurance policies could increase compliance but there is no clear evidence on whether this will produce a significant effect.

There are seven other KPIs that are regularly referenced in international policy documents and frameworks. These relate to:

- KPI for infrastructure – Percentage of distance driven over roads with a safety rating above an agreed threshold

- KPI for vehicle safety – Percentage of new passenger cars with a Euro NCAP safety rating equal or above a predefined threshold (e.g. 4-star)

- KPI for sober driving – Percentage of drivers driving within legal limit for blood alcohol content (BAC)

- KPI for driver distraction – Percentage of drivers not using handheld mobile device

- KPI for use of safety belts and child restraint – Percentage of vehicle occupants using the safety belt, or child restraint system, correctly

- KPI for protective equipment – Percentage of riders of powered two-wheelers and of cyclists wearing protective helmet

- KPI for post-crash care – Time elapsed in minutes and seconds between the emergency call following a collision resulting in personal injury, and the arrival at the scene of the emergency services

Although these KPIs have been well documented, undertaking the analysis in practice is less common. As a part of this report we will briefly consider each KPI from the list above in turn.

Infrastructure

This KPI requires evidence about the safety quality of the road network that is independent of other factors such as vehicles or road users. One standard approach is that promoted by the International Road Assessment Programme (iRAP). The iRAP star rating is a tool that assesses the safety standard of a road against safe system principles. The star ratings are based on road inspection data and provide a simple and objective measure of the level of safety which is 'built-in' to the road. The higher the star rating, the safer the road. The iRAP star rating model used today is the result of 20 years of development work, which began with EuroRAP in 1999. The model is adjusted as new knowledge, new ideas, and better understanding come to light.

iRAP assessments have been undertaken in dozens of countries across the globe and do require significant investment. Highways England have had their networks assessed and a summary map is shown as *Figure 21*. They have a KPI to ensure that 90% of traffic is travelling on roads that are three stars or above. As the iRAP model is developed the rating for individual roads could change, however.

The European Commission is carrying out the following tasks to develop an EU-wide KPI for infrastructure:

- establishing an expert group to elaborate a framework for road classification that better matches speed limit to road design and layout in line with the Safe System approach

- facilitating exchange of experience on Safe System methodologies between practitioners (e.g. in a Forum of European road safety auditors)

- publishing the results of the network-wide safety assessment (safety ratings) to be carried out by Member States by end 2024 in accordance with the revised EU Road Infrastructure Safety Management Directive

- analysing the need for further research and innovation on infrastructure safety e.g. on new technology for monitoring infrastructure conditions

Any KPI for infrastructure needs to be robust and reliable, is applicable to all road classes and reflects risk experienced by different road users. Adopting the iRAP methodology would be a tried-and-tested solution but this could be very costly. Transport Scotland may wish to consider which elements of a risk rating could be adapted and used in a new local model that is cost-effective but still meaningful. As this requires further consideration no recommendation can be provided for adoption of an infrastructure KPI.

Figure 21 – Sample iRAP map for the Highways England network

Vehicle safety

In Europe, the standard measure of passenger car safety is the European New Car Assessment Programme (Euro NCAP[19]). These tests cover a multitude of vehicle safety features and provide assessments for adult occupants, child occupants, vulnerable road users (i.e. those struck by the vehicle) and safety assist features. These are combined to form a 'star rating' for each vehicle. The vast majority of new cars tested in 2018 and 2019 received a five star rating.

The standard suggested KPI for vehicle safety relates to these ratings and could be expressed as 'the percentage of new registered vehicles with a high Euro NCAP safety rating'. This could be adjusted to mean a specific star rating, or even applied to the whole fleet.

The first step to adopting this as a KPI would be to identify whether it is possible to collect baseline data regarding the safety ratings of current vehicles registered in Scotland. Once this is established a target can be adopted based on expected fleet renewal and removal rates, assuming this calculation can be made. It is not within the scope of this analysis to establish this figure and no existing data is available for Great Britain.

Measuring progress would be possible by matching cars within the DVLA database to a safety rating, probably using year of manufacture plus make and model. Transport Scotland would have the opportunity to influence the vehicle fleet by promoting and incentivising safer cars, introducing requirements for government vehicles, and promoting messages to fleet buyers and the general public.
A further, and more detailed analysis of vehicle safety levels would be to examine the penetration of specific safety features within the national fleet. We will review the European Union General Safety Regulations for Vehicles[20] later in this report.

Sober driving

This KPI would relate to both drink and drugs, and whether road users are under the influence of a specific set of substances at the time of driving.

There are currently two offences in the UK relating to drugs; firstly driving while impaired (being unfit) through the use of either legal or illegal drugs; secondly driving if you have certain levels of illegal drugs in your blood (even if they have not affected your driving). The law on drink driving is well established and has been toughened up in Scotland since late 2014[21], harmonising the limits with most other EU countries, and lower than that allowed in England and Wales.

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[19] https://www.euroncap.com/en

[20] https://ec.europa.eu/growth/sectors/automotive/safety_en

[21] https://www.mygov.scot/drink-drive-limit-scotland/

Establishing a KPI based on these two offences is challenging as it requires a good understanding of the number of people or percentage of journeys undertaken while meeting either of the criteria for drugs, as well as the maximum limit for alcohol. Evidence of prosecutions or convictions is unsatisfactory as it may simply reflect the ability of enforcement agencies to detect offences and bring a case to court.

Road user surveys are undertaken each year[22] asking questions about driver attitudes and behaviour provide a better guide as to offending behaviours. The most recent report showed that self-reported offending for drink or drugs are extremely low, usually two percent or less of those interviewed say that have driven whilst not in a sober state in the last year.

One other source of data is through police stops where a drug or breath test was taken. This could be used to establish the level of sober driving, but may be biased if the reason for the check is non-random. If a driver is stopped as they have committed an offence, or is displaying erratic behaviour, then it is biased against the vast majority of drivers who are sober.

The preferred measure is 'percentage of drivers driving within the legal limit for blood alcohol content (BAC) or without prescribed limits of specified substances. This would still not cover those driving under the influence of prescription drugs. The best way to establish the baseline for this and to carry on monitoring compliance is random driver testing. If this is not possible then self-reported behaviour is the next most acceptable metric.

Measuring performance outputs such as the number of checks, number of prosecutions, or even progress measures such as the percentage of drivers involved in injury collisions whilst not sober are worthy of collection but would not fit the criteria for a KPI on their own.

The most appropriate measure for a KPI would be one that, in the absence of truly random testing, combines evidence about self-reported behaviour as well as police checks for drink or drug-driving. These two measures have robust data collection methodologies and a significant time series which can be used to set a baseline.

Driver distraction

Driver distraction is largely considered to be 'Percentage of drivers not using a handheld mobile device', although there are increasing calls[23] to recognise the distraction caused by hands-free calling and other in-car technologies such as navigation system or in-car entertainment.

[22] https://roadsafety.scot/wp-content/uploads/2019/04/2018-Wave-17.pdf

[23] http://www.brake.org.uk/brake-blog/entry/time-for-a-ban-on-hands-free-phone-use-behind-the-wheel

As with sober driving, estimating the level of compliance for a KPI would be difficult without random sampling. This is possible however and there is an established methodology for doing so. The DfT have for many years, although with reducing frequency, carried out surveys of mobile phone and seatbelt use in Great Britain[24]. In 2017, 1.1% of drivers were observed using a hand-held mobile phone whilst driving on weekdays in Great Britain, of which 0.4% were observed holding the phone to their ear and 0.8% holding the phone in their hand. In England and Wales, 0.6% of drivers were observed using a hand-held device whilst driving in 2017, compared to 2.0% in Scotland.

It is not known whether the figure for Scotland in 2017 is significant and reliable for use as a benchmark. There were 30 observation sites in Scotland (compared to 60 in England and Wales) which would indicate that the results are significant, although we would recommend a further survey across a greater number of locations in Scotland to establish a more robust benchmark.

Creating a KPI based on this data source and setting a target for greater levels of compliance would be relatively straight forward.

Use of safety belts and child restraints

The collection of data for seatbelt compliance is undertaken at the same time as that for mobile phone use[24] and data already exists for Scotland. Vehicle occupants are classed as either drivers, front seat passengers, or rear seat passengers. Further information on gender and estimated age are also included.

In 2017, 96.5% of all drivers were observed using a seatbelt in Great Britain compared to 95.3% in 2014 for England and Scotland combined. This rate was lower in England and Wales (96.0%) than Scotland (97.3%) in 2017.

For front seat passengers, 93.1% were observed wearing a seatbelt in Great Britain in 2017 compared to 90.4% in England and Wales and 98.7% in Scotland.
There were 90.7% of rear seat passengers observed wearing a seatbelt in Great Britain in 2017. This compares to 88.3% in England and Wales and 95.1% in Scotland in 2017.

As with mobile phones, creating a KPI based on this data source and setting a target for greater levels of compliance would be highly desirable.

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[24] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/777018/mobile-phone-seatbelt-use-surveys-2017.pdf

Protective equipment

Motorcycle helmet wearing rates are almost 100% in the UK, although there is no evidence collected on non-wearing rates. It is not therefore considered to be a road safety priority worthy of measuring through a KPI.

Other protective equipment for motorcycle riders or cyclists could be measured through random surveys similar in nature to those for seatbelt or mobile phone use. There is no legislation in place however to mandate the use of such equipment which would make the establishment and improvement of KPI performance difficult. There is significant debate as to whether the use of cycle helmets should be made mandatory, although the evidence for effectiveness is less controversial. We do not therefore consider a KPI for protective equipment to be established at this moment.

Post-crash care

According to European Commission research[25], About 50% of deaths from road traffic collisions occur within minutes at the scene or in transit and before arrival at hospital. For those patients who are taken to hospital, 15% of deaths occur within the first 4 hours after the crash, and 35% occur after 4 hours. The role of post-crash care is therefore vital in achieving the best outcomes for road casualties.

The appropriate KPI measurement is 'Time elapsed in minutes and seconds between the emergency call following a collision resulting in personal injury, and the arrival at the scene of the emergency services'.

Measuring this is not a straightforward task and carrying it out for all incidents may be burdensome on the emergency services, especially at a time when prioritising treatment is the overriding concern. It could be carried our retrospectively by examining communications records and incident logs but this may be costly.

In terms of selecting KPIs to be prioritised it is difficult to recommend this measure, in some respect due to the difficult of accessing accurate information, and also as it is not well-related to the injury severity target. It would however be very relevant to a fatality target.

According to MAST Online[14] in the baseline period, 76% of all fatalities on Scotland's roads were in a rural areas (649 out of 859). One measure may be to estimate response times using known collision locations and emergency treatment centres. A baseline for this could be easily established, although putting in place improvements to reduce average response times to fatal or serious collisions would be more challenging.

[25] European Commission (2018), ERSO Synthesis on post-impact care.

Driving for work

The percentage of collisions occurring while someone is work, or travelling to or from their place of work, varies depending on the source data. STATS19 records in Scotland for 2018 indicate that of 8,411 reported road casualties, 1,299 of these occurred where the driver journey was work-related (15.4%). Analysis by other road safety groups estimate this figure is much higher, somewhere between a quarter and a third[26].

As a distinct road safety topic, occupation road risk, or simply driving for work, is an area where there is significant potential for safety improvements. Unlike for an individual citizen, who makes their own decision about risk, those driving as a part of their job are often controlled to some extent by managers who seek to mitigate this risk. The reasons for wanting to reduce road collisions in company fleets are straight-forward and primarily linked to better financial performance, but also recognising that companies have a duty to protect others.

Creating a KPI or measure around the number of collisions that are 'work related' would not in itself be satisfactory as it may simply reflect and increase or decrease in these types of journeys. The figures should be collected of course, and consideration given to how reliable the 'journey purpose' field in STATS19 is. A better KPI would be one that looks at the behaviours of companies, what technologies they are implementing, and what systems they are adopting.

Technology adoption is something that companies and governments can influence. Transport for London have implemented a 'direct vision' standard[27] and from 26 October 2020, all HGVs more than 12 tonnes (GVW) entering or operating in Greater London will need to hold a valid HGV Safety Permit. A potential KPI would be to monitor and report on the percentage of vehicles operating in in Scotland that comply with a specific safety standard. This may be the one used by TfL, or another adopted by the Scottish Government. It is not the purpose of this report to recommend standards but measuring the take-up rates of specific safety technologies within fleets of goods vehicles, buses and coaches, and company cars may be possible.

Another option would be to record the number of companies, and the size of fleets, where established road safety risk management processes are formally adopted. The global certification standard is ISO 39001 Road Safety Traffic Management[28]. This 'gold standard' helps companies identify risks and put in place solutions to help mitigate for them. It also includes requirements for monitoring and reporting. This standard does require significant effort to achieve and a commitment to maintain practices, which may not make it suitable for all business.

[26] https://www.roadsafetyobservatory.com/Review/10047

[27] https://tfl.gov.uk/info-for/deliveries-in-london/delivering-safely/direct-vision-in-heavy-goods-vehicles

[28] https://www.bsigroup.com/en-GB/iso-39001-road-traffic-safety/

A less onerous standard would be to promote sign-up to Driving for Better Business (DFBB)[29] which adopts many of the same principles but does not require the same level of policy management or documentation. DFBB is supported by Highways England who provide certificates to key supply chain members who become a part of the scheme.

There are several options available for the creation of a KPI relating to driving for work, although establishing baselines and setting targets would require further work.

[29] https://www.drivingforbetterbusiness.com/

Discussion

Impact of Graduated Driver Licensing (GDL) and future vehicle safety measures

Before considering the evidence so far within the report there is a final task to review the potential for casualty reduction beyond that predicted in the earlier sections. The two elements to be considered are the modelled casualty reductions to 2030 for new vehicles safety measures, as included in the European General Vehicle Safety Regulations, and how restricting the ability of newly qualified young drivers to carry passengers may also reduce casualties.

Turning first to the issue of GDL, the RAC Foundation produced a report modelling the impact of a range of GDL schemes in 2018[30]. Their approach was first introduced in 2014 and is based on international evidence around the impacts of different GDL components. For their report the analysis focussed on a very specific group of collisions which involved a car driver aged 17-19, with a passenger casualty aged 15-24 years old in their vehicle, but without a passenger casualty aged over 25 years old in their car between 2008 and 2012. This was then re-calculated using a 2012 – 2016 baseline.

The resulting analysis for Scotland showed that the introduction of a passenger restriction where no more than one 15-19 year old passenger would be allowed, unless accompanied by a 25+ year old, would result in 13 fewer KSI casualties per year. There is a weakness in the analysis as it assumes that the presence of an injured passenger is the only way to assess whether any passenger was present, and it is likely that there would be more collisions with uninjured passengers. It is unknown whether the casualties included those from other vehicles or pedestrians involved in the same collision.

Analysis of the GB STATS19 data for the same period, including crashes where a 17-19 year old car driver was involved in a collision in Scotland, showed that there were 542 KSI casualties at an average of 108 per year. Although the two crash scenarios are not precisely the same as it doesn't filter for those where an injured passenger was present, it points to a casualty reduction benefit of around 8.3%.

Without access to more precise details about the number of crashes where uninjured passengers were present it cannot be determined for certain what the future reduction would be. As mentioned previously, the age band analysis in this report is for all casualties, rather than just drivers or even casualties that resulted from collisions with vehicles driven by young drivers. Given the relatively small benefit per annum and the predicted reducing trend in killed or seriously injured young people, it is likely that the annual benefit will be in single digits by 2030.

[30] https://www.racfoundation.org/wp-content/uploads/GDL_Update_Makwana_RACFoundation_2018.pdf

Vehicle safety measures

As referenced earlier, previous analyses had attempted to estimate the effect of known future safety benefits, some of which related to vehicle safety. Following the publication of analysis provided by TRL for the European Commission[5] and the introduction of the new General Safety Regulations (GSR)[31] it is possible to review the impact of a set of different vehicles safety measures, or individual measure on their own, across Europe. We will now consider these potential savings in a Scottish context.

The report provided three central estimates for casualty reductions based on three scenarios. A first policy option (PO1) considered the implementation of state-of-the-art and widely available package of safety solutions that are not yet mandatory in EU; their fitment varies from around 5–90%. A second policy option brought in more safety solutions that focus on vulnerable road user protection and on ensuring driver attention to the driving task. The third and final policy option included all measures in PO2, plus additional safety solutions that are feasible and already exist in the marketplace, but that have a low fitment rate and market uptake. The policy options are each studied for their cost-effectiveness compared to a baseline scenario (PO0), where none of the measures are implemented on a mandatory basis, but voluntary uptake would continue.

A full list of the different technologies and vehicle types was included within the report and will not be repeated here. It is worth noting the report also reviewed benefit cost ratios for each policy option against different classes of vehicle. The conclusions which were that generally, PO1 was most cost-beneficial in terms of fitment versus casualty saving, but that PO3 still provided a positive figure greater than 1 and was the highest in terms of casualty saving.

	Benefit-Cost Ratio		
	PO1	PO2	PO3
Passenger Cars	3.0	2.1	1.39
Vans	1.8	1.4	0.53
Buses and coaches	4.6	3.1	2.11
Trucks	0.6	1.5	1.03

Table 11 – Estimated benefit cost ratios for vehicle technology policy options

The recommendation that was adopted and became law on the 5th January 2020 was for the full range of safety features outlined in policy option 3 be made mandatory from 2022. The impact of this was modelled to 2030 using European casualty data, based on an initial analysis of potential effectiveness using STATS19. The careful analysis accounted for severity migration (fatal to serious, serious to slight), and overlapping benefits from a combination of technologies to avoid double-counting. We have taken the predicted reductions at EU level which can be seen in

[31] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2019.325.01.0001.01.ENG&toc=OJ:L:2019:325:TOC

Figure 22 and *Figure 23*. The impact on fatal casualties is slightly more pronounced than for serious casualties.

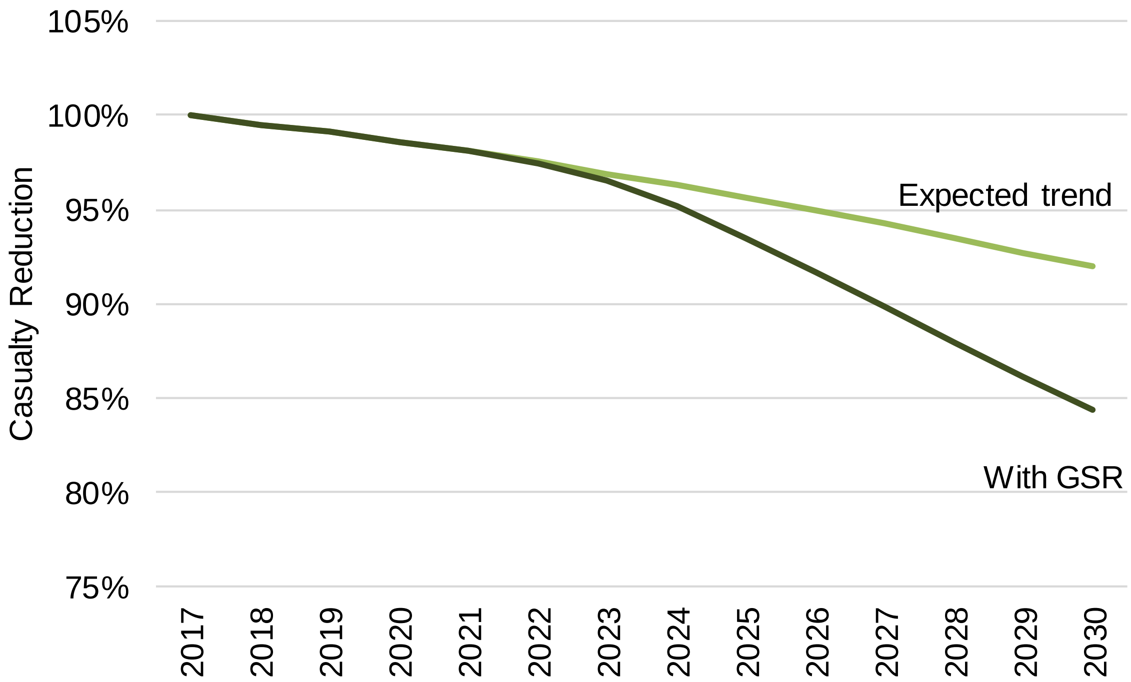


Figure 22 – Predicted killed casualty reduction benefits of three technology implementation scenarios across Europe

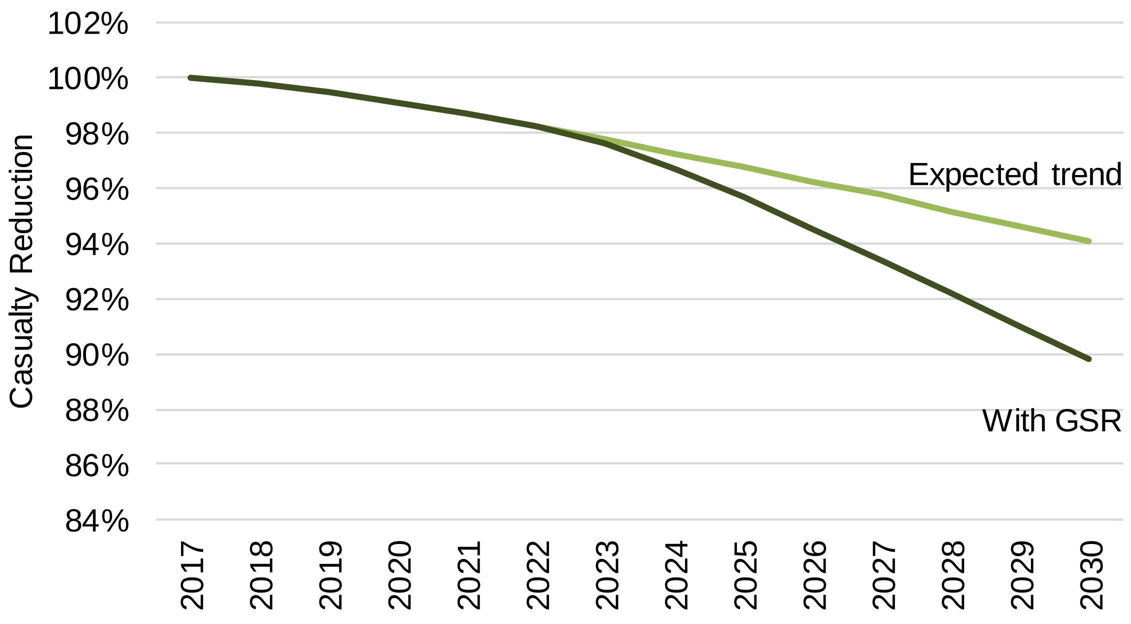


Figure 23 – Predicted serious casualty reduction benefits of three technology implementation scenarios across Europe

To put these figures into a Scottish context we have applied casualty reductions to the 2014-2018 baseline, taking into account the projected saving for 2018 included in the TRL analysis. The results are shown in *Table 12* as casualty savings per year through to 2030. As this is a modelled saving the first decimal place is included for clarity. The percentage reductions are shown in the appendix as *Table 14*.

Year	Non-GSR Fatal	Non-GSR Serious	GSR Fatal	GSR Serious
Baseline inc 2018 saving	172	2003	172	2003
2019	1.6	11.4	1.6	10.5
2020	2.4	19.1	2.4	17.6
2021	3.3	28.2	3.3	26.0
2022	4.3	38.2	4.3	35.3
2023	5.3	48.6	5.9	47.8
2024	6.4	59.3	8.4	65.8
2025	7.5	70.0	11.3	86.5
2026	8.7	81.0	14.3	108.7
2027	9.9	92.7	17.5	132.3
2028	11.2	104.8	20.7	156.3
2029	12.5	117.0	23.8	180.4
2030	13.8	128.5	26.9	204.0

Table 12 – Predicted casualty savings from each policy scenario in Scotland

The reductions here are significant, even without the implementation of policy options. Even though the UK has left the European Union in 2020, the UK government has said it will adopt the regulations. With significant further analysis and access to more information about the calculation methodology it may be possible to estimate the impact of the policy options against different vehicle types, although it would not always separate out the impact to pedestrians and cyclists as they are included within the figures for the associated vehicles. In addition, the impact on motorcycles of the technologies is unknown. No mention of motorcycle-specific technologies was included in the report, although it is possible that technologies fitted to other vehicles may prevent collisions with motorcycles.

Using the analysis from chapter two we have added on the predicted benefits from the TRL study. *Figure 24* and *Figure 25* show how casualty reduction in Scotland could be affected by the implementation of GSR. Each chart shows three figures; the current baseline average, the output from the central prediction model shown in *Table 4*, and finally the estimated impact of the GSR on top of this second value.

It is important to note at this point two important caveats:

- The casualty reductions are modelled on predicted savings across the EU27 countries and therefore assumes that these would also be experienced in Scotland. As casualty rates are generally higher across Europe than in Scotland, the casualty savings in Scotland could be smaller than those experienced in an area with a higher background level. This is a possible weakness in any attempt to transfer casualty savings from places with a greater potential for reduction. We will address this issue for specific measures later in the report.

- The previously-modelled casualty reductions take into account the effect of improved vehicle safety technologies in the analysis period 2009 – 2018. It is therefore possible that some of these effects would have been continued in the predictions and may therefore lead to some double counting.

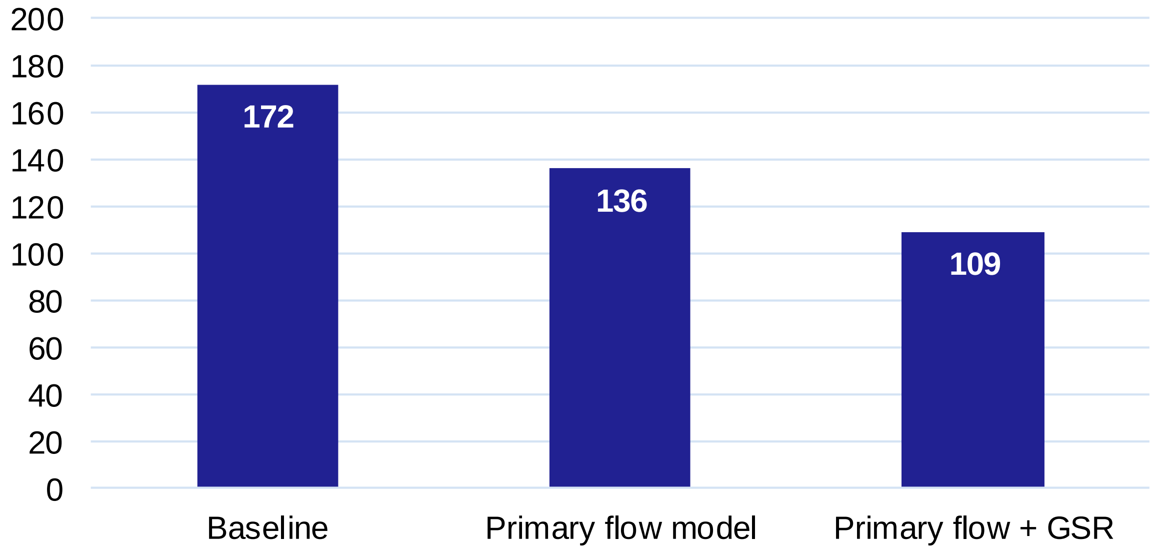


Figure 24 – Predicted killed casualty reduction benefits by 2030

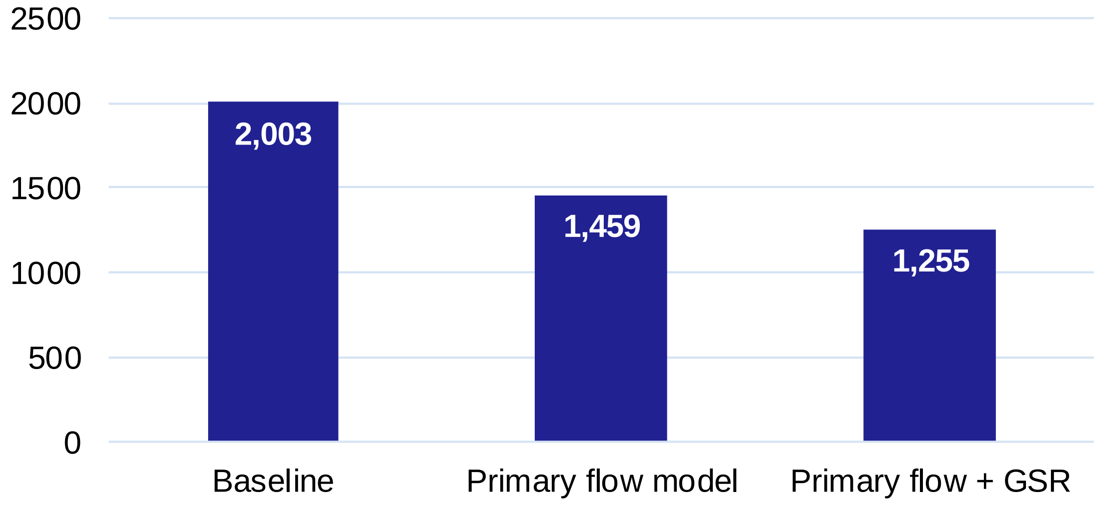


Figure 25 – Predicted serious casualty reduction benefits by 2030

The predicted reduction in killed casualties under the primary flow model is 20.8% which improves to 36.5% with the implementation of the GSR.

The predicted reduction in serious collisions under the primary flow model is 27.1% which improves to 38.2% with the implementation of the GSR.

There are a certain number of assumptions and estimates of effectiveness and uptake of vehicle technologies within the TRL report and the results of the modelling also contain potential error. These predictions are therefore a guide as to potential reductions and should be viewed accordingly.

As the road user and age-group predictions in chapter two were made for KSI casualties it is not possible to produce separate figures for killed and serious within these groups. There is also uncertainty around how casualty reductions within individual road user groups and age bands may be affected by the introduction of new vehicle safety systems. It is likely that car vehicle users will benefit the most, although there are several new technologies specifically aimed at preventing collisions with cyclists and pedestrians.

To assist in understanding potential future trends, a set of predictions have been made that take the potential impact of GSR and align them with the KSI casualty totals seen in *Figure 15* and *Figure 16* which already took into account demographic change and traffic. These are shown in *Figure 26* and *Figure 27* with the supporting table included in the appendix as *Table 16*.

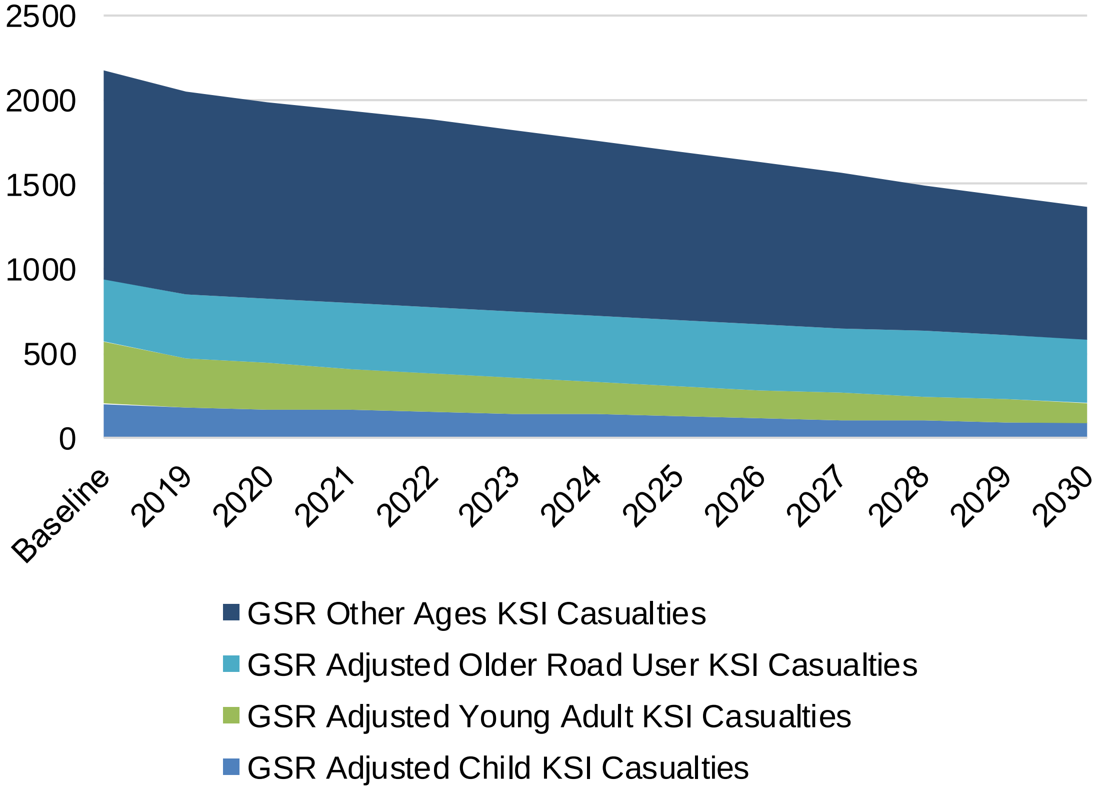


Figure 26 – Predicted KSI casualty reduction benefits by 2030 for individual age groups

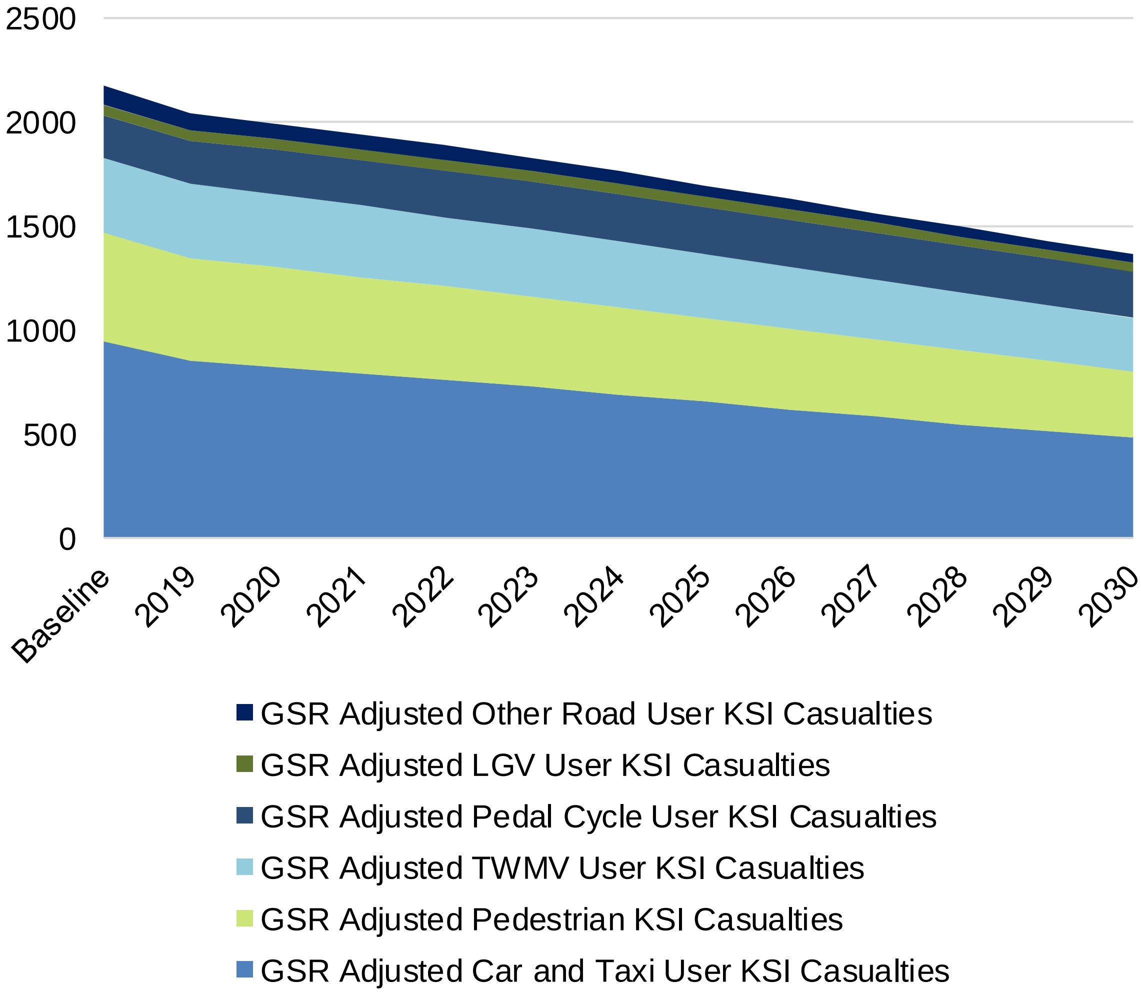


Figure 27 – Predicted KSI casualty reduction benefits by 2030 for individual road user groups

All groups except for pedal cyclists are predicted to see reductions in KSI casualties. Older road user casualties will remain largely the same as they were in the baseline period despite an increasing population in this demographic. The greatest reductions are expected in the young adult, child and cars and taxis groups.

In order to understand the benefit of specific technologies, which could therefore be promoted or mandated independently of the European Union, an analysis has taken place on the following technologies:

- AEB-VEH — Autonomous emergency braking for vehicles (moving and stationary targets)
- AEB-PCD (p) — Autonomous emergency braking for pedestrians
- AEB-PCD (C) — Autonomous emergency braking for cyclists
- ALC — Alcohol interlock

- EDR Event data recorder
- ESS Emergency stop signal
- ISA-VOL Intelligent speed assistance - voluntary type system
- ESC Electronic stability control

Each of these technologies were analysed independently and the appropriate target populations selected from the STATS19 database in the baseline period. The full results are included in the appendix as *Table 15*. The casualty savings rely on three values, the aforementioned target population proportion, effectiveness in mitigating for a specific injury severity, and an estimate of fleet penetration by 2030. As these measures are reported individually it is not possible to combine them to form a total reduction and instead reference should be given to the policy option packaged mentioned earlier.

Figure 28 illustrates potential casualty reductions for fatal and serious casualties in Scotland as a result of individual vehicles technologies. The two biggest areas for potential gain are AEB – VEH and ISA-VOL. These collision mitigation and speed control measures are well understood in the academic literature and are currently fitted to many vehicles. Pedestrian AEB is also an effective solution, as is ESC. ESC is however already well established in vehicle fleets, hence the lower percentage reduction opportunities. It was not possible to evidence the effectiveness of alcohol interlocks from the data sources, although this is a well-known solution implemented in many countries for those convicted of drink driving.

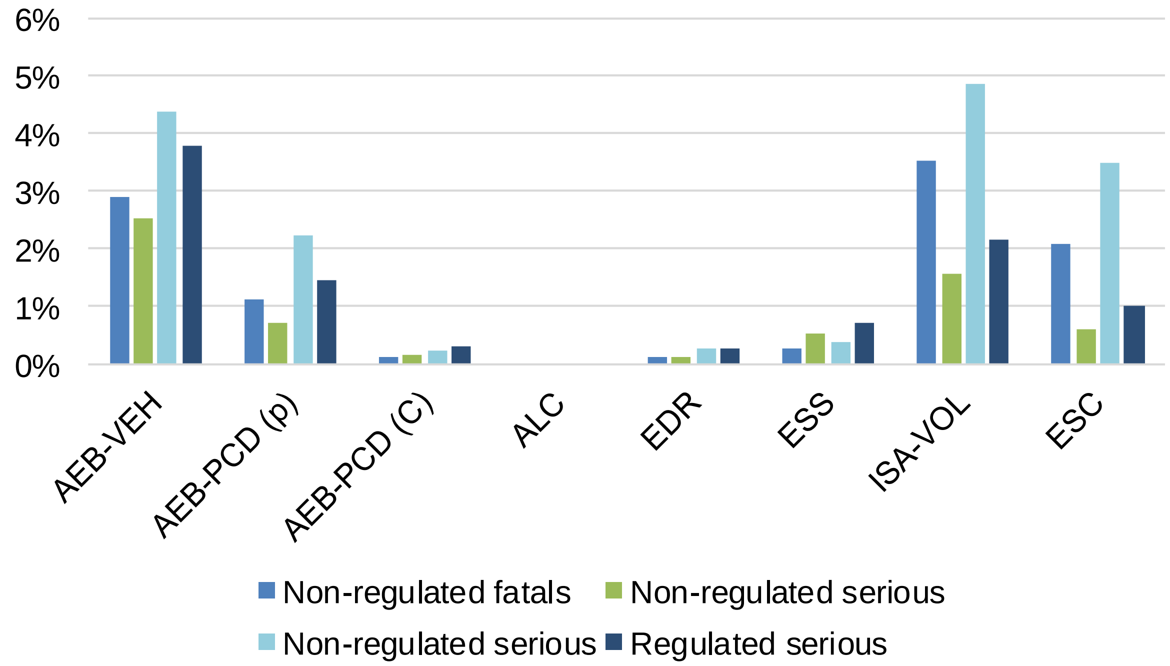


Figure 28 – Predicted casualty reduction benefits of seven individual vehicle technologies in Scotland

Review of casualty reduction models and final estimations of casualty reduction

This report has considered many datasets and carried out several techniques to try and estimate potential casualty reductions to 2030 based on previous trends and modelled changes in population and traffic. It has now also considered the potential impact of emerging vehicle technologies and the relative benefits of mandatory fitment.

The original brief was to provide an estimate of the following four target metrics:

- People killed
- People seriously injured
- Children (aged <16) killed
- Children (aged <16) seriously injured

Firstly, on the matter of child fatalities we believe it is important to set a vision zero target for this group. Annual numbers fluctuate around an average of six per annum and it is conceivable that with generally reducing casualty numbers to 2030 we may see a single year with no child fatalities.

Based on the analysis of modelled traffic and population growth, together with consideration for different vehicle types and casualty ages we believe the figures in *Table 13* represent a realistic set of targets.

The people killed target is informed by the flow model combined with EU policy option one which would result in a 36.5% reduction. This could be stretched further, beyond 40% if there was a desire to introduce more progressive casualty reduction measures, such as speed limit changes, or extensive protection of vulnerable road users from vehicles.

The people seriously injured target is again informed by the flow model combined with EU policy option one which would result in a 38.2% reduction.

Finally, the seriously injured child casualties target has been set at 60%. The analysis shown in *Figure 26* estimates a 57% reduction in child KSI casualties against the baseline period.

Target	Percent Reduction
People killed	40%
People seriously injured	40%
Children (aged <16) killed	100% (Vision Zero)
Children (aged <16) seriously injured	60%

Table 13 – Recommended casualty reduction targets for Scotland to 2030

Recommended performance management measures

In our review of Intermediate measures we considered whether metrics for specific road user groups and age bands should be analysed. Our analysis of demographic change indicates that this is very much recommended, and attention paid to the groups that are likely to show the lowest casualty reductions, or even rises through to 2030. Most notably these groups are cyclists and older road users.

On the subject of KPIs we believe that measures should be put in place to establish baselines and introduce future monitoring of the following KPIs:

- percentage of motorists driving within the speed limit
- percentage of motorists driving whilst not distracted by a hand-held mobile phone
- percentage of motorists driving whilst wearing a seatbelt
- percentage of passengers travelling whilst wearing a seatbelt
- percentage of drivers failing a drink driving check plus
- percentage of drivers self-reporting to have driven whilst under the influence of alcohol
- percentage of drivers failing a drug driving check plus

Percentage of drivers self-reporting to have driven whilst under the influence of drugs.

We would recommend further consideration of the measuring of KPIs relating to vehicle safety, post-crash care, driving for work, and road infrastructure. We acknowledge that this may take some time however and these are unlikely to be in place by 2021 when any framework would commence.

Appendices

Section 1: Calculation notation and explanation

The primary assumption of the baseline methodology is that $\boldsymbol{C(y)/T(y)}$, where $\boldsymbol{C(y)}$ is the baseline prediction of casualty numbers (for a fixed casualty class) in the year $\boldsymbol{y}$ and $\boldsymbol{T(y)}$ is the predicted traffic (taken as exposure for the fixed casualty class) in the year $\boldsymbol{y}$, decays exponentially as $\boldsymbol{y}$ increases. That is,

$$C(y+1)/T(y+1) = \alpha\, C(y)/T(y)$$

for some value of $\boldsymbol{\alpha}$. As a result,

$$C(y')/T(y') = \alpha^{(y'-y)} C(y)/T(y)$$

for years $\boldsymbol{y' \geq y}$. The value of $\boldsymbol{\alpha}$ is determined by fitting a linear model through $\mathbf{log}\big(\boldsymbol{C(y)/T(y)}\big)$,

$$log\big(C(y)/T(y)\big) = ay + b + \varepsilon(y)$$

fitting $\boldsymbol{a}$ and $\boldsymbol{b}$ to minimise the error $\boldsymbol{\varepsilon}$. The value $\boldsymbol{\alpha}$ is then taken to be $\mathbf{exp}(\boldsymbol{a})$ so that

$$\boldsymbol{C(y)/T(y) = \alpha^y\, exp(b)}$$

up to minimal error, so that, approximately,

$$\boldsymbol{C(y+1)/T(y+1) \;=\; \alpha\,(\alpha^{\,y})\; exp(b) \;=\; \alpha\, C(y)/T(y)}.$$

Note that this implies

$$\boldsymbol{C(y') = \alpha^{(y'-y)}\big(T(y')/T(y)\big)C(y)}$$

for years $\boldsymbol{y' \geq y}$ and so the modelled number of casualties in any particular year depends only on the observed number of casualties in a year and the relative change in traffic, once $\boldsymbol{\alpha}$ is determined. As mentioned in Broughton et al, this reduced the dependence on any fixed data source for traffic volume under the assumption that different data sets agree up to rescaling.

For each casualty class, the corresponding number of casualties per kilometre travelled by the relevant vehicle type was calculated for each year between 2009 and 2018. The logarithm of these casualties-per-flow values was then calculated, and a linear model was fit through these annual values to determine the rate ($\boldsymbol{a}$ in the notation above) at which this logarithm changes over time. This coefficient was then exponentiated to give the value $\boldsymbol{\alpha} = \mathbf{exp}(\boldsymbol{a})$ described above. This was carried out in R[32] using the *lm* function in the stats package.

[32] https://www.r-project.org/

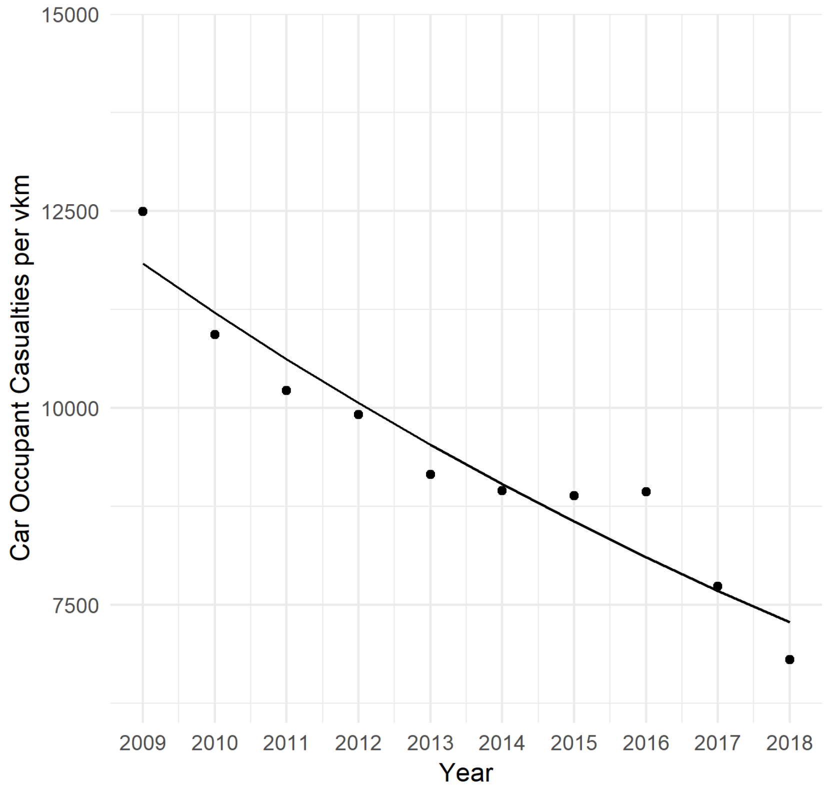
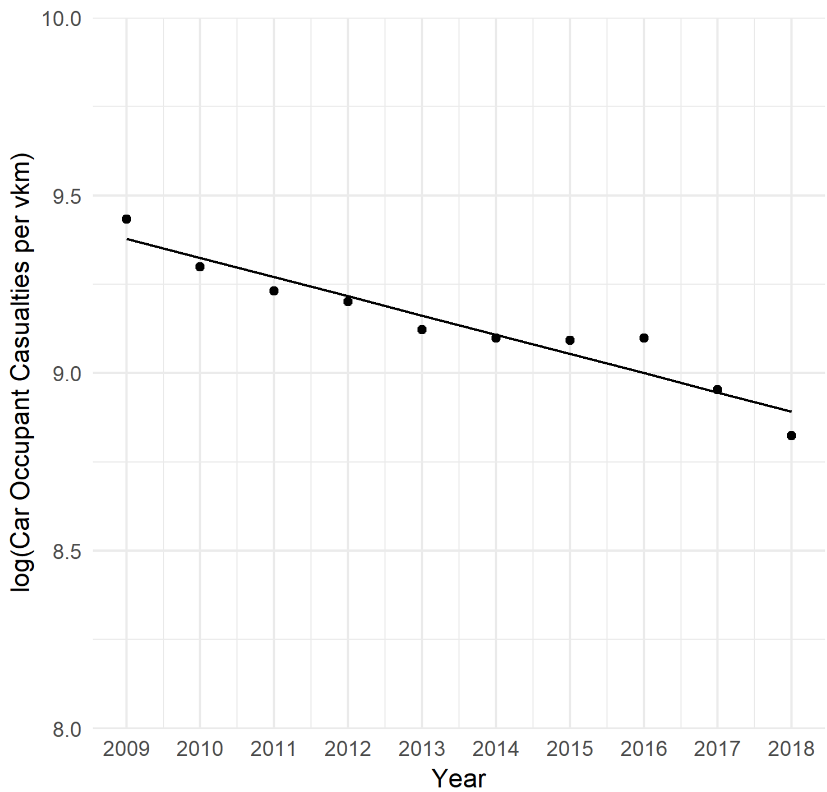


Figure 29 shows firstly the linear model fit to the log values and secondly the resulting exponential curve fit to casualties per flow for car occupant casualties.



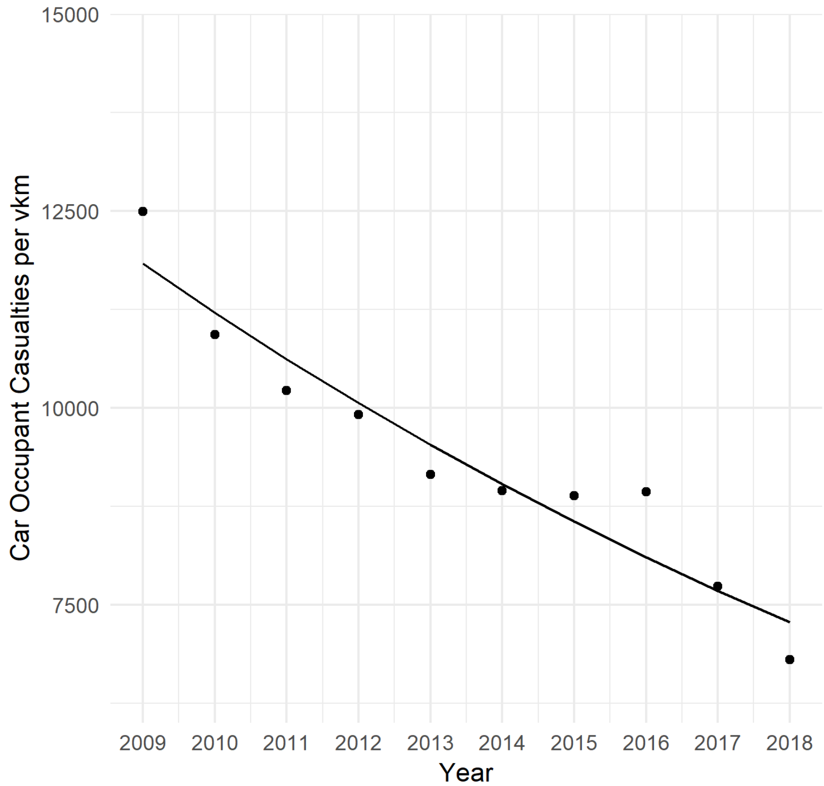


Figure 29 – Linear and log models for car occupant casualty rates

Once the various values of α are determined for each class of casualties, the formulae above are used to determine casualty numbers in future years. The initial observed value, $C(2016)$, is taken to be the average of $C(2014)$, $C(2015)$, $C(2016)$, $C(2017)$ and $C(2018)$. This baseline is taken to reduce the effect of annual fluctuation on future prediction.

For the population growth model the following method

$$C(y+1)/P(y+1) = \beta C(y)/P(y)$$

for some value of β, where $C(y)$ is the number of casualties in year y as before and $P(y)$ is the population count in year y. This is done separately for the following age groups: under 5; 5 to 15; 16 to 24; 25 to 34; 35 to 44; 45 to 54; 55 to 64; 65 to 74; 75 to 84; and 85 and over. The methodology for determining the various values of β are analogous to those used to determine α for the previous collection of models.

Section 2: Artificial Neural Network (ANN)

Ideally, we should view the coefficient α from the basic methodology as a function of a variety of other trend data including trends in traffic flow on the network, changes to age group demographics, changes in car ownership, changes to employment levels, modal shift, and changing rurality. We would also include contextual data about Scotland that influences α, including free flowing speed on the network, population levels and breakdown of age demographics, car ownership levels, employment levels, and rurality of the network.

Given a model that approximates $\boldsymbol{\alpha}$ to a high level of accuracy, a wide variety of scenarios for the future of Scotland can be devised and passed through the model to determine the casualty trends one would expect to see. This would give, for each scenario, a prediction of casualty rates up to 2030 against which KPIs can be set. However, as small changes to the values of $\boldsymbol{\alpha}$ can lead to significant changes in projected casualty numbers, it is vital than any model of $\boldsymbol{\alpha}$ is highly accurate.

Several attempts were made to model the function $\boldsymbol{\alpha}$ by fitting an artificial neural network to both contextual and historic trend data. An artificial neural network is a series of stacked layers, each built from a network of artificial neurons. Using a combination of linear transformations of the input data and non-linear perturbations of the data, they are theoretically capable of approximating any sufficiently smooth function to any degree of accuracy. Given a set of training input data and known output data, a sophisticated back-propagation algorithm efficiently fits the neural network as closely as possible to the given data. However, the successful approximation of a function such as $\boldsymbol{\alpha}$ using a neural network relies on two things. Firstly, it requires that such a function exists. That is, we need to assume a priori that it is possible to accurately predict the values of $\boldsymbol{\alpha}$ using the variables in the input data alone. Secondly, it requires that both the input data and known output data are accurate and reflective of the situation which is being modelled.

To ensure that a large and varied set of data was being used to fit the neural network, a combination of casualty, trend and contextual data was taken at the level of TMfS14 Zones. Trend data was observed over the complete series of continuous time periods ranging from 5 years to 7 years taken from between 2012 and 2018. For each trend variable and over each time period, trend data was summarised as a single value, calculated in a similar way to how $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are calculated in the *Regression* methodology That is, for each trend variable, the trend value is taken to be the exponential of the gradient of a linear model expressing the logarithm of the trend data as a (linear) function of the year in which it was recorded. Hence, over the chosen time period and for a fixed trend variable, the trend value approximates the ratio by which the trend variable changes each year. This was undertaken for:

- the number of households with no cars, one car, and two or more cars
- the population numbers separated into children, working adult, non-working adult and retired adults
- vehicle kilometres travelled by cars broken down into in-work traffic, commuting, and non-work journeys
- vehicle kilometres travelled by buses, LGVs and HGVs
- and population by ten-year age bands

Additionally, both the proportional values and the annual percentage change over each time period (fit using a series of linear models) of these proportional values for the following variables were included:

- population split by employment
- population split by ten-year age bands
- households split by car ownership
- network length split by rurality
- and network length split by free-flowing speed

The following three charts compare observed trend values for casualties (all casualties, KSI casualties, and killed casualties respectively) per vehicle kilometre of traffic (along the x axis) to the values predicted by one of the trained neural networks on data that was withheld from the training of the model (along the y axis). The purpose of these charts is to compare the trained model's predictions directly with real world outcomes. Ideally, these plots should approximate a diagonal line from the bottom left to the top right of the chart, which would show a high degree of correlation between prediction and reality.

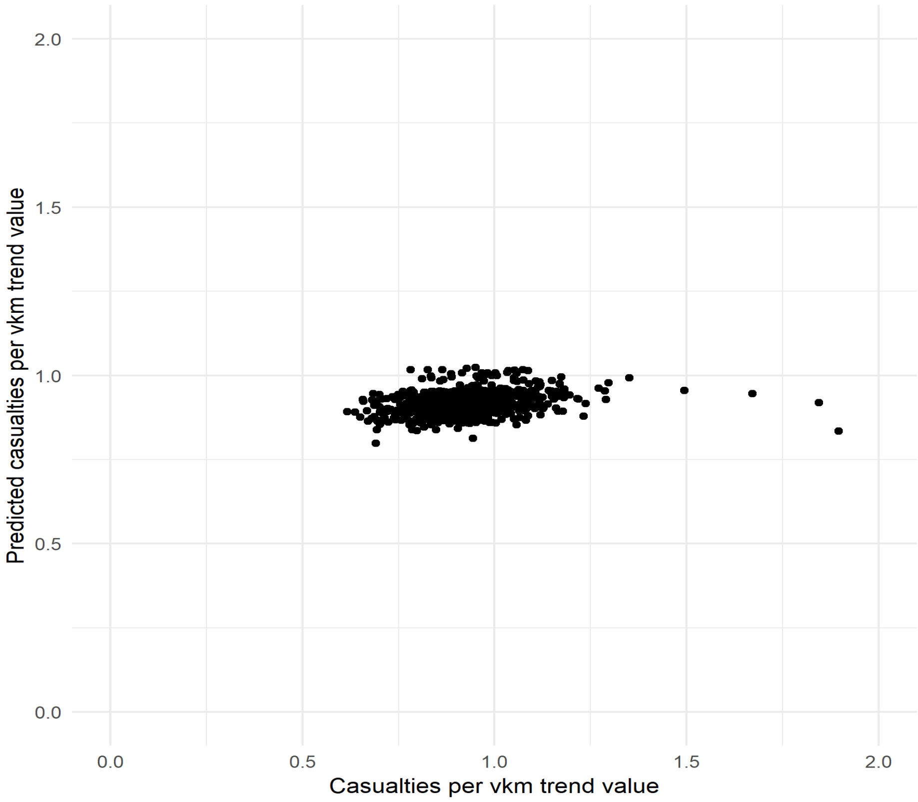


Figure 30 – All casualties, trained versus predicted

For the KSI casualty trend predictions, there is some correlation, but not enough to be deemed a reliable prediction. There is even lower accuracy in the all casualty predictions, although there is still some differentiation in the trend predictions. Unfortunately, the neural network is predicting a singular value for fatality trends, indicating that the model cannot detect a correlation between the input trend data and the observed fatality trends. This is most likely because fatality numbers at the level of TMfS14 Zones are low and trends are more vulnerable to random fluctuation.

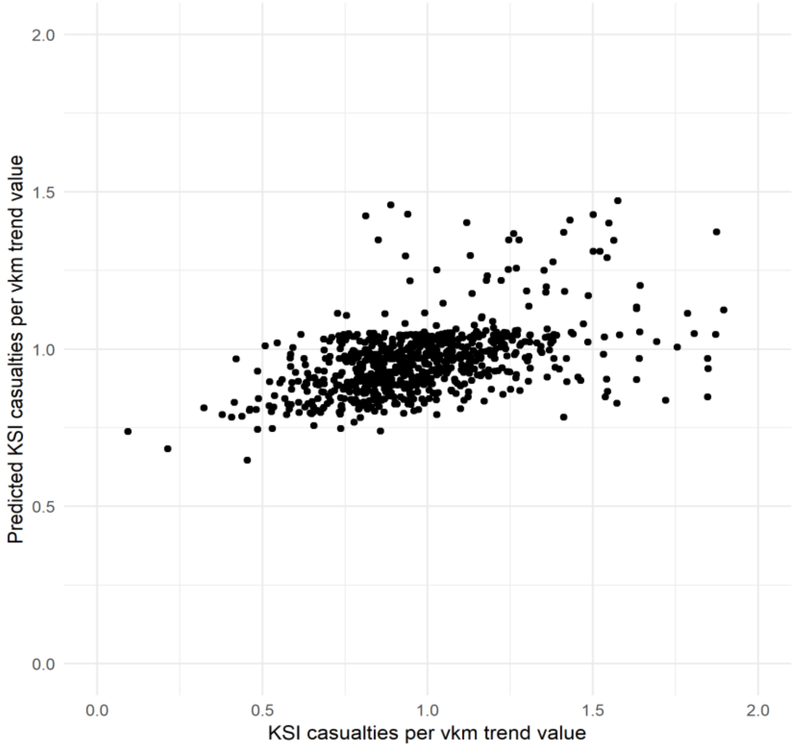


Figure 31 - KSI casualties, trained versus predicted

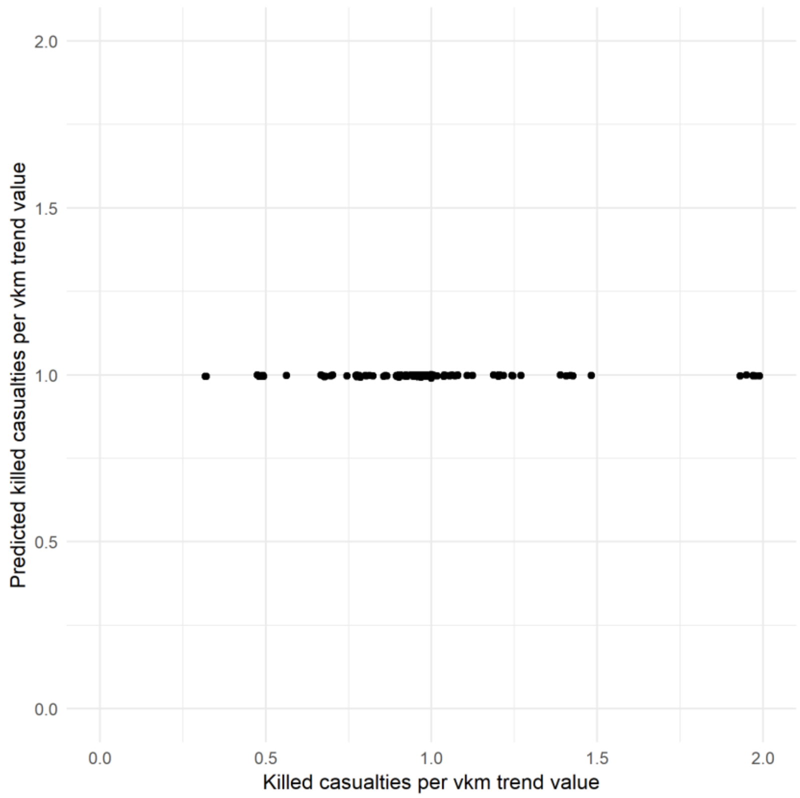


Figure 32 – Killed casualties, trained versus predicted

We believe that there are two main reasons that the neural network could not approximate α to a sufficient level of accuracy.

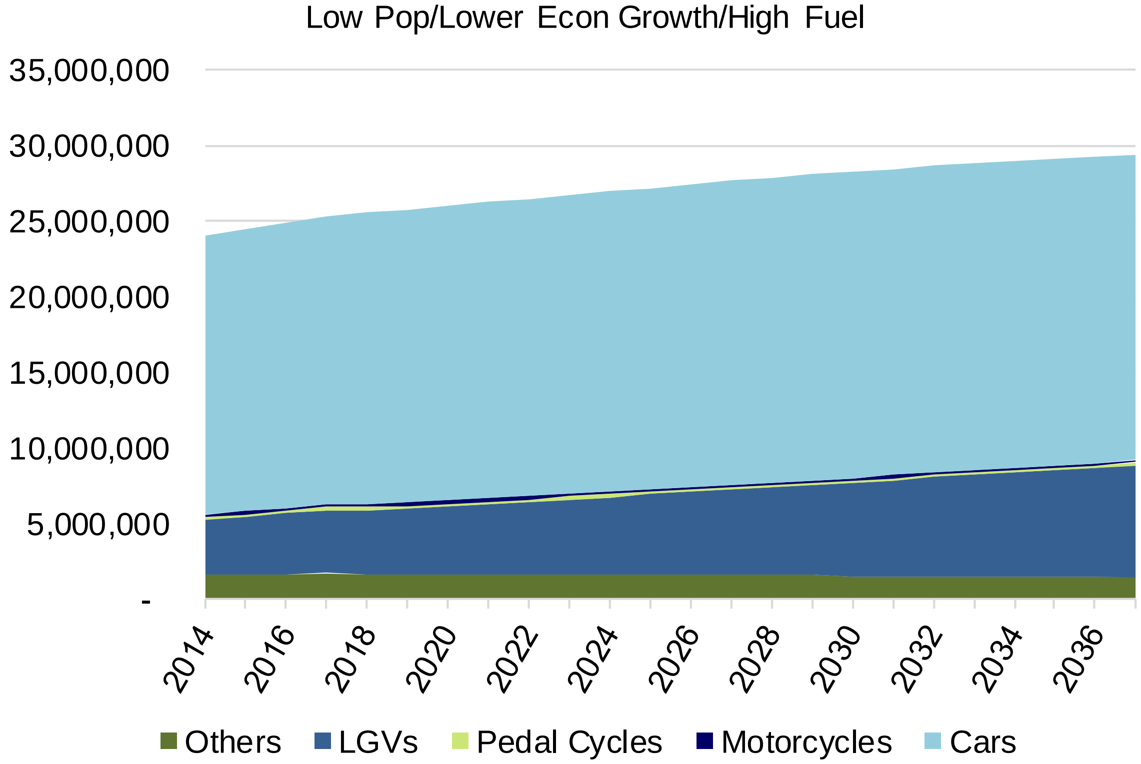
Firstly, there may have been too little variation in the trend data from Zone to Zone. Generally, population levels and traffic flow have increased steadily and are projected to increase into the future, and these trends are largely uniform across the whole of Scotland. It was therefore difficult for the model to use this data to differentiate between Zones. To some extent this is pre-determined by the nature of the data sources. Population data is usually interpolated or extrapolated from periodic census data, and so there is a limit to which trends can vary from year to year. Likewise, the LATIS traffic data is modelled for periodic years and interpolated for the intervening years. It became apparent whilst training a range of neural networks that the most influential variables were the proportional values such as population split by employment and by age bands, households split by car ownership, and network length split by rurality and by free flowing speed, and the trends these proportional breakdowns exhibited. These values allowed the model to more successfully differentiate between the input data to better predict casualty trends.

Secondly, the number of years for which we had historic trend data was limited. The TELMoS data, consisting of car ownership and employment demographics, was provided from 2012 onwards, whilst the modelled flow data from TMfS was provided for 2014 onwards but was extrapolated back to 2012. As a result, the neural network had at most seven years of historic data to learn from. It is possible that longer term historic data could exhibit more varied trends and result in a richer dataset for the model to learn from.

It is important to note that the success of this methodology relies on the assumption that α can be determined by observed trends in other available datasets. This assumption makes sense intuitively, but it is possible that either there is insufficient existing trend data to accurately model α or that trends in casualty rates depend on more than contextual trends alone.

Due to the failure to reliably predict α we are not able to produce casualty predictions using the ANN technique.

Supporting figures and tables for Section 2 - Forecasting Casualty Numbers



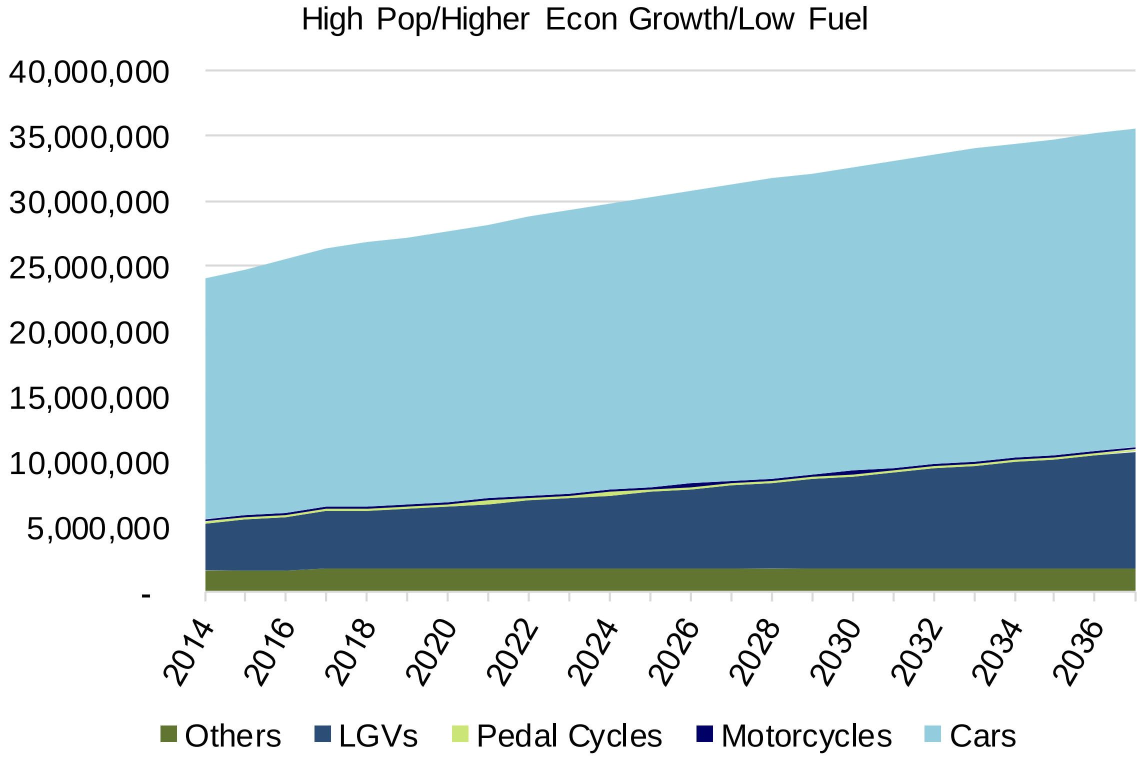
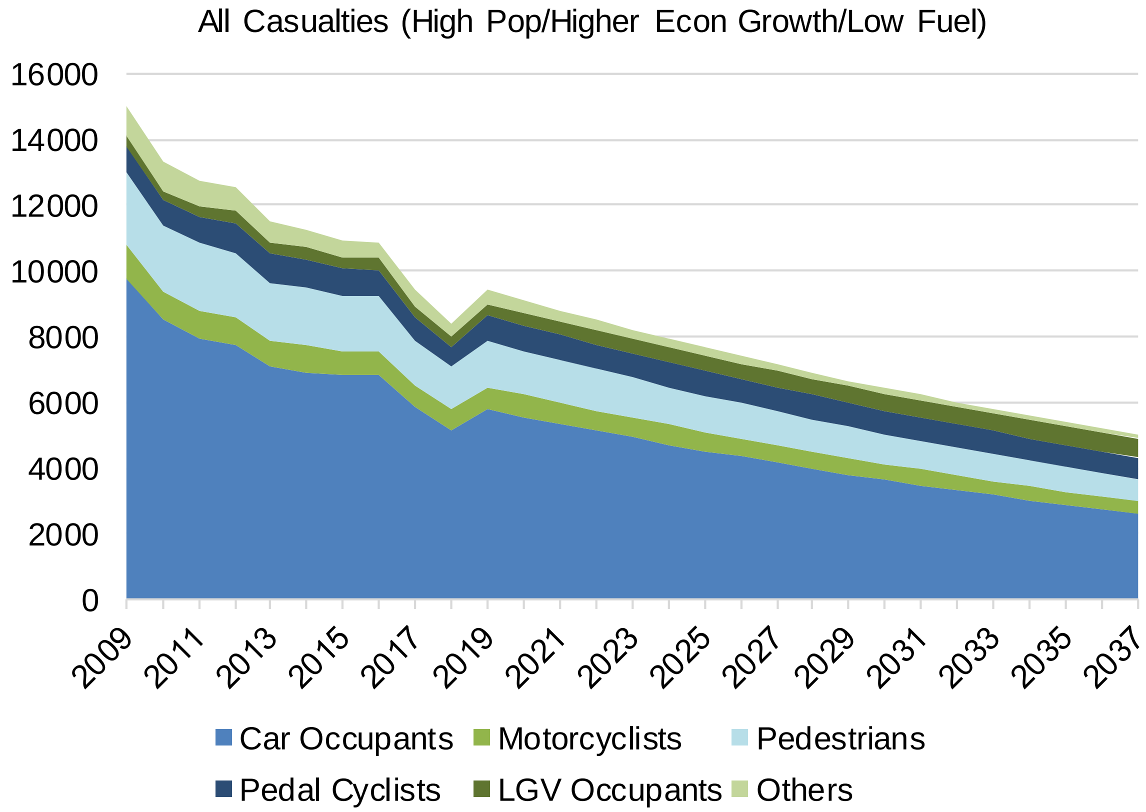


Figure 33 – Alternative traffic growth projections



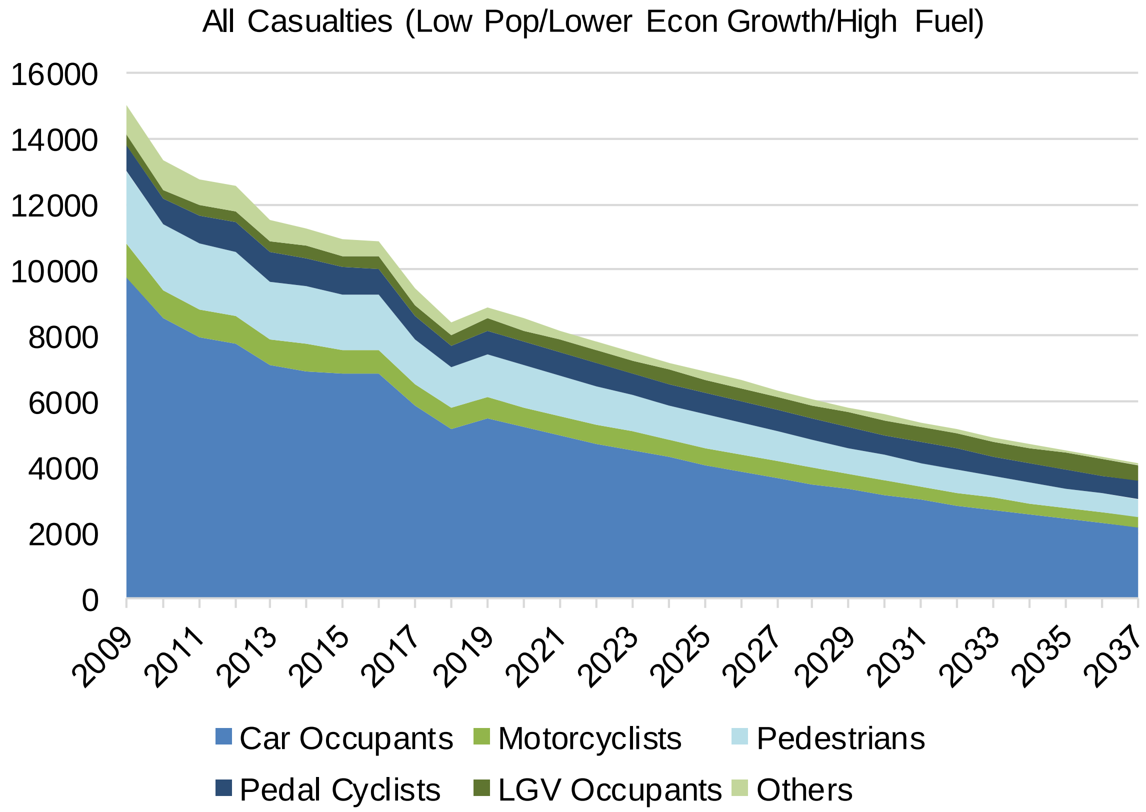
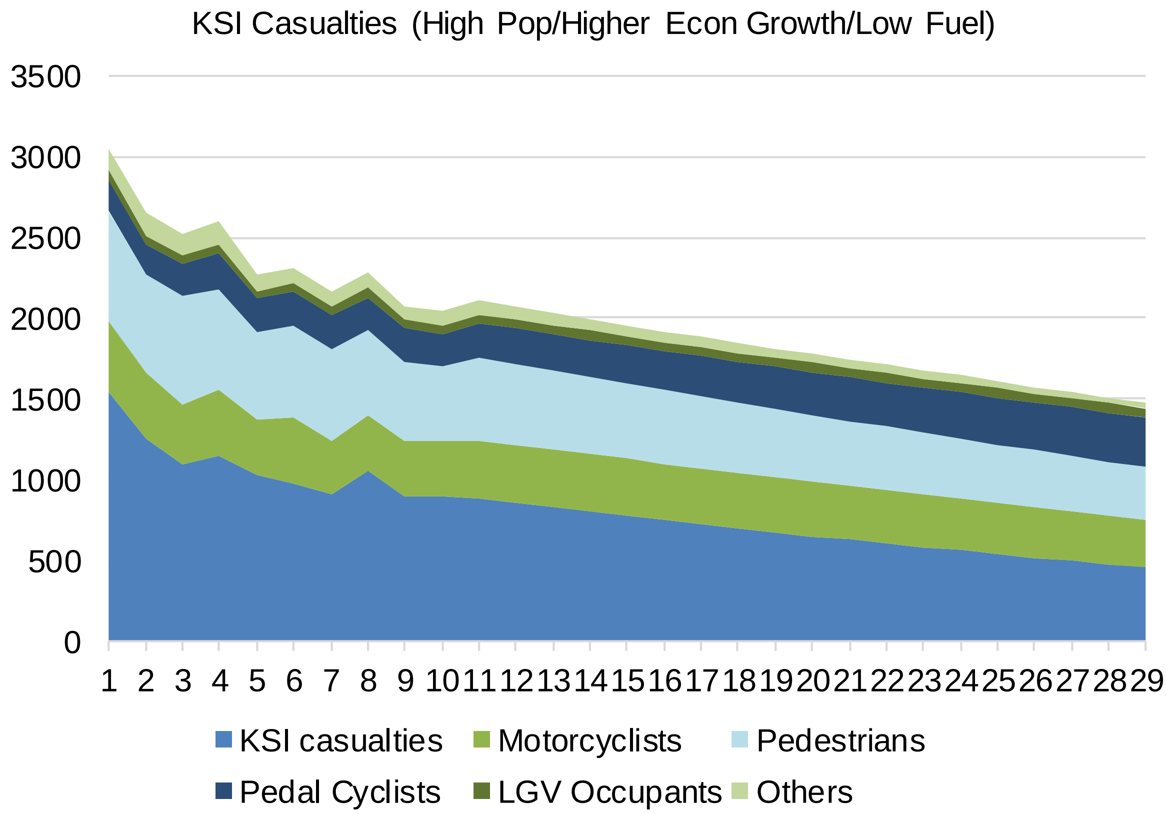


Figure 34 – Alternative scenarios for all casualties to 2037



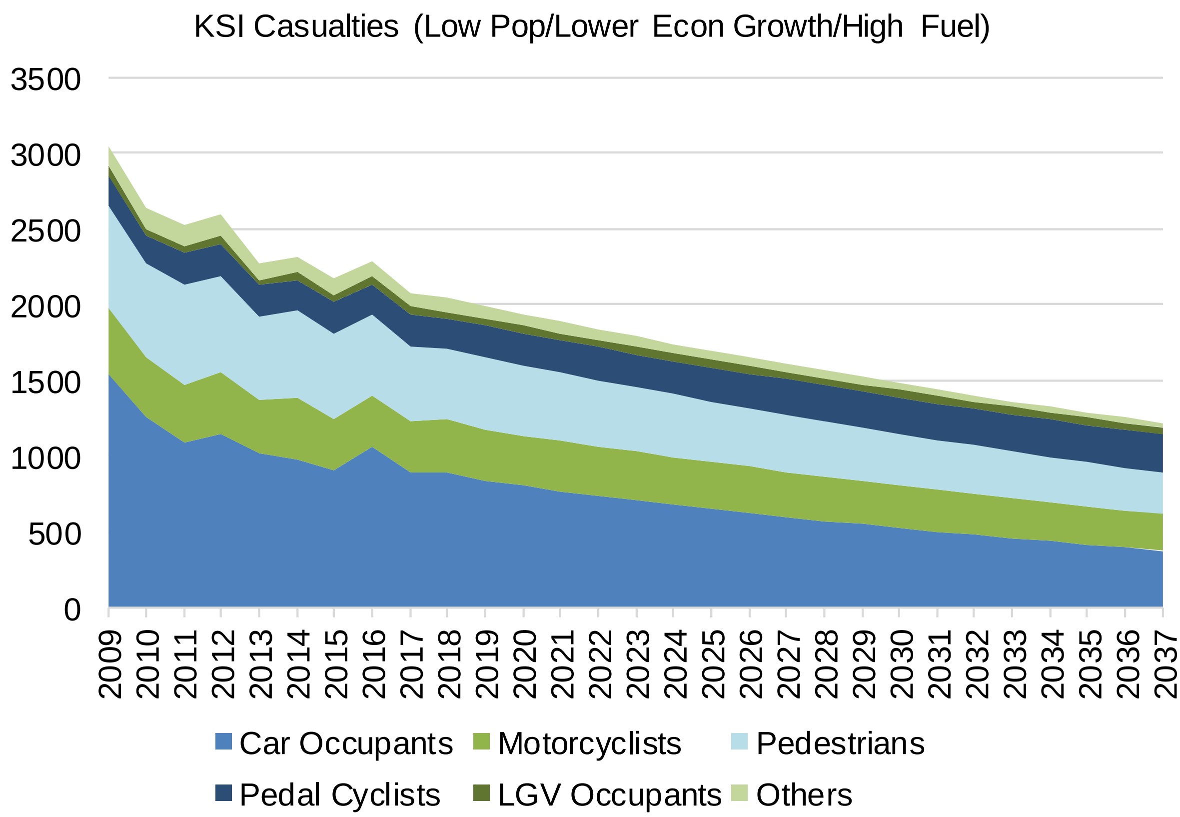
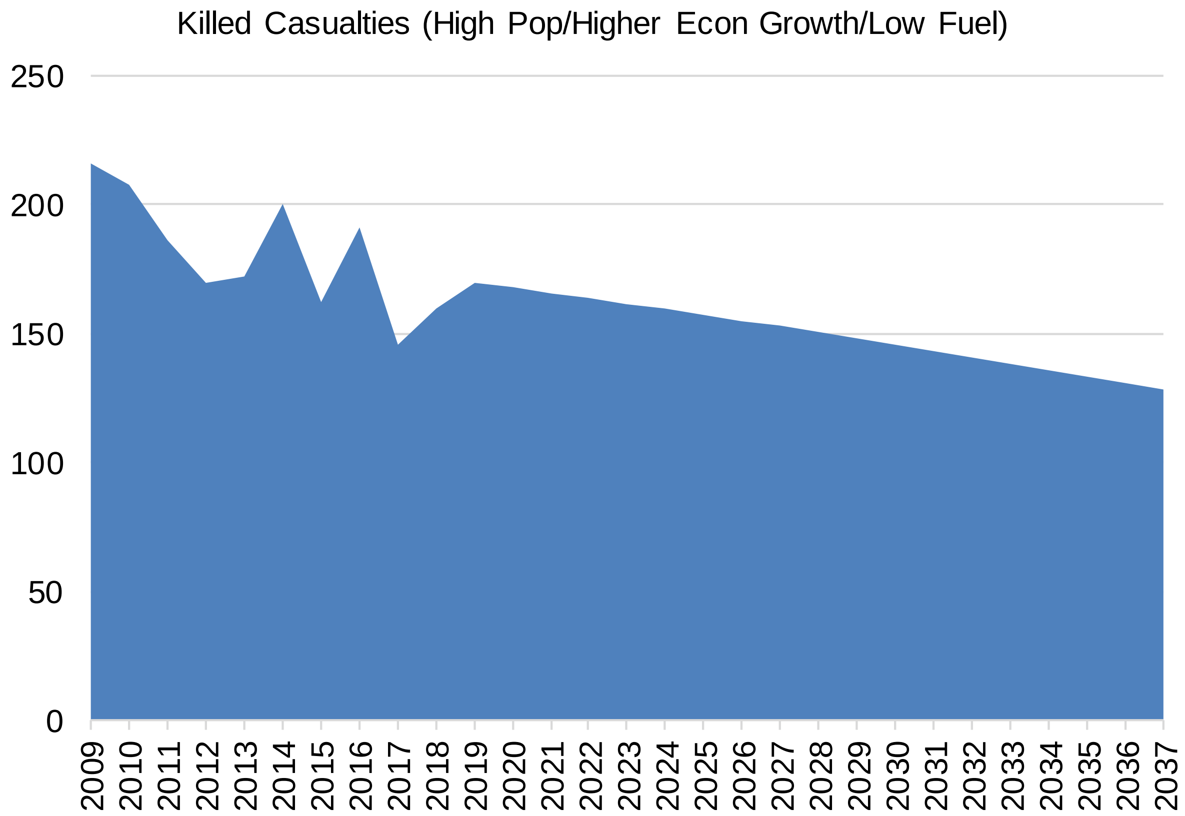


Figure 35 – Alternative flow scenario for KSI casualties to 2037



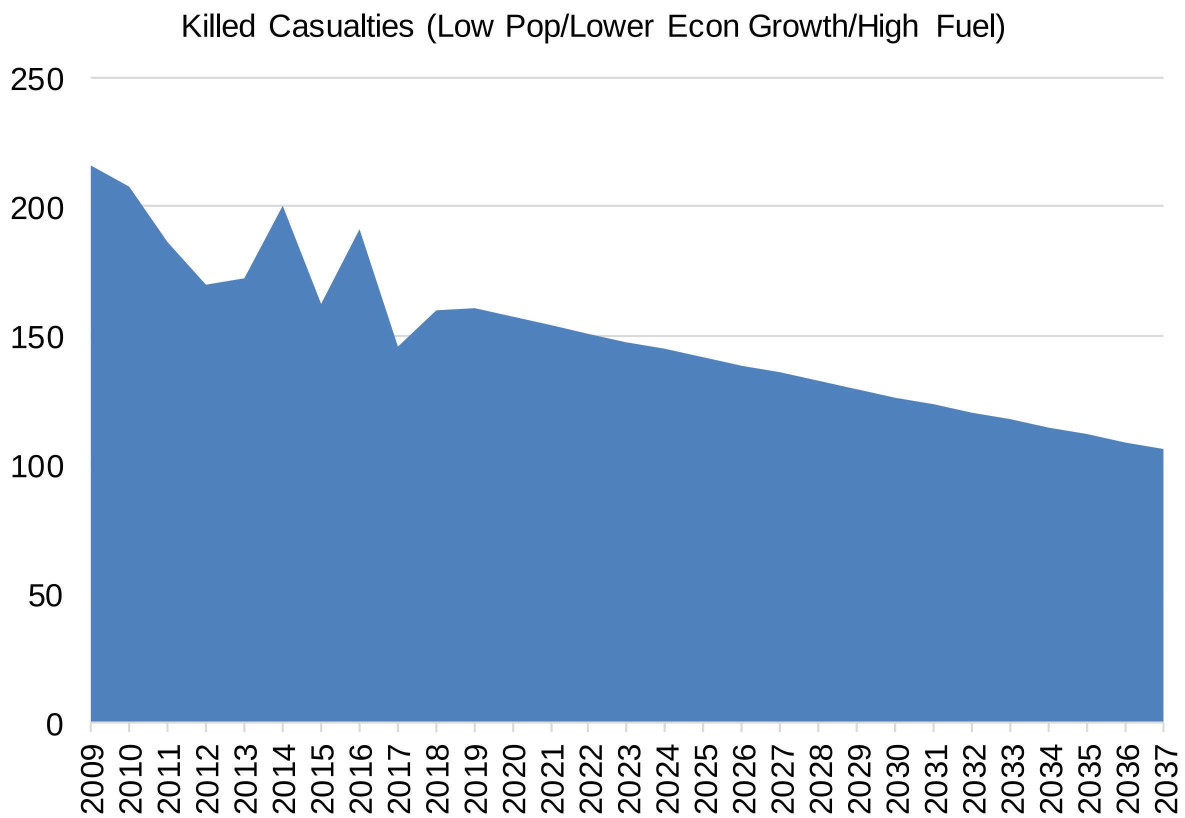
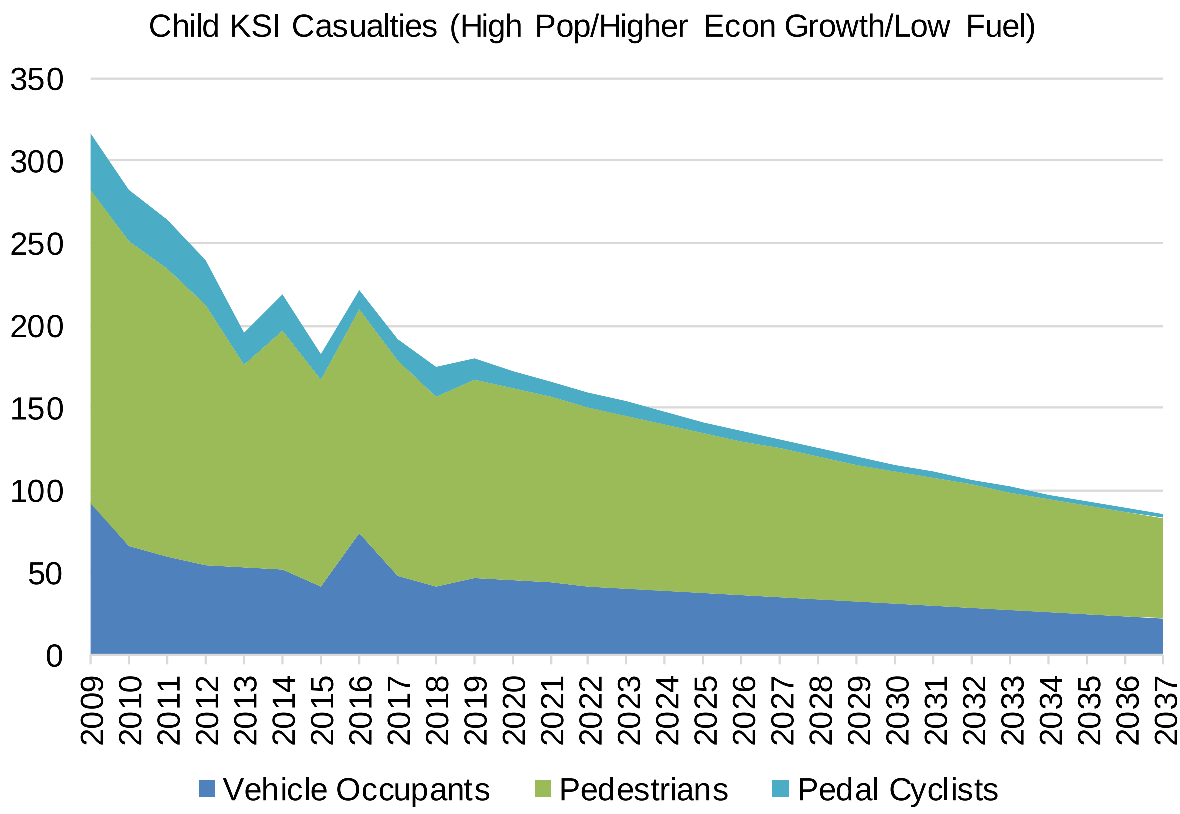


Figure 36 – Alternative flow scenario for fatal casualties to 2037



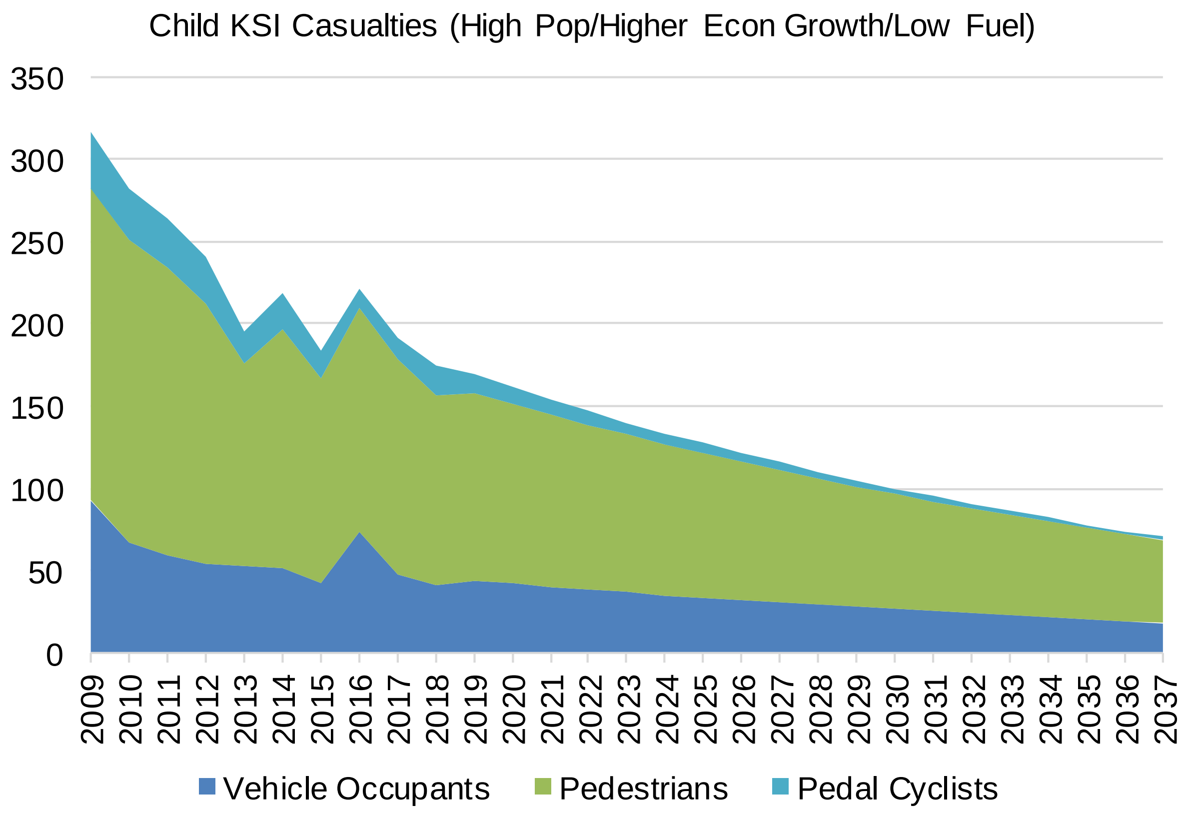
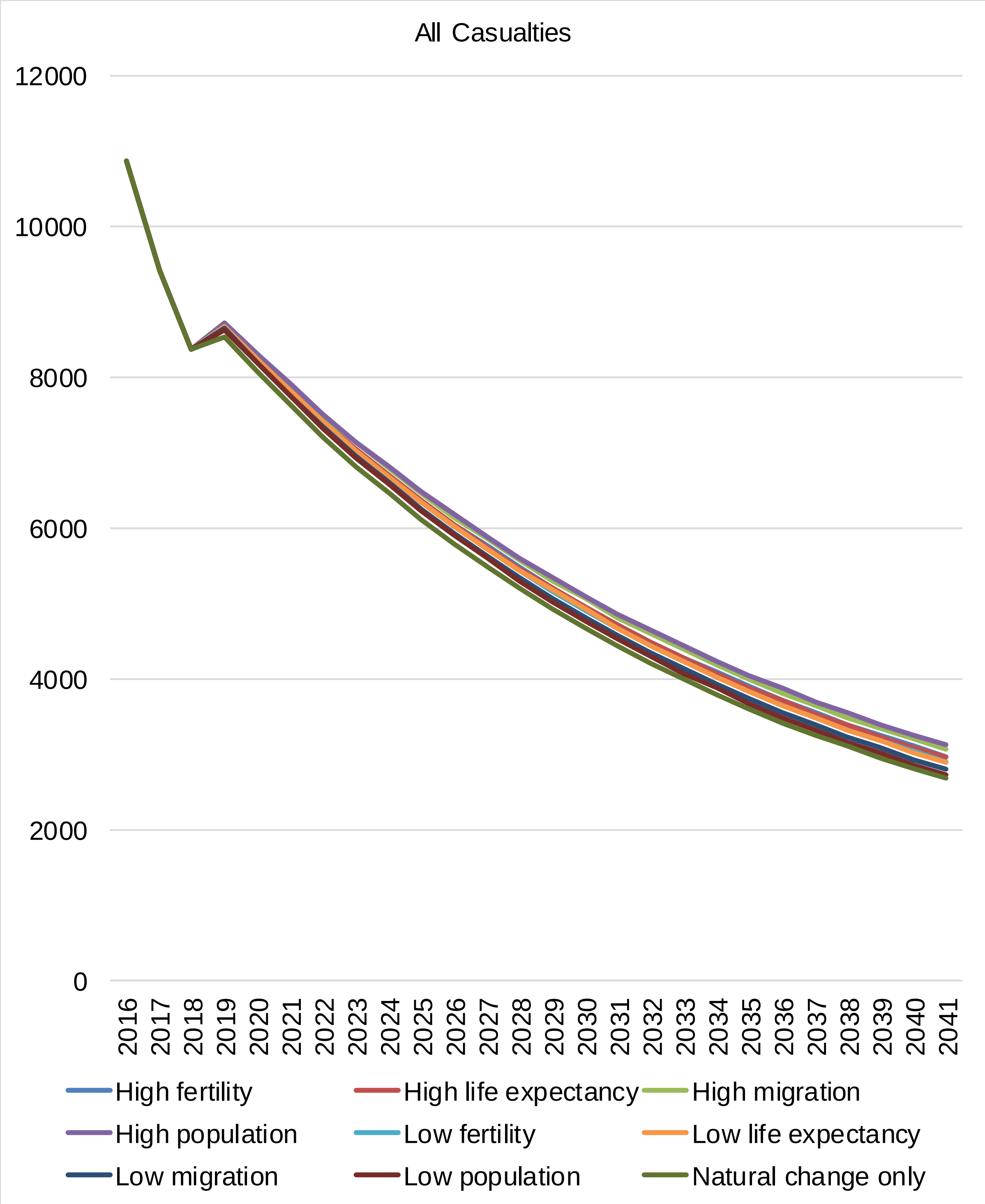
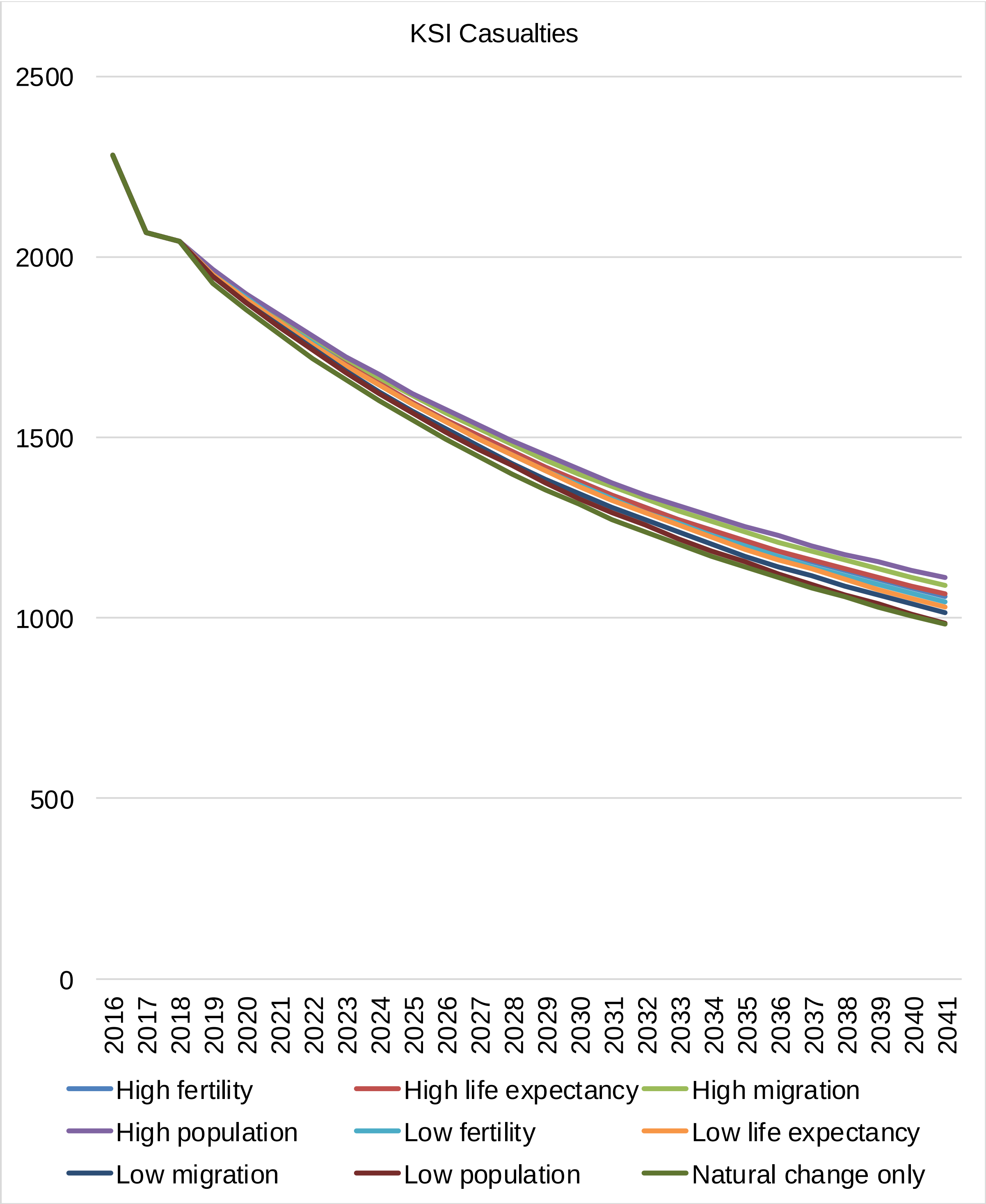


Figure 37 – Alternative flow scenarios for child KSI casualties to 2037


All Casualties
12000
10000
8000
6000
4000
2000
0
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
High fertility
High life expectancy
High migration
High population
Low fertility
Low life expectancy
Low migration
Low population
Natural change only


KSI Casualties
2500
2000
1500
1000
500
0
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
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2039
2040
2041
High fertility
High life expectancy
High migration
High population
Low fertility
Low life expectancy
Low migration
Low population
Natural change only

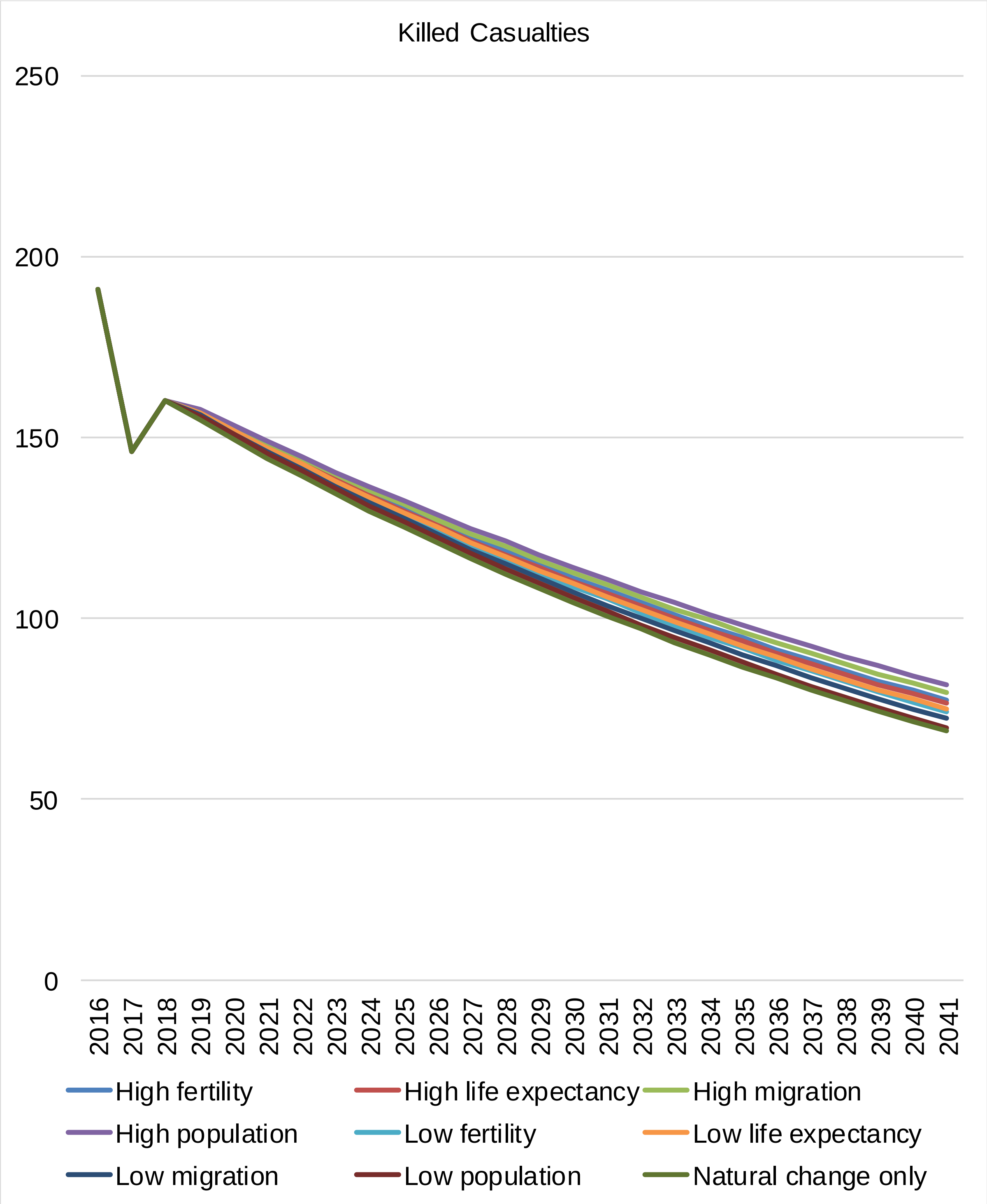

Figure 38 – Alternative population scenarios for casualties to 2030

	Expected Reductions					
Year	**Fatal**	**Serious**	**GSR Fatal Impact**	**GSR Serious Impact**	**GSR Fatal**	**GSR Serious**
2017	100.0%	100.0%	0.0%	0.0%	100.0%	100.0%
2018	99.5%	99.8%	0.0%	0.0%	99.5%	99.8%
2019	99.1%	99.5%	0.0%	0.0%	99.1%	99.5%
2020	98.6%	99.1%	0.0%	0.0%	98.6%	99.1%
2021	98.1%	98.7%	0.0%	0.0%	98.1%	98.7%
2022	97.5%	98.2%	0.0%	0.0%	97.5%	98.2%
2023	96.9%	97.8%	0.3%	0.1%	96.6%	97.6%
2024	96.3%	97.3%	1.1%	0.6%	95.1%	96.7%
2025	95.6%	96.8%	2.2%	1.1%	93.4%	95.7%
2026	95.0%	96.3%	3.3%	1.7%	91.7%	94.6%
2027	94.2%	95.7%	4.4%	2.3%	89.8%	93.4%
2028	93.5%	95.2%	5.5%	3.0%	88.0%	92.2%
2029	92.7%	94.6%	6.6%	3.6%	86.2%	91.0%
2030	92.0%	94.1%	7.6%	4.3%	84.4%	89.8%

Table 14 – Predicted impact of EU General Safety Regulations in Scotland

Measure	Definition	First year of Implementation	Target population applicability	Correction factor	Target population proportion (%)			Effectiveness (%)			2030 fleet penetration estimate (difference between 2017 and 2030) (%)		Total effectiveness free (%)			Total effectiveness enforced (%)		
					Fatal	Serious	Slight	Fatal	Serious	Slight	Free	Enforced (mandatory)	Fatal	Serious	Slight	Fatal	Serious	Slight
AEB-VEH	Autonomous emergency braking for vehicles (moving and stationary targets)	2009	Casualties in two motor-vehicles	1	51.28	44.21	62.65	19	19	42	30	45	2.92	2.52	7.89	4.38	3.78	11.84
AEB-PCD (p)	Autonomous emergency braking for pedestrians	2012	Front vehicle impact with pedestrians	1	18.45	14.03	6.36	24.4	21	42	25	50	1.13	0.74	0.67	2.25	1.47	1.34
AEB-PCD (C)	Autonomous emergency braking for cyclists	2015	Front vehicle impact with cyclists	1	1.86	3.61	2.98	27.5	16.4	32.8	25	50	0.13	0.15	0.24	0.26	0.3	0.49
ALC	Alcohol interlock	2019	Casualties in two motor-vehicles	0.75				4.2	4.2	4.2								
EDR	Event data recorder	2006	Cars and vans occupant casualties in all motor vehicle collisions	1	67.87	66.87	82.26	1	1	1	20	40	0.14	0.13	0.16	0.27	0.27	0.33
ESS	Emergency stop signal	2010	Casualties in two motor vehicle collision, front-to-rear, speed limit > 30 mph	4.5	3.25	2.98	7.6	5	10	20	40	55	0.29	0.54	2.73	0.4	0.74	3.76
ISA-VOL	Intelligent speed assistance - voluntary type system	2015	Casualties where only speed limit related CFs are recorded	4.5	10.33	4.61	2.98	19	19	19	40	55	3.53	1.58	1.02	4.86	2.17	1.40
ESC	Electronic stability control	1996	Loss of control crashes (casualties in loss of control crashes)	1	36.77	19.65	12.57	38	21	21	15	25	2.1	0.62	0.4	3.49	1.03	0.66

Table 15 – Predicted impact of specific vehicle technologies in Scotland

GSR Adjusted KSI Casualties	KSI Casualties	Child Casualties	Young Adult Casualties	Older Road User Casualties	Other Ages Casualties	Car and Taxi User Casualties	Pedestrian Casualties	TWMV User Casualties	Pedal Cycle User Casualties	LGV User Casualties	Other Road User Casualties
Baseline	2175.4	198.0	370.5	371.3	1235.7	947.5	524.1	354.4	205.5	50.4	93.5
2019	2042.7	177.5	291.4	384.3	1189.6	856.9	490.5	351.8	211.4	51.1	80.9
2020	1990.0	169.6	268.1	386.7	1165.6	823.6	477.0	346.5	214.8	51.2	76.9
2021	1936.7	161.4	246.6	389.3	1139.3	790.5	463.2	340.9	217.9	51.2	73.0
2022	1883.4	153.0	226.4	392.5	1111.5	757.8	449.4	335.0	220.7	51.1	69.3
2023	1823.5	144.3	208.8	393.7	1076.7	723.1	434.0	327.6	222.6	50.8	65.4
2024	1758.0	135.0	193.0	393.0	1037.0	686.7	417.2	318.9	223.4	50.3	61.4
2025	1690.3	125.7	178.8	390.7	995.1	650.2	399.9	309.5	223.6	49.6	57.5
2026	1622.1	117.1	165.3	387.9	951.8	614.2	382.4	299.7	223.2	48.8	53.7
2027	1553.3	108.3	153.8	384.3	906.8	578.7	364.9	289.4	222.3	47.9	50.1
2028	1483.2	100.1	142.2	379.9	861.1	543.6	347.1	278.6	220.6	46.9	46.5
2029	1414.4	92.4	130.4	374.7	816.8	509.6	329.5	267.8	218.6	45.8	43.1
2030	1347.3	85.3	119.0	368.8	774.2	477.1	312.5	256.9	216.3	44.6	39.9
Reduction from baseline	-38%	-57%	-68%	-1%	-37%	-50%	-40%	-27%	5%	-11%	-57%

Table 16 – Predicted impact of GSR on KSI casualties in different road user and age groups in Scotland

Year	Killed	Serious
2019	164.3	1879.4
2020	160.9	1830.6
2021	157.4	1781.4
2022	153.9	1732.5
2023	149.5	1678.0
2024	144.2	1619.3
2025	138.6	1559.1
2026	132.8	1498.4
2027	126.9	1437.5
2028	120.9	1375.5
2029	115.0	1314.6
2030	109.1	1255.4

Table 17 – Final predicted killed and seriously injured casualty totals per year

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