Road Safety Research Report No. 105

Road Safety Strategy Beyond 2010: A Scoping Study

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EXECUTIVE SUMMARY

This report follows on from a presentation given to Department for Transport delegates at a meeting on 8 November 2007. It brings together and expands on inputs from those presenting papers at that meeting. The work reported on draws together research across some of the core disciplines related to road safety. It does not report on any new research.

The context for setting road safety policy encompasses many fields and considerations. To address these fully is beyond the scope of this report. Some of the key considerations—population, traffic, non-road modes and technology—are raised. For example, different population groups (with different road risk, choosing different vehicles and with different resilience to collisions) are growing at different rates. This can be expected to exhibit some control over accident numbers and severities going forward. These differences suggest that changes to test procedures may be required to ensure that vehicles are designed appropriately for users going beyond medium-sized adults.

The Transport Research Laboratory (TRL) report The Numerical Context for Setting National Casualty Reduction Targets (TRL Report No. 382, see Broughton et al., 2000) presents the details of the method used to aid development of the road safety casualty reduction targets set for 2010. This report reviews the progress towards those targets and considers improvements to the method used.

Visions for road safety are used in a number of countries, including Sweden and the Netherlands. The motivation and nature of visions from other countries is examined and their implications for road safety practice, policy and strategy are reviewed and considered. Slowing progress in fatality reduction and the need for a new approach to address stalling risk reduction can act as motivation for considering the benefits of a vision in Great Britain.

In order to develop thinking on the practicalities of using a vision for road safety in Great Britain, consideration is given to how targets, infrastructure, behaviour, institutions and public opinion interplay with a vision. For example, scheme evaluation or prioritisation tools and approaches familiar to road safety practitioners need to fit in with the vision.

Good progress has been made through engineering interventions over the recent past. Despite this, there is still much scope for engineering to play a significant role beyond 2010. Even on arguably the safest roads (motorways), investment in the protection of nearside hazards would still yield a benefit to a cost ratio of around 10:1.
The benefits from engineering have been achieved through a broad range of intervention types. This review brings together evidence on the historical effectiveness of these different interventions and reviews their likely efficacy going forward beyond 2010. In rural environments, most benefits are to be gained from speed management, road restraint systems, simple measures at bends such as the WYLIWYG (Where You Look Is Where You Go) approach, vehicle-activated signs (VAS) and crash-friendly signposts/columns. For urban roads, the best benefits are likely to come from passive furniture, speed cushions and 20 mph zones.

While the economic case for engineering schemes is traditionally viewed as more clearly made than for education or enforcement schemes, further improvements could be made. For example, consideration of the value time and staff resource could be included as well as the longevity of the benefits of the schemes considered, particularly with respect to business cases.

A great many new vehicle safety measures have been implemented in recent years, many of which have not yet fully penetrated the UK vehicle fleet. The report reviews and presents reported safety benefit results from a large number of these. As penetration increases in future, further casualty reductions are expected to be derived from these measures. One of the measures expected to have the highest future benefit is Electronic Stability Control (ESC).

Further improvements are expected to be derived from new secondary safety measures. However, an ageing population could make this task more difficult and carries a risk of casualty increases.

Active and integrated safety systems have a very large potential for casualty reductions. Systems such as intelligent speed adaptation, collision mitigation braking and collision avoidance are expected to produce substantial benefits. However, there are also a range of risks and barriers to introduction that need to be adequately resolved before the full benefit of such systems could be achieved.

Overall it can be concluded that some of the systems discussed have significant safety potential. The systems related to longitudinal vehicle control, affecting speed and rear-end conflict situations, are perhaps the most mature in technical terms and offer the greatest benefit. Systems addressing road departure are less mature (certainly less reliable from a technical point of view, with many more missed situations and false alarms) and are relevant to fewer accident situations, although such events can have very serious outcomes. The proposition that eCall will have a large impact on fatalities is not convincing, and there are doubts about the benefit-to-cost ratio for the system.

Going forward there is a need to recognise the importance of integrating any road safety strategy and vision with other policy areas, and to further recognise the challenges described by the Eddington (2006) and Stern (2006) reports. Any road
safety strategy, whether or not in pursuit of a vision for road safety, should reflect the need to understand and improve road safety in the context of the full end-to-end journeys of people and movements of goods, and to do so in ways that are consistent with an overall reduction in emissions and support for economic growth.

Furthermore, appropriate performance indicators should be selected with the following characteristics:

- the level of the indicator should be transparently susceptible to improvement through cost-effective road safety activity and proof against influence by activity that has no beneficial impact on road safety;
- improving the level of the indicator should contribute incontrovertibly to casualty reduction; and
- the indicator should be measurable unambiguously and reliably in ways that are understandable by the public and at a cost which is clearly only a very small proportion of the resource devoted to road safety activity to improve the level of the indicator.

In seeking and winning commitment across and beyond government to vision and strategy for road safety, it will be helpful to emphasise the contribution that radically enhanced road safety with radically reduced death and injury on the roads can make to the five broad goals set out in the White Paper *Towards a Sustainable Transport System* (Department for Transport, 2007a):

- the competitiveness and productivity of the economy;
- addressing climate change;
- improving people’s safety, security and health;
- the quality of life; and
- promotion of greater equality of opportunity.

In all of these ways, a newly invigorated determination to bring down the risk of death and injury on the roads from its still disproportionate level will contribute directly and substantially to evolving transport policy and the wider quest for sustainable prosperity and equity.
1 INTRODUCTION

The objectives of this report are:

- to review areas of research relating to vehicle technology, road safety engineering and casualty forecasting methods; and
- to review international practice in these areas and the role of visions in road safety strategy development.

The report makes initial recommendations based on this review. The purpose of these recommendations is to generate consideration of recent developments and approaches to inform the development of a road safety strategy beyond 2010.

This report is primarily aimed at looking forward, beyond 2010, to give consideration to some of the drivers of trends in road accidents and casualty numbers. In service of this aim, some of the drivers of road use and risk are introduced for context, and a brief review of the forecasting process and progress towards the current 2010 casualty reduction targets is given.

Following this, consideration is given to the purpose and applicability of a vision for road safety beyond 2010, along with an overview of the potential for casualty reduction through road safety engineering and vehicle technologies.

The report brings together material that was presented to delegates from the Department for Transport on 8 November 2007. A wide variety of reports and publications has been used to bring this material together. Little critical analysis of the findings in these reports and publications has been possible as part of this work.

1.1 Demographics

The Office for National Statistics has recently published population forecasts up to and beyond 2020. Population growth is a key driver of road use, and the make up of the population is a key driver of road use and behaviour. Figure 1.1 shows growth forecasts for all ages, those over 65 years of age, and males aged 17–25 (Government Actuaries Department, 2007).
The population overall is forecast to rise by around 10% over the period 2006–20. However, the chart also shows that different groups within this growth have different growth forecasts. For example, the number of males aged 17–25 years old (a high-risk group in terms of accident liability) in the population is forecast to peak in around 2012 and then decline back to current levels around 2017, before falling to levels below those of today. Also, the number of people aged over 65 (a lower-risk group in terms of accident involvement, but not necessarily in terms of accident outcomes) is forecast to grow by over 30% between 2006 and 2020. Table 1.1 shows the different growth rates for these two groups alongside the current proportion of the population and casualties in these groups (Department for Transport, 2007b, 2007c).

### Table 1.1: Population growth and proportion of population and accidents for over 65s and males aged 17–25

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<th>Growth 2006–20 (%)</th>
<th>2006 population (%)</th>
<th>2006 casualties (%)</th>
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<td>Over 65</td>
<td>31</td>
<td>15</td>
<td>7</td>
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<td>Males 17–25</td>
<td>–3</td>
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### 1.2 Congestion, journey times and traffic

Figure 1.2 shows the forecast increases in congestion, journey time and traffic over the period 2010 to 2025, from the National Transport Model (Department for Transport, 2007c).
This has implications for accident and casualty numbers. For example, the traffic growth forecast differs for different modes which have different accident risk associated with them. Figure 1.3 shows how forecasts of traffic growth vary by mode, with large goods vehicle (LGV) traffic growth expected to be 67% up on current levels by 2025, but heavy goods vehicle (HGV) traffic growth to 2025 forecast at 12%.

As with different road users, where different growth is forecast for different vehicle groups (with different risk profiles), different accident and casualty numbers may arise. Modelling how these different growth rates impact on expected levels of accidents and casualties is not part of this project, but should be considered in a more complete modelling exercise.
1.3 Other modes

In addition to differences in accident liability by road-based vehicle modes, and groups within the road-user population, the changing importance of other modes provides further context for future travel and accident patterns. For example, as Figure 1.4 shows, air and rail passenger kilometres are forecast to grow significantly (Department for Transport, 2004a). The types of journey made by non-road modes will differ from those made by road-based modes. This may change the average risk profile of road-based trips.

The risk levels (casualties per billion passenger kilometres (bpm)) differ between these modes. At a high level it appears that the greatest growth is forecast for the modes with, currently, the lowest risk (Department for Transport, 2007b) see Table 1.2.
1.4 Technology

The technologies considered in this report are primarily those directly focused on improving the safety of vehicle occupants and vulnerable road users. There are a wide variety of other technology developments that may come to the fore over the period 2010-20 that are not primarily aimed at reducing accident numbers or severities of outcome. For example, insurance based on the times of day that vehicles are used, road-user charging, driver information technologies and navigation devices. Furthermore, there are technologies associated with improvements in enforcement which are not considered in any great detail in this report. For example, developments in evidential breath testing, automatic number plate recognition and database developments linked to enforcement.
1.5 Behaviour

This report focuses primarily on the accident and casualty reduction benefits that might be achieved over the period to 2020 through engineering and vehicle technology improvements. Driver behaviour should be considered fully alongside developments in these fields: it is vehicles and the roads that moderate driver behaviour. In this report, aspects of driver behaviour relating to, for example, HMI (human machine interface) and driver overload are considered alongside the primary focuses of engineering and vehicle technology. Some of these results can be found in Sections 3.7.3, 4.3.5.2, 5.5.3 and 7.7.

1.6 Targets

Targets and performance indicators are discussed in Sections 2.3 and 3.7. Broughton J (2009) Post-2010 Casualty Forecasting will cover the targets and will be published by the DfT in parallel with this document.
2 PROGRESS TOWARDS 2010 TARGETS/ TRENDS, FORECASTS AND POST-2010 TARGETS

2.1 The TRL 382 methodology

The 2010 casualty reduction target was informed by a range of casualty forecasts that were developed around 10 years ago. These were based on:

- analyses of disaggregate casualty trends from 1983–98 which took account, as far as possible, of the known effects of road safety measures;
- extrapolation of these trends to 2010;
- ‘transport scenarios’ that represented alternative views of the volume of road transport in 2010, in particular traffic growth; and
- the likely effects of new road safety measures that might be introduced by 2010.

The analyses and results are described fully in TRL Report No. 382, *The Numerical Context for Setting National Casualty Reduction Targets* (Broughton et al., 2000), and are briefly summarised below. The analyses needed to be disaggregate because the effects of many road safety measures are specific to certain road-user groups, but on the other hand relatively large groups were needed in order to increase the likelihood of identifying stable trends. The groups chosen were:

- car occupants;
- motorcyclists;
- pedestrians;
- pedal cyclists; and
- others.

The basic unit of analysis was the rate of casualties per billion vehicle-kilometre for these road-user groups. Analysis of data from 1983–98 showed that these rates had generally fallen reasonably steadily through the period, and Figure 2.1 illustrates a typical albeit important example. As the red line shows, the rate fell each year between 1984 and 1998 by a percentage that scarcely changed.
The regularity with which the rate has changed in the past means that it is reasonable to assume that the past pattern of change will continue in future. Under this assumption, the number of casualties in a future year $Y$ can then be estimated in two stages:

- predict the casualty rate in year $Y$, as illustrated by Figure 2.2 for $Y = 2010$; and
- multiply the casualty rate prediction by the official traffic forecast year $Y$.

Clearly, the forecast will only be as reliable as this assumption, and Figure 2.2 presents a case where the assumption has proved incorrect, i.e. the trend after 1998 differed from the pre-1988 trend.
This basic approach to forecasting took no account of the effects of road safety measures, and it was important to incorporate such effects where they could be estimated reliably. The effects of only three types of measure could be estimated reliably:

- improved standards of secondary safety in cars;
- measures to reduce the level of drink-driving; and
- road safety engineering.

These were known as the ‘DESS’ measures (drink-driving, engineering, secondary safety) and the remainder were grouped together as the ‘core’ measures. The road safety measures that might be included in any new road safety strategy can be grouped as follows:

- the DESS measures;
- the core programme; and
- new measures, including all measures which are either innovatory or a substantial expansion of existing measures.

To allow for uncertainty over the future level of road use by the various transport modes, a series of ‘transport scenarios’ were defined. Each scenario consisted of predictions for the year $Y$ of the levels of traffic (all motor vehicles, cars, motorcycles) and of pedestrian and pedal cycle activity. The stages of the procedure for forecasting the consequences of a new road safety strategy for a specific transport scenario were:

- estimate casualty rates in year $Y$ to show what would be expected if there were no further DESS measures and only the core road safety activities were undertaken at the current level;
- prepare a baseline casualty forecast using these estimated rates together with predictions of the volume of road travel in year $Y$; and
- apply the assumed effects of the measures in the new road safety strategy (including any further DESS measures) to the baseline forecast.

The parameters required for the first step are the expected rates of change of the various adjusted casualty rates over the forecasting period. The term ‘adjusted’ refers to the statistical adjustment of the actual rates to remove the effects of the DESS measures, i.e. these adjusted rates estimate what would have been found in the absence of the DESS measures.

The forecasts for the five road-user groups were then summed. The main forecasts were of KSI (killed or seriously injured) and slight casualties, and fatality forecasts were also prepared. Figure 2.3 gives an overview of the results, with one point
representing the KSI and slight forecasts for each of 36 transport scenarios. For example, the top-right circle labelled ‘b’ shows that, for this combination of traffic growth, the number of slight casualties would rise 22% above the 1994-98 average (the baseline for the target setting) while the KSI total would fall by 42% relative to the 1994-98 average. Clearly, the casualty forecasts are sensitive to the assumptions made about future traffic growth, although it was recognised that some assumptions were more credible than others. Note that the national target adopted in 2000 of reducing KSI by 40% (DETR, 2000) corresponds to a KSI forecast of 60%, i.e. the upper edge of Figure 2.3.

### Figure 2.3: Forecast for KSI and slight casualties in 2010 36 transport scenarios

**Motorcycling assumptions**
- × 1995 level (B)
- * 25% less (A)
- • 50% more (C)

**Forecast for slight casualties**
- 85% 95% 105% 115% 125%
- 40% 45% 50% 55% 60%

2.2 **Checking the TRL 382 forecasts**

After the casualty reduction target for 2010 was announced in March 2000, the Transport Research Laboratory (TRL) was commissioned to monitor progress towards the target. Consequently, the forecasts have been re-examined annually, using the most recent casualty and exposure data. TRL Report No. 663, *Monitoring Progress Towards the 2010 Casualty Reduction Target 2005 Data* (Broughton and Buckle, 2007), presents the results with data to 2005. Thus, the reliability of the TRL 382 forecasts has been checked annually against the actual data. This provides important guidance when deciding whether to apply the same approach when considering potential future targets.
Figure 2.4 provides one example. The solid squares show the actual rates from 1999, while the open squares show the data upon which the forecast was prepared. The red line shows the forecast based on extrapolation of the 1983–98 trend, while the blue line is based on 1991–98. There was much debate over whether to base the forecast on the 1983–98 or 1991–98 trend, and the latter was chosen in this case. The choice was more difficult for other casualty groups and had greater consequences. Clearly, the forecast rates for pedestrian KSI rates have proved remarkably reliable so far.

The forecast rates for car occupant KSI rates are shown in Figure 2.5, and have a different pattern. The forecast was based on the red line, the 1983–98 trend. This was followed until 2002; the later points lying below the red line show that, in these...
years, there were fewer casualties than had been forecast, so may be evidence of new measures improving the safety of this group.

The KSI forecasts have proved generally reliable. TRL Report No. 663 (Broughton and Buckle, 2007) presents updated KSI forecasts for 2010 which suggest that the target of reducing KSI by 40% (relative to the 1994–98 baseline) by 2010 will be achieved. The updated fatality forecasts suggest, however, that the number of deaths will fall by less than 20%.

The main reason for the divergence of the overall fatality and KSI trends is that the car occupant fatality trend has been much less consistent than the KSI trend. Figure 2.6 shows that this fatality trend changed in the mid-1990s, although this was not apparent at the time when the TRL 382 forecasts were prepared. The rate has risen fairly steadily since about 1996 (note that Figure 2.6 shows the adjusted rate, Figure 2.2 shows that the actual rate fell over this period although less rapidly than prior to 1996).

Analyses of STATS19 data from 1996 indicate that the change in trend may have been caused in part by a progressive deterioration in driver behaviour. TRL 663 shows, for example, that the proportion of car occupant casualties killed or seriously injured when their cars hit objects off the carriageway rose steadily between 1997 and 2005. Another example is the increase in the proportion of casualties whose cars overturned in the course of the accident yet this proportion might have been expected to reduce as a result of the improving standards of car design.
2.3 Future plans

The basic approach developed in the late 1990s has provided forecasts that have proved to be reasonably reliable. It has also provided a framework for assessing annually the progress being made in reducing casualties, although it is not possible to predict changes in trend as demonstrated by the example car occupant fatalities (Figure 2.2). It thus provides a good basis for investigating the numerical context of any post-2010 casualty reduction target, although the caveat about unforeseen future changes in trend needs to be borne in mind. It would clearly be sensible, however, to review the experience of other countries.

Among the larger countries, Great Britain, Sweden and the Netherlands have the best level of road safety, as shown by the generally accepted comparison of fatality rates. All three have casualty reduction targets, although expressed in terms of fatalities in Sweden and the Netherlands. Unlike Great Britain, neither Sweden nor the Netherlands has set its targets on the basis of formal calculations: they are based on a political calculation that a given percentage fatality reduction should sufficiently motivate those involved in improving road safety.

Both Sweden and the Netherlands have enjoyed greater success than Great Britain in reducing fatalities in recent years, although in both countries there had previously been a ‘plateaux’ of the sort currently being experienced in this country. Hence, it cannot be claimed that a more elaborate approach when setting targets necessarily leads to more rapid progress. In neither country is it clear, in statistical terms, why they have been more successful in reducing fatalities in recent years; one possible factor that may have contributed in the Netherlands is the establishment by the Dutch police of teams of traffic officers charged with the particular task of improving road safety by enforcing the traffic laws.

A group of statisticians at the Dutch road safety institute SWOV (Stichting Wetenschappelijk Onderzoek Verkeersveiligheid) has been active in developing new statistical models of casualty trends. Jeremy Broughton and Louise Walter visited SWOV in October 2007 to see whether these could suggest ways of improving the current forecasting approach. The role of SWOV in developing Dutch road safety policy and casualty reduction targets was also explored. The visit was most illuminating in terms of statistical methodology, which is summarised in Section 2.3.1. It was concluded, however, that these more sophisticated methods were unlikely to provide improved casualty forecasts. While relatively sophisticated in their treatment of the underlying error structure, their ability to forecast has not been evaluated and the models have provided no additional insights into the fatality reductions in the Netherlands of recent years.

For the present, it appears that that the current approach is the most suitable for preparing post-2010 casualty forecasts and casualty reduction targets. Certain minor improvements can be made to the modelling, but no major change is envisaged at
present. In addition to the statistical analyses needed to prepare the forecasts for the new target year \( Y \), the main requirements are:

- predictions of the volume of travel by road in year \( Y \) for the various modes;
- assessment of which new road safety measures are likely to be implemented by year \( Y \), taking account of likely political considerations and technical developments; new measures are either innovatory or a substantial expansion of existing measures; and
- prediction of the casualty reduction (%) that is likely to be achieved by year \( Y \) by each of these new measures; it will be important to consider whether some new measures may substitute for existing measures whose effectiveness is expected to diminish over the period until year \( Y \).

### 2.3.1 The latent risk model approach for modelling casualty trends

Standard statistical techniques such as regression and General Linear Modelling (GLM) are used at TRL to model and forecast casualty trends. These techniques concentrate on one series and treat other factors as independent variables. These techniques are relatively simple to understand and visualise, but there is a technical disadvantage: they assume that errors in the observations are independent. The data, however, consist of measurements made sequentially in time (e.g. numbers of accidents or casualties) and are usually not independent of each other. For example, the number of fatalities in year \( n \) is usually a fairly good indicator of the number of fatalities in year \( n + 1 \). This implies that the variation in the observations is also likely to be dependent. The confidence interval around the model estimated by GLM and regression techniques is likely to be underestimated if the assumption of independence is violated.

Sophisticated time series techniques are available and utilised in many different fields to model repeated measures over time. These techniques allow the researcher to model the dependent data taking into account trend or seasonal effects. These methods have been used in the road safety context in the past: a key example is Harvey and Durbin (1986), who assessed the effects of the compulsory wearing of seat belts in Great Britain in 1983.

SWOV statisticians have spent the last seven years developing the latent risk time series model for road safety (SWOV, 2006a). This method extends the concepts of trend and seasonal effects, allowing each effect to be modelled separately and also allows for the parameters to vary in time. Risk is estimated from official accident and traffic data, as usual, but these sources are treated as inexact and prone to error: hence the term **latent** risk. The errors remaining in the results from this model are generally independent of each other and thus confidence intervals are identified more accurately.
Techniques and programmes have not been developed so far that use the latent risk model for forecasting. This is clearly possible, however, and SWOV is likely to pursue this development.

Discussions with the SWOV staff who developed the latent risk model and an initial assessment of their results suggest that the estimates that are reached using the current TRL forecasting techniques would be similar to or the same as (to a useful level of precision) those reached by this more sophisticated technique. The difference between the two techniques would be in the estimates of confidence intervals — the time series technique would give a wider, more accurate interval.

Following discussions with the SWOV statisticians who developed this model, TRL has been given access to the results of their highly technical work. A TRL self-funded project has been carried out to determine whether this model produces estimates that differ appreciably from those produced by the methods currently used. The initial expectation was that the model would produce results that were similar to, if not the same as, results from a technique that could be understood by the majority of readers. This was broadly confirmed by the experience of the project. The more sophisticated techniques allow confidence intervals to be predicted more accurately, but the lack of forecasting potential is a distinct disadvantage and the technical sophistication of the time series methodology makes it unapproachable for the general reader.

The latent risk time series model is described in detail by Bijleveld et al. (2008). To give a flavour of the model, it is a subset of state space time series and extends the state space methods by simultaneously modelling exposure to an event, the risk of the event occurring and the severity of that event. The current coding is not able to deal with distinguishing between different severities. In the planned research, the latent risk model will be applied to model car kilometres in Great Britain ($M_t$) and the number of car drivers killed or seriously injured ($F_t$) simultaneously by month from 1979 to 2006.

This method assumes normality of errors and linearity, and it is therefore not appropriate for data with small counts, for example highly disaggregated data. There is ongoing work in extending the latent risk model and coding for non-linear models, including Poisson models.

The coding used to determine latent risk models in this research was written by Frits Bijleveld and Jacques Commandeur at SWOV. It contains five programmes which run together to produce a model and associated diagnostics and, now, forecasting. The code is based around state space methods and is sufficiently general that the model can vary in complexity from simple linear regression to the full latent risk model. Explanatory and intervention variables, such as the introduction of the seatbelt law in 1983, can also be included as components.
3 VISIONS

3.1 Why have a vision?

3.1.1 Slow progress in fatality reduction

Progress in reducing fatalities is slowing in many countries, but particularly in Britain (Figure 3.1). The fatality rate per vehicle and per vehicle-kilometre and per head in Britain is now not as low as the rates in Norway, Sweden and the Netherlands; a comparison of the fatality rate per head of the population in 2006 is shown in Figure 3.2.

Figure 3.1: The trend in the total number of fatalities from 1996 to 2005 for nine selected countries (1996 = 100)

Figure 3.2: The fatality rate per 100,000 people in 2006 for nine selected countries
3.1.2 *Diminishing underlying trend in reduction in fatalities*

The general trend in fatality reduction across many countries (Figure 3.3) indicates that there is limited scope for further fatality reduction from traditional policies. A new approach to reducing safety risk is needed to achieve substantive additional reduction.

Figure 3.3: General trend in fatalities per number of motor vehicles for the SUNflower+6 countries (source: Wegman et al., 2005)

SUNflower (Wegman *et al.*, 2005) analyses of risk data up to 2003 show that Sweden, Britain and the Netherlands (of the SUNflower countries) to have progressed furthest along a graph linking reducing personal safety risk and traffic safety rate (Figure 3.4). No countries yet have experience of going much further in reducing risk.
3.1.3 **A vision can act as a promotional tool as well as giving a steer to policies through focusing on how a future safety scenario should look**

If going beyond traditional safety policies means a change in expenditure level or in public behaviour, this change will need to be justified by a clear statement of what policies are aiming to achieve, in terms that both politicians and the public wish to sign up to.

Loo *et al.* (2005) explained what a ‘vision’ is in this context and what benefits a vision brings: ‘A vision is an innovative description of the future traffic system or a desired direction of safety development. A vision ensures that road safety gains a prominent position in transport policy and decision-making processes, raises public interest and creates public support for road safety improvements. With the vision as a long-term goal, short-term objectives, targets and action plans can be set.’
Loo et al. (2005) identified the vision, objectives, targets and action plans of various administrations:

- for Australia, the vision was ‘safe road use for the whole community’;
- for Great Britain, there was no vision though the objective identified was ‘making the roads safer for everyone’;
- New Zealand’s vision was to ‘reach and keep up with the standard of “the safest countries in the world”’, and the objectives were ‘to achieve the current world’s best road safety practices’; and
- Sweden had ‘Vision Zero’, with the objective ‘manage injuries so that they do not cause deaths or even serious damage to health’.

3.1.4 A vision is not a substitute for safety strategy

A strategy is an essential tool to guide policy development and organisational change. Visions and targets are ways to promote, justify and assess progress in achieving the strategy outcomes.

Castle and Kamya-Lukoda (2006) conducted a review of international road safety good practice and identified the major strengths of road safety strategies: ‘A crucial component of an effective road safety strategy is to have a quantitative target. However, a road safety strategy should include policy objectives, a special budget, new design safety features, integrated community programmes and new technologies. The major factors for the success or failure of road safety initiative are political will, proper organisation, and knowledge. Good planning and a clear national framework, and support at all levels are emphasized for the successful implementation of an effective road safety programme. Through a detailed analysis of various road safety strategies in different countries, Loo et al. (2005) developed a framework, with nine main components, of a road safety strategy: vision, objectives, targets, action plan, evaluation and monitoring, research and development, quantitative modelling, institutional framework, and funding.’

‘To demonstrate the usefulness of this comparative framework’, Loo et al. (2005) examined ‘the road safety strategies of six selected administrations: Australia, California, Great Britain, Japan, New Zealand and Sweden’. Castle and Kamya-Lukoda (2006) also considered the strategies in place in various countries. Of Great Britain, they identified that: ‘The administration is good at setting targets, action plans, evaluation and monitoring, research and development, developing an institutional framework, and funding. The specific areas are:

- [Great Britain] is realistic in its target setting. Its objectives can be easily understood from the title of its road safety strategy paper (Tomorrow’s Roads: Safer for Everyone)
• The action plan carries ten main themes: safety; for children, drivers, infrastructure, speeds, vehicles, motorcycles, pedestrians, cyclists and horse riders; better enforcement; and promoting safer road use

• The evaluation is conducted in a timely manner and the review is made accessible to the general public. The DfT published the first 3 year review in 2004 that reports and evaluates the progress towards the targets and the effectiveness of measures undertaken under the major ten themes (DfT, 2004b cited in Loo et al., 2005.)

• The action plan is well supported by research and development programmes. Research has been commissioned in the three major areas of analysing and understanding accident causation, developing and evaluating road safety measures, and monitoring the effects of road safety policy

• There is a clear line of responsibility running from local to central road safety bodies. Whilst the DfT is responsible for developing and coordinating the implementation of the national road safety strategy, partnership amongst the Central Government and its agencies, LAs [local authorities], police forces, voluntary groups and road user associations, motor manufacturers and individual road users is stressed

• Funding comes from all sectors including public and private sources.’

When comparing the strategies between different countries, it explained that ‘Loo et al., 2005 applied the ranking technique to pin point areas of excellence’ and therefore the study concluded that the administrations with good practice in road safety are as listed in Table 3.1 against the road safety strategy component. In general, implementation of efficient and effective safety policies needs not only

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<th>Table 3.1: Road safety good practice</th>
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<td>Road safety component</td>
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<td>Vision</td>
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<td>Objectives</td>
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strong governmental support, but clear guidelines set and budgets provided for the local authorities which will deliver many of these policies. In addition, policies need to be seen as fair and balanced, and this is best achieved through public participation in preparation of the policies. A communication strategy to encourage constructive debate is important so that policies can stand criticism from the public.

‘In comparison to other administrations, [Great Britain] has a well balanced road safety strategy though there is scope for improvement as can be deduced from Table [3.1] above’ (Castle and Kamya-Lukoda, 2006).

Castle and Kamya-Lukoda also surmised that: ‘Gaining acceptance for controversial road safety initiatives is one area that has not been given emphasis by any administration. Loo et al. (2005) suggested that this area was to be part of the Vision component of a road safety strategy. A vision ensures that road safety gains a prominent position in transport policy and decision-making processes, raises public interest and creates public support for road safety improvements (Loo et al., 2005).’

3.2 Visions from other countries

3.2.1 What does Vision Zero imply?

As the Swedish Ministry of Industry, Employment and Communications explained in 1999, ‘In October, 1997, the Swedish Parliament adopted a “vision zero” approach as a basis for Sweden’s long-term road safety objectives. As the name implies, the objectives involve the eventual reduction of fatalities and serious injuries resulting from road accidents to zero. The Government has set a first-phase maximum target for the year 2000 of 400 deaths and 3,700 serious casualties. By 2007, the number of people killed on the roads should have fallen to 270, or 50% of the total for 1996, when 537 people were killed.’

It also identified the ‘foundation stones’ of the vision: ‘safer roads, safer vehicles and better compliance with road traffic regulations’, explaining that ‘Central to the “vision zero” approach . . . is the concept that a driver should be able to make a mistake on the road without suffering serious injury as a result’ (Ministry of Industry, Employment and Communications, 1999).

Castle and Kamya-Lukoda (2006) also explained that ‘Vision Zero alters the view of responsibility in that those who design the road transport system i.e. road managers, vehicle manufacturers, road transport carriers, politicians, public employees, legislative authorities and the police bear the ultimate responsibility for safety and it is the responsibility of the individual person to abide by laws and regulations. Prior to this, practically all the responsibility had been put on the individual road user.’
The elements of Vision Zero are identified in *Vision Zero on the Move* (Swedish Road Administration, 2006a):

- based on ethics no one should be killed or seriously injured for life in road traffic;
- mistakes should not be punishable by death there is no perfect human being;
- adaptation to the human body taking into account biological tolerance against external violence;
- a system where everything is interrelated the importance of harmonising the development and design of vehicles and road environments on the basis of human limitations;
- the system designers have the major responsibility shifting a major share of the safety responsibility from road users to those who design the road transport system; and
- driving forces for change good consumer information on safety systems.

### 3.2.2 What does Sustainable Safety imply?

In the Netherlands, the approach adopted is known as ‘Sustainable Safety’. Some background to this is given in the publication *Sustainable Safety: A New Approach for Road Safety in the Netherlands*, (Vliet and Schermers, 2000):

‘The second Structure Plan for Traffic and Transport . . . of 1990 laid down the road safety goals for 2010, namely a 50 per cent reduction in fatalities and a 40 per cent reduction in injury accidents over the period 1986 − 2010. However, in the early 1990s doubts arose whether these goals would be met. The spearhead policies were effective but did not adequately address problems at the source. While overall reductions in road accidents were still evident, analysis of accidents on certain parts of the road network reflected that remedial actions were necessary to reduce the large discrepancies in fatality and serious injury accident rates on the different road classes. This resulted in the issuing of the “twin-pronged” policy of the [third long-term road safety policy], the first aiming at the renewal and intensified application of the focus areas and the second at a preventative strategy now known as Sustainable Safety.

In contrast to the spearhead policy the sustainable safety strategy is characterised by a proactive and preventive approach. Whereas the spearhead-policy was [a] reactive (and curative) approach aimed at addressing problems when they occurred, sustainable safety has “prevention is better than aim” as its motto.
Sustainable safety recognises that 90 per cent of road accidents are attributable (to a greater and lesser extent) to human error. Consequently sustainable safety realises that the human is the weakest link in the traffic and transport chain.

In summary a sustainable safe traffic system comprises

- A road environment with an infrastructure adapted to the limitations of the road user;
- Vehicles equipped with technology to simplify the driving task and provided with features that protect vulnerable and other road users; and
- Road users that are well informed and adequately educated.

Sustainable safety distinguishes three categories of road:

- Roads with a **through** function (for the rapid movement of through traffic);
- Roads with a **distributor** function (for the distribution and collection of traffic to and from different districts and residential areas);
- Roads with an **access** function (providing access to homes and shops while ensuring the safety of the street as a meeting place).

All road categories should comply with the following three safety principles:

- **Functionality** (preventing unintended use of the infrastructure); a road functions properly if function, layout and use are geared to one another.
- **Homogeneity** (preventing major variations in the speed, direction, and mass of vehicles at moderate and high driving speeds);
- **Predictability** (preventing uncertainty among road users); design should make roads so recognizable and their alignment make them so predictable that the correct expectations of both own and other road users’ driving behaviour are evoked.’

In addition to the engineering approach, Schagen and Janssen (2000) also explain that ‘The road user, the key player in every road traffic system, has to be informed and educated to understand the aims and the product of sustainable safety as well as its consequences for his or her mobility, travel pattern and behaviour. Sustainable safety automatically means a rather severe restriction in the individual freedom of road users. It will take time and effective “marketing” to convince them and to achieve overall acceptance. In short, creating sustainable safety in road traffic requires an integrated approach.’
SWOV’s publication *Advancing Sustainable Safety* (SWOV, 2006b), an update of the original Sustainable Safety plan, identified that ‘There are five principles that lead to sustainably safe road traffic: functionality, homogeneity, predictability, forgivingness (of the road layout and of road users) and state awareness (by the road user). The last two principles are new in this advanced Sustainable Safety vision. All five principles have their origins in scientific theories.’ The two new principles are described as:

- forgivingness of the environment and of road users ‘injury limitation through a forgiving road environment and anticipation of road user behaviour’; and
- state awareness by the road user ‘ability to assess one’s own task capability’.

The publication also explains that: ‘People not only make traffic unsafe by unintentional errors but also by deliberate violations. The original Sustainable Safety vision did not emphasize deliberate violations explicitly as causes of crashes as much as this advanced version. When the traffic environment does not more or less automatically invite correct and safe behaviour, road users should comply with the rules from an inner motive. In this case, behaviour is the most consistent and thus sustainable. To improve rule acceptance, rules should be appropriate to the traffic environment and credible to road users, and people should be educated to accept the usefulness of rules. For those who still fail to obey the rules, the Sustainable Safety vision includes enforcement with a fairly good chance of being caught when violating rules.’

### 3.2.3 Implications for expenditure

While broad statements of desired outcomes can generate support for safety policies, achievement of these desired outcomes can have substantial expenditure implications.

Of the countries setting out new visions in 2000, New Zealand was perhaps the one giving most consideration to cost implications. Loo *et al.* (2005) suggested that, among the administrations they considered, ‘New Zealand has one of the most sophisticated evaluation mechanisms. The major approach is cost-benefit analysis, based on the calculation of the social cost.’

When the New Zealand government announced their *Road Safety to 2010* strategy in 2003 (and Transport New Zealand, 2003) their Minister of Transport stated that ‘There are cost-effective ways to implement the strategy’. The strategy is ‘part of a broader set of government goals’ ‘The government’s transport vision is that “by 2010, New Zealand will have an affordable, integrated, safe, responsive and sustainable transport system”.’

Developers of the strategy had identified two major policy streams, each with very different cost implications a dominant focus on infrastructure measures that would be affective but at high cost, or a dominant focus on enforcement to modify
road-user behaviour whose initial cost was much lower, but where the outcome in
terms of fatality reduction was much less certain. Not surprisingly, the strategy
comprises a mixture of both approaches.

Increasing investment in reducing fatalities through focusing on forgiving
environments (i.e. infrastructure where crashes resulting from driver error will not
result in fatality) is inevitably accompanied by reducing marginal returns. Cost
effectiveness has been and is likely to remain a key determinant in British policy,
but the marginal returns on further infrastructure improvements appear to remain
substantial and well beyond current GB expenditure budgets.

### 3.3 How were visions promoted?

#### 3.3.1 To politicians

In both Sweden and the Netherlands, parliament appears to take a stronger role than
in Britain in debating and endorsing the safety vision as well as the accompanying
safety strategies. At a political level, the existence of a vision can make it easier to
explain and justify shorter-term policies, in the context of their contribution towards
a longer-term goal, particularly if the latter is expressed in terms that appear to
follow ethical or environmental principles that are difficult to refute. Such principles
can be elaborated both in terms of desired physical environments and health and
safety principles that organisations, at all levels, should support.

#### 3.3.2 To the public

The extent to which the public were involved in the decisions leading to the visions
is less clear. Several strategy documents mention ‘consultation’ on various aspects
for example, the New Zealand strategy consulted on the balance between
engineering and enforcement policies but this is usually with groups with a
particular interest in safety rather than an attempt to gain support from the public in
general. It is likely to be difficult to find an appropriate level at which to raise public
debate grand statements of principles are likely to cause far less interest than the
local implementation of the policies which are required to underpin them. Where
visions extend to intermediate principles as, for example, with the Dutch
Sustainable Safety the language used (e.g. functionality, predictability,
homogeneity) is aimed at professionals and it is not likely to be easily understood by
the general public. This does not argue that the public should not be consulted, but
rather that careful development of concepts and principles is needed in a form which
the public can understand and be engaged by.
3.4 Focus of 2000–10 strategies

3.4.1 Policies

3.4.1.1 General focus of policies

The SUNflower report (Koornstra et al., 2002) summarises the proportions of casualty reduction expected from safety strategies for 2010 from Sweden, Britain and the Netherlands. Britain expected to gain more from vehicle safety strategies and less from infrastructure strategies than the other two countries. The gains that were expected from infrastructure strategies in Britain were mainly expected to be the result of speed management policies, while the other two countries were expected to invest in direct infrastructure improvements.

3.4.1.2 Sweden

Various examples of measures being introduced and the reasons for them are given by the Swedish Road Administration (Vision Zero on the Move (Swedish Road Administration, 2006a)):

- If the key objective is to reduce the number of accidents, then traffic lights are the best solution. There will be fewer accidents, but those that do happen often result in serious injury. If the key objective is to avoid serious injuries, a roundabout will provide better results. There will probably be more accidents, but the injuries will mostly be minor. Roundabouts have, thus, become more commonplace at intersections, particularly in populated areas.

- A new and widely discussed innovation is the ‘2 + 1 lane’ highway with a median barrier, a road type developed in Sweden.

- One of the first effects of Vision Zero was that municipal authorities were able to establish a 30 km/h speed limit in built-up areas. A speed of 30 km/h in built-up areas is nothing new, but the work on turning Vision Zero into reality has emphasised that this must be the limit if pedestrians and cyclists are to survive a collision.

- Speed limits on parts of the road network have been reviewed in order to ensure that they reflect the safety standard of the road. For example, it is now quite unusual to find a road with a speed of 110 km/h without a median barrier.

- Major investments have been made to minimise the damage ensuing from cars veering off the road. Guard rails have been erected, and potentially dangerous objects, such as trees and boulders, have been cleared away from roadside areas.
3.4.1.3 The Netherlands

Vliet and Schermers (2000) states: ‘Traffic calming measures are integral to sustainable safety and their use is heavily dependent on the road category.’ These include:

- roundabouts;
- residential areas and 30 km/h zones:
  - intermittent road narrowing;
  - humps;
  - plateaus;
  - full or partial diagonal closures;
  - informal street furniture;
  - chicanes;
  - combinations of the above;
- electronic means; and
- Intelligent Speed Adaptation (ISA).

A number of specific areas are considered in detail, for example, when focusing on cyclists and pedestrians, Schagen and Janssen (2000) explain: ‘The original vision of Sustainable Safety resulted in many measures with a positive effect for pedestrians and cyclists. Examples are:

- The physical separation of vehicles with major differences in masses, speeds and directions;
- The measure of directing mopeds onto the carriageway inside urban areas
- The implementation of 30 and 60 km/h zones;
- The obligatory side-underrun protection for new lorries;
- The development of a pedestrian-friendly car front.’

Schagen and Janssen (2000) identify the ‘functional requirements for a sustainable safe road network’:

1. Realise residential areas that are as large as possible.
2. Minimal part of trips over unsafe roads.
3. Trips as short as possible.
4. Shortest and safest route are the same.
5. Prevent searching for destinations.
6. Make road categories recognisable.
7. Reduce the number of traffic solutions and uniform them.
8. Prevent conflicts with oncoming traffic.
9. Prevent conflicts with crossing traffic and pedestrians.
10. Separate different means of transport.
11. Reduce speeds where conflicts could occur.
12. Avoid obstacles along the road.

When considering the implications of this, Schagen and Janssen (2000) recognised that ‘This asks for parallel roads and cycle lanes which both from a financial point of view and from a land use point of view are not easily realised. When aiming at sustainable safety, halfway solutions such as assigning a mixed function instead of a monofunction to [distributor roads] should be avoided. Discussions are ongoing focussing on the question to what extent not ideal solutions are acceptable in a transition situation.’

3.4.1.4 New Zealand

Various policy themes were identified and explored in the New Zealand strategy:
• integrating safety into the transport system;
• devolving safety management;
• communicating within partnerships;
• making the best use of resources;
• accommodating human error; and
• improving road-user behaviour.

Further information needs to be sought on the progress of these themes.

3.4.1.5 France

Although France has not developed a formal vision, strategy and target for fatality reduction, substantial reductions have been achieved in fatality numbers in France. The policies resulting in these changes were promoted by a major initiative by the French president to improve France’s safety record compared with other countries (FIA Foundation, 2006).

3.4.1.6 Britain

The policies within the 2010 safety strategy for Britain (DETR, 2000) follow similar general principles to those in Sweden and the Netherlands in many areas. The difference is in the extent to which they have pursued some of these principles and the lack of defined or measurable end objectives.
3.4.2 Institutionally

3.4.2.1 Sweden

Two initiatives in Sweden are of interest: the setting up of a Road Traffic Inspectorate and the introduction by the Swedish Road Administration of a new working approach called ‘OLA’.

The duties of the Road Traffic Inspectorate include ‘monitoring and analysing conditions that could have a significant impact on safety in the road transport system’ and ‘through discussion, encouraging responsible stakeholders to maintain a systematic approach to their road safety activities’ (Swedish Road Administration, 2006b). As well as evaluating and encouraging the work of the Swedish Road Administration, local authorities and the police, the Inspectorate have engaged with public and commercial sector employers and with the Swedish Work Environment Authority and trade unions on safety equipment and working practices.

OLA stands for ‘Objective data, List of solutions and Addressed action plans’. It entails systematic collaboration between different organisations, companies and authorities that have been designated as the designers of the road transport system. Included within that group are the Swedish Road Administration, local authorities, vehicle manufacturers, the police, emergency services, transport companies and purchasers of transport services. Politicians and civil servants that work with community planning are also included. In its initial evaluation of OLA, the Traffic Inspectorate concluded that it ‘led to greater insight among different stakeholders on the importance of a safe road transport policy’, but they also considered ‘intentions . . . are often vaguely formulated and not linked to a time schedule. This applies in particular to national OLAs’ (Swedish Road Administration, 2006b).

3.4.2.2 The Netherlands

Since the end of the 1980s, government has become increasingly decentralized in the Netherlands. Many road safety policies are now the responsibility of local and regional governments. The financing of road safety measures has also changed, with the introduction of the Bundled Goal Payment in 2005 which is for transport generally; as with Local Transport Plans (LTPs) there is no money earmarked specifically for road safety. SWOV recognise in their Advancing Sustainable Safety report (SWOV, 2006b) that these changes are not necessarily consistent with seeking greater uniformity in road design and safety policy, but argue that the principles can still be achieved if measures are developed in co-operation with regional and local government. Looking forward, SWOV suggest the need for a rigorous quality assurance system for road safety, starting with road authorities, but extending to all agencies influencing road safety. They also suggest a separate committee might be formed to focus on ‘Financing a Sustainably Safe Infrastructure’ (SWOV, 2006b).
3.4.2.3 France

In France, a major change in road safety policy was heralded when the President stated improved road safety as one of his three national priorities in 2002. A key focus of the action following this was a more automated ‘control and sanction’ system with improved the detection of offences and set tougher penalties. Greater detection was to be provided by the widespread implementation of speed cameras and by the use of electronic breathalysers. Tougher penalties were proposed for causing death or serious injury while offending. Of interest to Britain might be the inclusion of penalty points for blood alcohol levels between 0.5 and 0.8 gm/l, for failure to wear seat belts, and for the use of mobile phones. These proposals appear to result in a marked improvement in behaviour (FIA Foundation, 2006).

An interesting aspect of the French initiative is that large reductions in fatalities were observed as soon as the measures were announced. The proportion of drivers exceeding the speed limit by more than 10 km/h was down by 10% and seat-belt wearing increased from 91% to 95% (FIA Foundation, 2006). Implementation was gradual over 2002 to 2004, but publicity was sustained at a high level by the general media as well as by government announcements. By the end of 2004, the number of fatal crashes involving alcohol fell by 11%, speeding was further reduced and seat-belt wearing further increased. In three years the national death toll fell by almost a third. The only group resistant to change were 18–24-year-olds.

3.5 What has happened to strategies and to fatality trends?

3.5.1 Fatality trends

Figure 3.1 shows that between 2000 and 2003 there was relatively little change in fatality numbers in Sweden, although having risen above 1996 numbers by 2000, they then did drop back to 1996 levels. Between 2003 and 2005, a substantial reduction of around 15% occurred. The Swedish Road Administration have commented that traffic growth and, in particular, the growth in motorcycling influenced the trend between 2000 and 2003.

In the Netherlands, Schagen and Janssen (2000) had commented, early in the new millennium, that ‘The effect of sustainably-safe for 2010 is, for the time being, expected to be modest. Nevertheless, with 45 per cent more car kilometres during the period 1998–2010 and the already-mentioned rate reductions per road type, the annual number of road fatalities in the Netherlands will be about 770. The target of 50 per cent less than in 1986 will just be achieved. The expected reduction for all victims is smaller. It is not yet clear whether the target reducing serious injuries will also be achieved.’

However, having again been relatively steady between 2000 and 2003, fatality numbers in the Netherlands decreased by around 25% between 2003 and 2005. SWOV have investigated this decrease (SWOV, 2006c) and concluded that, while it
was very difficult to identify many of the effects, improvements in seat-belt wearing, drink-driving and speeding behaviour all played a part in the reduction. At present the information is not available on which to assess the effect of the road design adaptations.

It may be noted from Figure 3.1 that fatality numbers in Germany have also shown a steady decline since 1996, being now some 35% lower, while fatality numbers in France reduced by a similar overall amount, but with most of this occurring since 2001.

Over the same period, Britain has achieved a far more limited reduction in fatality numbers. Some reasons for this, such as the increase in motorcyclist fatalities, are well established, but policy changes in several areas have also been slower.

### 3.5.2 Review of strategy progress – the Netherlands

Schagen and Janssen (2000) state that: ‘Evaluation and monitoring is done through the various stages of the sustainable safety programme.’ They identify the longer-term context:

> ‘The ultimate aim is to have realised a full sustainable safe traffic system by 2030. This target date is not arbitrary, but reflects the average length of life of road infrastructure. Clearly, the sustainable safety operation is very costly. SWOV estimated that full implementation of the sustainable safety principles would require around 35 billion US$. By far the largest investment is needed for the reconstruction of existing infrastructure to fulfil the sustainable safety principles. The direct costs can be reduced markedly by having the reconstruction work to coincide with regular maintenance work. Given the average life of road infrastructure, in a period of around 30 years all roads could have been treated.

> These days, the Dutch authorities spend approximately 1.5 billion US$ on major and minor maintenance work annually. This means that the realisation of sustainable safety could be paid by merely redirecting existing budgets and would not rely on additional financial resources. Cost-benefit estimates indicate that the usual government standard of 4 per cent return on investment is easily met by the potential reduction in road traffic victims and related costs.’

In assessing the impact of Sustainable Safety, Schagen and Janssen (2000) explain that ‘to date, Sustainable Safety has mainly been translated into measures for a safer road infrastructure. Although it is important to focus extensively on the infrastructure, the vision embraces the whole interaction between “human”, “vehicle”, and “road”, going on to say that ‘safety-improving ITS developments have only become more visible in the last few years and will provide a great
contribution to sustainable road safety improvements in the future’. The authors explain that: ‘We do not know enough about the safety effects of Sustainable Safety measures yet. These measures have not been structurally assessed, although we were able to make rough estimations of their safety effects. Ad hoc evaluations indicate moderate to very positive effects of various (infrastructural) measures. On this basis, we have estimated that all the infrastructural Sustainable Safety measures taken . . . have together saved 6 per cent of severe casualties (fatalities and in-patients) in the Netherlands.’ They conclude that ‘we are certainly on the right track, although we do not have a sustainably safe traffic system yet. In addition, we still need to gather more information regarding the contents of the measures in the area of infrastructure as well as in the areas of education, enforcement and vehicle and technological measures. All this information is important if we are to work cost-effectively towards a sustainably safe road system. For the continued implementation of Sustainable Safety, new agreements between the police, judicial authorities, social organisations and industry are required for effective and efficient implementation of policies.’

Finally, the authors comment on the implementation of Sustainable Safety, explaining that integration, innovation, research and development, and knowledge dissemination ‘are crucial for the successful implementation of the various Sustainable Safety measures’.

3.5.3 Review of strategy progress – Sweden

The Review of International Road Safety Good Practice (Castle and Kamya-Lukoda, 2006) concluded that: ‘The Swedish administration is strategically successful in formulating and implementing the vision, and establishing the necessary institutional framework.’ But as the Swedish Ministry of Industry, Employment and Communications explained in 1999, ‘The [National Road Administration] arrived at the conclusion that the interim target set for 2000 cannot be met. The authority proposes instead that efforts be concentrated on the target for 2007.’ Castle and Kamya-Lukoda concluded that: ‘The problems associated with meeting the targets in Vision Zero highlight the need to ensure that targets are evidence based and realistic, rather than set to a political agenda.’

The elements of Vision Zero are identified in Vision Zero on the Move’ (Swedish Road Administration, 2006). When considering the results of Vision Zero, the authors concluded that:

‘In the years since Vision Zero was first introduced in 1995, Sweden has seen major changes both as regards views on road safety as well as in the working approach adopted. An important milestone was the parliamentary resolution adopted in 1997 when Vision Zero became the foundation for road safety operations in Sweden.'
Another step was the establishment of the Road Traffic Inspectorate in 2003, whose task it is to monitor and analyse safety developments in the road transport system.

It explained that ‘One obvious result of Vision Zero is the change in road environments in Sweden. Central median barriers and roundabouts have become much more common, as have different types of speed calming measures in built-up areas.’

The report highlights ‘Safer Vehicles’ ‘Private passenger cars have become much safer, which considerably reduces the risk of being killed or seriously injured in new car models. This can in part be attributed to the European New Car Assessment Programme, Euro NCAP, which road safety experts at the Swedish Road Administration (SRA) were instrumental in setting up . . . There is no doubt that improvements have been implemented at a much faster pace than if legislation had been used for the same purpose.’

It also highlights ‘Safer Transports’ ‘Since the introduction of Vision Zero, the SRA has been involved in the quality assurance of transports as part of its effort to convince both those who provide and procure transport services to feel a greater sense of responsibility . . . The intention is that all private companies and organisations that either procure or operate transport services themselves will assume responsibility for the impact this has on the environment and road safety.’

Other specifics that have been progressed as part of Vision Zero include the use of seat-belt reminders, alcohol ignition interlocks, road safety cameras and cycle helmets.

3.6 Safe System approach

The approaches adopted, for example, in Zero Vision and Sustainable Safety, described earlier, have coalesced into a Safe System approach which is now being generally promoted among safety professionals as the basis for future safety philosophies. The Organization for Economic Co-operation and Development (OECD, 2008) provides a good overview of the principles underlying this approach, stating ‘a fundamental policy shift, characterised as the Safe System approach, is required both to consolidate the significant improvements in road safety in recent decades and to generate further gains in the future’. In addition to recognising the need for systems to accommodate human error and provide better management of crash forces, it emphasises the need for ‘shared responsibility’ and for ‘aligning safety management decision making with broader societal decision making’.

Physical interventions focus on the interaction between infrastructure (vehicle and road), speed and physical vulnerability, with safe speed thresholds suggested for different road types. In the Safe System approach, it remains the case that traditional
designers of transport systems have a primary responsibility for ensuring safe conditions by addressing all these factors, but the approach stresses that there are many other ‘system designers’ who affect the design and functionality of the road transport system. This represents a shift from placing sole responsibility on the road user to requiring all ‘designers’ to provide an intrinsically safe environment. The OECD (2008) concludes that ‘given the level of change implied by a Safe System approach, a vision-led approach is required’.

Implementing a Safe System approach ‘builds on existing knowledge’, but ‘pushes the analysis . . . to a greater level of systemic thinking’. It requires a response that ‘extends basic co-ordination to more widespread engagement’, and involves ‘a greater acceptance of community views’. The OECD also suggests that the approach ‘requires considerable attention to be paid to the development and management of performance indicators, and the re-orientation of these indicators to the systems and interventions that are going to create the greatest safety value’.

3.7 Should Britain have a vision post-2010?

3.7.1 Numbers or outcomes?

Previous British strategies have been supported by numerical targets, enabling assessment of progress in terms of casualty reduction. But these numerical targets, even if based on a summation of casualty reductions in individual accident types, are poor at clarifying the policy changes that are needed to achieve them. Clearer statements of the outcomes desired in terms both of behaviour and environment are necessary. A strategy involving further incremental improvement and an associated numerical target alone are unlikely to result in substantive change either in public attitude, organisational change or expenditure.

At the highest level, a short-term numerical target might simply be accompanied by a long-term aim of achieving an outcome such as ‘that the risk of death or serious injury while using the roads should be no greater than the average risk while engaging in other everyday activities’ (e.g. Allsop, 2005) or some multiple of this risk (e.g. Crawford, 2007). However, such statements on their own are unlikely to affect policy or gain public or political acceptance of alternative programmes unless the desired outcomes are defined in more detail in relation to individual policy areas.

3.7.2 Infrastructure

Ways of improving injury protection (and thus the likelihood of preventing a fatality) are well established for vehicle design and road infrastructure (and developed through the EuroNCAP and EuroRAP programmes). Benefit/cost ratios can still be used as a determinant of how far to go towards minimising the likelihood of fatalities occurring, but the desired outcomes can be debated more transparently. However, it is quite possible that proposals justified by benefit/cost ratios based on
the current valuation of fatality saving may not be consistent with publicly desired infrastructure standards. If so, this inconsistency between values expressed in willingness to pay surveys and public expectation of desired levels of safety should form part of public debate about potential safety visions to target, and may indicate a need to re-assess the value to be given to fatality saving.

### 3.7.3 Behaviour

It is less clear how to define a vision in terms of desired behavioural outcomes. Clearly an outcome could be set, for example, of 100% seat-belt wearing, and this might potentially be achieved through technology. But such a behavioural change would require public acceptance. While few people would object to an improved roadside environment to prevent deaths through run-off incidents, a substantial number are likely to continue to object, for example, to speed-limit policies.

The Dutch, in their Sustainable Safety strategy, initially focused on the behavioural implications of the infrastructure aspects of the strategy, such as self-explaining, easily recognisable, road types, minimising incorrect routeing, and ensuring that all road users are well informed and well trained. At the same time they implemented direct actions to improve seat-belt wearing rates and increase enforcement. In their ‘advanced’ definition of Sustainable Safety, however, they explicitly include the ‘ability to assess one’s own task capability’ and recognise that ‘people ... make traffic unsafe ... by deliberate violations’ (SWOV, 2006b). They go on to state that ‘rules should be appropriate to the traffic environment and credible to road users’ and that ‘people should be educated to accept the usefulness of rules’.

It is implicit in the Swedish Zero Vision policy that this would only be achieved if road users’ behaviour was consistent with the infrastructure design principles for example, deaths will still occur in impacts if seat belts are not worn by car occupants. The New Zealand strategy considers intermediate targets for compliance with various behaviours.

Lynam (2007a) suggests that substantial fatality reductions could be achieved through the greater control of behaviour using technologies which are currently available or being developed. However, he emphasises the need for these behaviours to be accepted by the large majority of road users who would be subject to them. This might mean that any ‘British Vision’ needs to include a consideration of how agreement should be reached on achieving more public consensus on such issues. It might also usefully address actions needed to remove or reduce the obstacles to changes in safety policy, both institutionally and in the public mind.

### 3.7.4 Role of public view

In recent years, public opinion appears to have played an increasing role in resisting some safety policies. There are several reasons for this, ranging from an increasing
distrust of politicians and of scientific evidence to resistance to the reduction in
driving freedoms and a greater willingness to contest traffic law in court.

Lynam (2007a) has argued the need for greater public involvement in decision
making and greater transparency in policies, but has also raised the question: ‘How
much should policies be led by public view and how much do public views need to
be changed?’

It is clear that more dialogue with the public, through whatever means, is desirable
in achieving the implementation of effective safety policies in future, and a ‘vision
statement’ of desirable outcomes to be achieved might help in this discussion.

3.7.5 **Institutionally**

Consideration of a possible vision for Britain should include the implications of any
long-term goal for the changes in public and private policy required, and the extent
of institutional initiatives that would be required to achieve these. The formalisation
of systematic collaboration between those who influence system design as a semi-
independent process, as with the Swedish Traffic Inspectorate, might be considered.
Sharper co-operation between government departments in relation to road safety
policies has been sought over many years, and may only result from more
independent oversight. Quality assurance processes are beginning to emerge in both
Dutch and Swedish thinking, and should also be considered on the British agenda.

3.7.6 **What are other countries doing for future targets?**

As a result of the fatality reductions observed in recent years, the Dutch Minister of
Transport has agreed with a SWOV proposal (SWOV, 2006c) to sharpen the 2010
target to 750 fatalities. The Netherlands already had a 2020 target of 580 fatalities.
SWOV have reviewed this target and conclude (SWOV, 2007a) that ‘without
additional measures, it is far from certain that the target will be achieved. With
additional measures, it may be possible to sharpen the present target for 2020’.

Sweden should be considering a new target as the current target was for 2007, but
little appears to have been made public about their plans.

3.8 **Implications for targets**

3.8.1 **Fatality targets can be calculated for different scenarios**

To be useful in target setting, a vision needs to be defined in terms of final outcomes,
i.e. not just ‘to improve seat-belt wearing rates’, but as a medium-term quantified
seat-belt wearing rate. If this is done, then estimates can be made of the numbers of
fatalities likely to occur with the resulting scenario.
3.8.2 Numerical target will depend on timescale for progress towards scenario

Any vision is likely to reflect a longer-term scenario than will be achieved within the likely timescale for the next national fatality target. Progress on polices requiring substantial investment will depend on the timescale in which those resources are made available. Progress on policies aimed at modifying road-user behaviour will depend on the nature and timescale of the legislation and campaigning programmes that are adopted. Progress on technology-based solutions will depend on the speed of their potential implementation. An analysis of the time frame for all these developments will be needed as part of the development of any new numerical target for fatality reduction.

3.8.3 Intermediate targets should be set for activities and behaviour

Safety Performance Indicators are useful in order to improve the understanding of the causes of accidents and to monitor policy interventions. These sorts of measurement are often more useful than simple counts of injuries, since random variation plays less of a part in these figures and under-reporting is less of an issue.

Safety Performance Indicators developed as part of the SUNflower (Wegman et al., 2005) and SafetyNet projects (ERSO, 2007) include:

- the percentage of the general road population impaired by alcohol and/or drugs;
- the percentage of drivers exceeding the speed limit;
- mean speed;
- deviation of speed;
- seat-belt wearing rate;
- crash-helmet wearing rate;
- percentage of vehicles using daytime running lights;
- average EuroNCAP rating of the car fleet;
- compatibility ratio based on the weight distribution of the vehicle fleet;
- road length percentage of different road types;
- share of intersection types;
- intersection density;
- percentage of roads with a wide median or a median barrier;
- percentage of roads with a wide obstacle-free zone or roadside barrier;
- percentage of road length with facilities for the separation of slow, vulnerable traffic and other, motorised traffic;
• arrival time of emergency services at the scene of the crash; and
• the quality of medical treatment.

The best example of attempting to use such indicators as part of a road safety strategy is provided by the New Zealand Strategy in which the intermediate targets shown in Table 3.2 were proposed.

<table>
<thead>
<tr>
<th>Table 3.2: Proposed intermediate targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (open road)</td>
</tr>
<tr>
<td>Mean 85th percentile</td>
</tr>
<tr>
<td>km/h</td>
</tr>
<tr>
<td>2004</td>
</tr>
<tr>
<td>99</td>
</tr>
<tr>
<td>107</td>
</tr>
<tr>
<td>Speed (urban road)</td>
</tr>
<tr>
<td>Mean 85th percentile</td>
</tr>
<tr>
<td>km/h</td>
</tr>
<tr>
<td>2004</td>
</tr>
<tr>
<td>55.2</td>
</tr>
<tr>
<td>61</td>
</tr>
<tr>
<td>Alcohol</td>
</tr>
<tr>
<td>Driver deaths with excess alcohol</td>
</tr>
<tr>
<td>number % of all drivers deaths</td>
</tr>
<tr>
<td>2004 at least</td>
</tr>
<tr>
<td>48</td>
</tr>
<tr>
<td>21</td>
</tr>
<tr>
<td>Restraints</td>
</tr>
<tr>
<td>Vehicle occupants wearing safety belts</td>
</tr>
<tr>
<td>% (front) % (back)</td>
</tr>
<tr>
<td>2004 at least</td>
</tr>
<tr>
<td>92</td>
</tr>
<tr>
<td>75</td>
</tr>
<tr>
<td>Children (under 15) restrained</td>
</tr>
<tr>
<td>%</td>
</tr>
<tr>
<td>2004 at least</td>
</tr>
<tr>
<td>90</td>
</tr>
</tbody>
</table>

Britain should consider which of these indicators are most important for the strategy that it wishes to develop, and what targets might be useful to set for such indicators, within a broad overall target.
4 HIGHWAY ENGINEERING

In 2006, a total of 3,172 people were killed and 28,673 were seriously injured on Britain’s roads. Of those, 169 children were killed and 3,125 were seriously injured. Including slight casualties, 258,404 people were killed or injured on the roads in 2006.

The Government’s road safety strategy and casualty reduction targets are set out in Tomorrow’s Roads Safer for Everyone, published by the then Department for the Environment, Transport and the Regions (DETR) in March 2000 (DETR, 2000). The strategy states that by 2010 the Government want to achieve, compared with the average for 1994–98:

- a 40% reduction in the number of people killed or seriously injured in road accidents;
- a 50% reduction in the number of children killed or seriously injured (children are defined as being those aged under 16); and
- a 10% reduction in the slight casualty rate, expressed as the number of people slightly injured per 100 million vehicle kilometres.

In July 2002 these targets were enhanced to address the significantly higher number of road accident casualties that occur in disadvantaged areas (HM Treasury, 2002). The target was to secure a greater reduction in the overall number of road casualties in the 88 Neighbourhood Renewal Fund areas in England, than for England as a whole, comparing the figure for 2005 with the average for 1999 to 2001. Local highway authorities (LHAs) are key partners in the delivery of the Road Safety Strategy. The vast majority of accidents occur on local roads and consequently the casualty reduction performance of LHAs is critical to achieving targets.

In support of the existing 2010 casualty reduction targets, the Department for Transport (then the Department for Transport, Local Government and the Regions (DTLR)) has issued guidance, such as Road Safety Good Practice Guide (DTLR, 2001). Additionally, road safety featured prominently in the Department for Transport’s review of local transport best practice (Atkins, 2005). More recently the Institution of Highways and Transportation (IHT) have published guidelines on Collision, Prevention and Reduction (IHT, 2007), which provides an up-to-date overview of general best practice. However, the achievement of casualty reduction is a complicated matter and there are many underlying factors that may affect local highway authorities’ achievement of casualty reduction targets. It is therefore important to continue to expand industry knowledge of what constitutes successful practice in reducing road casualties.
The Venn diagram in Figure 4.1 shows the proportions of accidents where the primary causation is the road environment, road user or road vehicle, or combinations thereof.

This review comes at an interesting time for road safety practitioners, where despite overall past good performance at reducing road casualties there is still a strong need to do better, but set against a background of some uncertainty as to which methods will yield ever-better results. With accident rates at historic lows, increasingly intelligent and strategic approaches are required if lower casualty numbers are to be delivered. Furthermore, although rates and absolute numbers of serious and fatal accidents are low, the consequential effects of such accidents now threaten other targets, such as those for congestion and air quality, as UK roads become busier than ever. The NHS is a service under some strain and the cost of accidents is unacceptably high to a growing economy. A House of Lords report (“Government Policy on the Management of Risk”, House of Lords Select Committee on Economic Affairs (June 2006) ) highlighted the gains that could be made with suitable investment targeted at improving road safety. Work for the Department for Transport by the Transport Research Laboratory (TRL; Lynam, 2007a) on rural road safety also indicated similar findings. In any event, it is clear that whatever the funding available, an increasingly intelligent targeted range of approaches will be required, particularly for those highway authorities with the lowest number of road accidents.
The European Commission has become increasingly concerned at the consistently high numbers of killed or seriously injured (KSI) across the Member States of the European Union. It has decided to legislate in the area of Road Safety Infrastructure Management after research showed that insufficient consideration is generally given to the strategic management of road safety by authorities. While it would be hard to demonstrate that this failing applied to many UK LHAs, it is clear that the chances of excellent performance will be highest for those LHAs with a clear structure in place. The European legislation (Directive 2008/96/EC) only applies to the Trans-European road network but offers a sound grounding for any LHA and covers:

- road safety impact assessment;
- road safety audit;
- management of high-risk road sections, including data management; and
- road inspections.

It has long been held that the three Es of ‘Education, Engineering and Enforcement’ offer the key to road safety solutions. A report by the Audit Commission (2007) offers strong direction to encourage greater use of education, training and publicity (ETP) via a partnership approach. Such an approach can be cost effective, but there is limited evidence to suggest which combinations of tactics work best and why, or to what degree ETP should be combined with engineering and in what proportions, particularly where funding is limited. It is important to gather demonstrable evidence of successful ETP initiatives in order to offer firm direction to LHAs investing in this important part of an overall road safety strategy. It would also be useful to record those methods that have produced useful alliances and outputs, but where road safety outcomes have been more difficult to prove. This will allow LHAs to view with clarity the relative chances and risks of success/failure of various options.

Some road safety practitioners have expressed concern that the Audit Commission report places an overemphasis on ETP to deliver casualty reductions. Road safety practitioners are still likely to balance investment across the three Es, but it is of paramount importance that LHAs are given clear guidance as to the relative contributions that the three Es can offer, particularly for those LHAs where staff are less experienced. Atkins (Highways Agency/Atkins, 2007) have demonstrated that even on the nation’s safest roads (trunk roads), engineering schemes are still delivering impressive first-year rates of return (an average of 99% FYRR). Our experience is that LHAs are achieving FYRRs far in excess of 99%, with average figures up to 300% being common. It is true that cluster sites may be less plentiful, but this will offer opportunities for other coherent engineering interventions on a route and area basis. Additionally, there is no evidence that a reduction in the length of authorities’ lists of priority cluster sites would threaten the delivery of very high rates of return: it would appear that there is a significant backlog of engineering schemes. In some quarters inferences have been made that road safety engineering is
nearing the ‘bottom of the barrel’. However, the evidence suggests that, although the cream may have been skimmed, the barrel is still apparently extremely full.

Joint work (unpublished) by EuroRAP and the Highways Agency has shown that even on our safest roads (motorways), investment on the protection of nearside hazards would yield a benefit to cost ratio of around 10:1. ETP solutions undoubtedly offer the potential for extraordinary rates of return due to their typically low costs. However, clear guidance on which methods work best will be invaluable, particularly as some unsuitable ETP interventions may carry the risk of offering little or no economic return.

We are not aware of work that seeks to determine what proportion of the driving population are receptive to ETP measures. It is noted that approaches that seek to educate young road users before entrenched attitudes are set are more likely to increase the proportion of the audience that may be swayed by road safety messages. However, it must be recognised that there is a natural limit to what ETP can achieve, particularly among some parts of the driving population that may be un receptive to education. For these road users, it is possible that road infrastructure features offer the best chance of casualty reduction. An obvious example is the issue of overtaking — the greater proportion of roads that are dual carriageway, the greater the potential to reduce head-on overtaking crashes.

There is also a limit to what engineering can achieve: road engineering is unlikely to prevent an overworked lorry driver falling asleep at the wheel, but may be able to mitigate the effects of the incident by preventing a cross-over to the opposing carriageway.

### 4.1 Numerical context

The numerical context for setting national casualty reduction targets is laid down in TRL Report No. 382 (Broughton et al., 2000). The report notes that forecasting the future is generally an uncertain and difficult process. The timescale required for improving road safety means, however, that it is important to prepare long-term plans which are soundly based upon current knowledge and which take account of likely future developments.

The benefits of road safety engineering were assessed by analysing the accident records of samples of sites where engineering work has been carried out (Helliar-Symons and Lynam, 1989; Toothill and Mackie, 1995; Webster and Mackie, 1996). That analysis, combined with the level of expenditure on these works nationally, indicates that the engineering programme carried out between 1985 and 1995 reduced casualties by an average of 0.5% per year.

The 2010 targets were based on the ‘assumed effects’ of Table 6 in TRL Report No. 382, re-produced in this report as Table 4.1.
Table 4.1: Assumed effects (%) of new policies, averaged over all types of road (reproduction of Table 6 in TRL No. 382 (Broughton et al., 2000))

<table>
<thead>
<tr>
<th>New road safety engineering programme</th>
<th>KSI</th>
<th>Slight</th>
<th>KSI</th>
<th>Slight</th>
<th>KSI</th>
<th>Slight</th>
<th>KSI</th>
<th>Slight</th>
<th>KSI</th>
<th>Slight</th>
<th>KSI</th>
<th>Slight</th>
<th>KSI</th>
<th>Slight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved secondary safety in cars</td>
<td>6.0</td>
<td>6.0</td>
<td>13.7</td>
<td>13.7</td>
<td>4.3</td>
<td>4.3</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
<td>7.7</td>
<td>6.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other vehicle safety improvements</td>
<td>10.0</td>
<td>15.0</td>
<td>5.0</td>
<td>2.0</td>
<td>3.2</td>
<td>6.0</td>
<td>8.0</td>
<td>7.0</td>
<td>4.0</td>
<td>3.0</td>
<td>4.6</td>
<td>3.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycle and Pedal Cycle helmets</td>
<td>5.4</td>
<td>5.0</td>
<td>6.0</td>
<td>6.0</td>
<td>4.2</td>
<td>1.0</td>
<td>4.1</td>
<td>1.0</td>
<td>1.3</td>
<td>1.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety on rural single carriageways</td>
<td>4.1</td>
<td>1.1</td>
<td>1.3</td>
<td>1.3</td>
<td>1.0</td>
<td>1.0</td>
<td>0.8</td>
<td>1.3</td>
<td>0.4</td>
<td>0.7</td>
<td>3.4</td>
<td>1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reducing accident involvement of novice drivers</td>
<td>2.8</td>
<td>3.4</td>
<td>1.3</td>
<td>1.3</td>
<td>1.0</td>
<td>1.0</td>
<td>0.8</td>
<td>1.3</td>
<td>0.4</td>
<td>0.7</td>
<td>1.9</td>
<td>2.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional measures for pedestrian and cyclist protection</td>
<td>6.0</td>
<td>6.0</td>
<td>4.0</td>
<td>4.0</td>
<td>1.2</td>
<td>0.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional measures for speed reduction</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional measures for child protection</td>
<td>6.9</td>
<td>7.9</td>
<td>0.6</td>
<td>0.7</td>
<td>1.7</td>
<td>1.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reducing casualties in drink/drive accidents</td>
<td>1.9</td>
<td>1.0</td>
<td>0.4</td>
<td>0.2</td>
<td>0.8</td>
<td>0.5</td>
<td>0.8</td>
<td>0.5</td>
<td>1.2</td>
<td>0.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reducing accidents during high-mileage work driving</td>
<td>2.1</td>
<td>2.1</td>
<td>0.9</td>
<td>0.8</td>
<td>1.2</td>
<td>1.1</td>
<td>1.9</td>
<td>1.9</td>
<td>2.3</td>
<td>2.5</td>
<td>1.9</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional measures for improved driver behaviour</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined effect of all measures</td>
<td>33</td>
<td>22</td>
<td>42</td>
<td>31</td>
<td>24</td>
<td>16</td>
<td>30</td>
<td>19</td>
<td>21</td>
<td>15</td>
<td>35</td>
<td>23</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Expert reviews carried out by TRL were the source of most of the assessments of these measures. Each review dealt with one of the three principal areas of road safety, and a report of each review has been published, for example road engineering was reported on in Lines and Woodgate (2000). Each review summarised recent developments and considered future commitments, then assessed the potential for innovatory measures to achieve casualty reductions by 2010. Some information about the costs of implementing the measures was available, but this was lacking in many cases. Three main categories of risk reduction were assumed to be attributable to engineering or pseudo-engineering measures. These were as per Table 4.2.

<table>
<thead>
<tr>
<th>Table 4.2: Assumed measures of an engineering nature that supported the 2010 targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety on rural single-carriageways</td>
</tr>
<tr>
<td>A package of measures for rural safety management was assumed</td>
</tr>
<tr>
<td>(In Table 6 of TRL 382 (see Table 4.1): assumed 3.4% of KSl to be saved)</td>
</tr>
</tbody>
</table>

The report by Lines and Woodgate (2000) contributed work to Table 6 of TRL Report No. 382 (see Table 4.1). They concluded that:

‘It is estimated that road safety engineering could save up to 80,000 casualties per year, around one-quarter of the total casualties. An investment of around £4800m would be needed to achieve this assuming a 50% rate of return for the measures installed and £30k for the cost of a casualty.’

The basis of this conclusion was:
- 200,000 urban casualties, of which 50,000 were saveable; and
- 100,000 rural casualties of which 30,000 were saveable.

It is not clear whether the concept of saving 80,000 casualties was a realistic recommendation or just an example of what was theoretically feasible. Saving 80,000 casualties through road safety engineering was not taken on-board at the time, presumably because the amount of expenditure was unaffordable. The KSI figures for the three engineering categories in Table 4.1 (Table 6 of TRL Report No. 382) give predicted KSI savings of 16.1% of all accidents from a total of 35% (just over the 33% actual target announced) to be saved.
Lines and Woodgate (2000) noted that the spending (then) on road safety engineering was around £63 million and the average annual spend would need to be (our interpolation of their Table 9) increased by about a factor of 10.8 (£4,800 million over seven years). The scale of the disparity between what could be achieved and what may be achievable is a matter of judging what a reasonable FYRR is likely to be. This issue will always be very sensitive when selecting any new target. Clearly a rate of return of 50% was a conservative assumption that has proven to be out by a large factor, given the rates of return being currently enjoyed. It is assumed by the Highways Agency, somewhat arbitrarily, that a FYRR of around 25% represents something approaching the minimum trigger below which money may be better focused elsewhere. As accidents reduce, the FYRR will normally naturally reduce as the worst sites are treated, but this assumes that the cost per scheme is constant and no cheaper solution or technologies are developed.

The estimates by Lines and Woodgate (2000) rely on the application of average casualty savings of around 50% (typical of single sites) being applied to the whole network. While 50% is achievable at any single site, this is unlikely to be repeatable as a national mass action in rural areas, although is achievable in urban areas on the basis that the solution is area speed management.

4.2 What works now?

In setting a new target it is important to establish what works now. The purpose of setting a casualty reduction target is generally accepted to be to provide a common goal for those involved with improving road safety. It is important that they feel that the goal is achievable in order to gain the support of the many people whose cooperation will be needed if the target is to be attained, but the target should also be demanding in order to avoid complacency and focus efforts on the most effective measures. The format of the 2010 target has been easily understood and is now widely accepted, so there may be good reasons for retaining the format of it.

A challenging target will be achieved by adopting a programme with new measures which incorporate aspirational elements as well as those which build upon existing measures.

Forecasting casualties more than 10 years into the future is an imprecise process, for the outcome will depend upon the future behaviour of travellers and the growth of road travel, as well as the means used to promote safe travel over that period. It also heavily relies on the amount of investment and the value that society puts on the prevention of casualties in relation to other forms of investment.

4.2.1 MOLASSES

MOLASSES is a database that contains information about Local Road Safety Schemes installed by local authorities in the United Kingdom. The acronym
MOLASSES stands for ‘Monitoring Of Local Authority Safety SchemES’. The database has been active since 1991.

A Local Safety Scheme is a road scheme implemented by a local authority on local roads to address identified road safety problems. A Local Safety Scheme may involve simple things like adding a new sign or road markings, or more complex things such as changing the layout or geometry of the road. Local Safety Schemes can be applied at a specify site (for example, at a junction), along a route or over an area.

The objectives of the database are to:

- assess the effectiveness of different treatments in relation to specific accident problems;
- give a better idea of the effectiveness of different types of Local Safety Schemes; and
- wherever possible, to produce reports and provide information in response to specific enquiries.

The purpose of a Local Safety Scheme is to reduce the number of road accidents and casualties. Although it may have other benefits linked with improving the road environment. Table 4.3 shows the impact of the schemes listed in MOLASSES.

In general, the use of MOLASSES has been patchy and it is understood that frustrations have led to a general lack of confidence in the database. So much so that a new database (UK MORSE) is now live, but as yet has very little data available. There are other sources of data, such as tables held on websites of road safety consultants, for example TMS.

It is noted that MOLASSES contains records to 1999. This shows an average rate of return of 372%. At best this figure should be viewed as an approximate indicator of the likely rates of return achievable. The Department for Transport has recently commissioned Atkins to investigate the performance of the 2004/5 local road safety programme. The results of this study are likely to be published in 2009 giving updated estimates of the rates of return.
<table>
<thead>
<tr>
<th>Treatment type</th>
<th>No. of schemes</th>
<th>No. of schemes with ‘after’ data</th>
<th>Average change in accidents per annum (%)</th>
<th>Average cost of scheme (1999 prices) (£)</th>
<th>Average annual accidents saved</th>
<th>Expenditure per accident saved per annum 1999 prices (£)</th>
<th>Average first-year rate of return (1999) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle scheme</td>
<td>30</td>
<td>12 (12)</td>
<td>–65 (–65)</td>
<td>59,155</td>
<td>3.79 (3.79)</td>
<td>15,607</td>
<td>444</td>
</tr>
<tr>
<td>Area–wide</td>
<td>45</td>
<td>12 (10)</td>
<td>–31</td>
<td>79,312</td>
<td>1.86 (2.58)</td>
<td>30,720</td>
<td>225</td>
</tr>
<tr>
<td>Route</td>
<td>283</td>
<td>77 (69)</td>
<td>–43 (–46)</td>
<td>22,419</td>
<td>1.51 (1.68)</td>
<td>13,331</td>
<td>520</td>
</tr>
<tr>
<td>Link–calming</td>
<td>321</td>
<td>78 (63)</td>
<td>–48 (–49)</td>
<td>39,612</td>
<td>1.48 (1.48)</td>
<td>26,764</td>
<td>260</td>
</tr>
<tr>
<td>Signalised junction</td>
<td>299</td>
<td>195 (159)</td>
<td>–37 (–37)</td>
<td>35,206</td>
<td>1.43 (1.35)</td>
<td>26,128</td>
<td>266</td>
</tr>
<tr>
<td>Bend</td>
<td>471</td>
<td>304 (265)</td>
<td>–48 (–54)</td>
<td>10,753</td>
<td>1.14 (1.12)</td>
<td>8,958</td>
<td>722</td>
</tr>
<tr>
<td>Roundabout</td>
<td>320</td>
<td>188 (164)</td>
<td>–33 (–35)</td>
<td>40,502</td>
<td>1.09 (1.03)</td>
<td>39,415</td>
<td>176</td>
</tr>
<tr>
<td>Pedestrian facility</td>
<td>579</td>
<td>317 (250)</td>
<td>–32 (–32)</td>
<td>27,296</td>
<td>1.02 (0.97)</td>
<td>28,036</td>
<td>246</td>
</tr>
<tr>
<td>Link (overall)</td>
<td>1,368</td>
<td>674 (435)</td>
<td>–25 (–32)</td>
<td>28,391</td>
<td>1.00 (1.13)</td>
<td>25,072</td>
<td>276</td>
</tr>
<tr>
<td>Link – general</td>
<td>1,157</td>
<td>636 (398)</td>
<td>–26 (–29)</td>
<td>27,333</td>
<td>0.90 (1.05)</td>
<td>26,262</td>
<td>266</td>
</tr>
<tr>
<td>Priority junction</td>
<td>830</td>
<td>519 (468)</td>
<td>–34 (–37)</td>
<td>11,930</td>
<td>0.87 (0.90)</td>
<td>13,231</td>
<td>523</td>
</tr>
<tr>
<td>Total</td>
<td>4,225</td>
<td>2,298 (1,832)</td>
<td>–38</td>
<td>23,409</td>
<td>1.08 (1.13)</td>
<td>20,726</td>
<td>372</td>
</tr>
</tbody>
</table>
4.2.2 Second review of 2010 targets

In February 2007 the Department for Transport produced *Tomorrow’s Roads Safer for Everyone: The Second Three-Year Review: The Government’s Road Safety Strategy and Casualty Reduction Targets for 2010* (Department for Transport, 2007d). Theme 4 (safer infrastructure) looked at activity for road safety engineering. This highlighted the following:

- The majority of accidents continue to occur on local roads, and local authorities have made considerable progress through a range of engineering solutions.
- The Highways Agency, Transport Scotland and Transport Wales continue to make good progress on their networks and, despite a small increase in accident numbers in 2005, our motorway network remains one of the safest in Europe, if not the world.
- TRL’s Monitoring Report (Broughton and Buckle, 2007). suggests that improvements to infrastructure have contributed to a significant reduction in casualty numbers. The rates of return on local schemes remain high, despite the average cost per scheme increasing.
- Many schemes have been implemented over the last few years. Examples here demonstrate the links between local authorities and central government, the role of Europe and the improvements possible on an already relatively safe network. As with all road safety initiatives, infrastructure should not be taken in isolation, but the aim is to create a structured and co-ordinated approach to engineering, education and enforcement, for all road users.
- Local authorities continue to develop their policies on a route or area basis, in addition to the old focus on accident clusters. The Road Safety Investment Monitoring 2005/06 report outlines in detail the number, cost and types of English schemes (Department for Transport, 2007f). The dedicated spend on road safety schemes totalled about £135 million in 2005/06.
- Local authorities produced new five-year transport plans in 2006, and road safety continues to be given a high priority by most.
- The estimated first-year benefit of direct spending on safety schemes by local authorities was £386 million in 2005/06. This is an excellent return rate. The safety benefits have increased due to extra spending over the last four years. Comparing the investment against the safety benefits, the return for 2005/06 is 305%.

4.2.3 Local Transport Plans

Data provided by 57 authorities show that casualty reduction schemes implemented during the first Local Transport Plan period have reduced the number of personal injury accidents (PIAs) by 21%. The data presented compares average annual number of PIAs three years before scheme implementation with data for three years
post-scheme implementation. Data for 2004/05 and 2005/06 are either based on data available or are forecast.

4.2.4 Evaluation of Highways Agency’s Making Better Use programme of works

Atkins have produced a report entitled *Making Better Use (MBU)* for the Highways Agency (Highways Agency/Atkins, 2006). That report involved reviewing the Project Appraisal Reports for projects constructed under the ‘Making Better Use’ banner. The report covers both safety schemes and journey time reliability/improvement schemes. The latter contribute very little to safety. The report looked in detail at the predictions of Project Appraisal Reports, used to initially justify projects, and the resultant effect that the project had on the network, particularly safety. The project examined the performance of Local Network Management (LNMs) schemes costing under £1 million in the first year of opening at a national level. While schemes which cost less than £10,000 are collated and stored on the MBU database, no evaluation of these schemes was undertaken due to their negligible costs.

Overall, safety engineering schemes (based on a sample of 158 schemes) were shown to represent good value for money, with an average out-turn FYRR of 99%. MBU safety schemes have contributed approximately 3% to this reduction (of the Highways Agency target) by reducing KSIs by 61 in three years. The report looks only at the rate of return in Year 1 and does not currently track accident performance after Year 1.

In addition to the overall results, further analysis was undertaken for safety schemes. The following provides a more detailed analysis of the 158 safety schemes evaluated to date, with summaries provided in Tables 4.4 and 4.9.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Scheme Type</th>
<th>No. of Schemes</th>
<th>Total KSI Reduction</th>
<th>KSI Reduction Per Scheme</th>
<th>Average Cost Per Scheme</th>
<th>Average Cost per KSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Speed Limit Reduction</td>
<td>13</td>
<td>20.8</td>
<td>1.6</td>
<td>£127,277</td>
<td>£79,539</td>
</tr>
<tr>
<td>2</td>
<td>Signing/Lining and Other improvements</td>
<td>42</td>
<td>19.1</td>
<td>0.4</td>
<td>£77,538</td>
<td>£174,241</td>
</tr>
<tr>
<td>3</td>
<td>Gap Closure and/or Right Turn Ban</td>
<td>11</td>
<td>4.2</td>
<td>0.4</td>
<td>£175,879</td>
<td>£456,960</td>
</tr>
<tr>
<td>4</td>
<td>Signing and Lining</td>
<td>41</td>
<td>3.2</td>
<td>0.1</td>
<td>£50,830</td>
<td>£652,227</td>
</tr>
<tr>
<td>5</td>
<td>Other</td>
<td>25</td>
<td>7.5</td>
<td>0.3</td>
<td>£227,271</td>
<td>£790,561</td>
</tr>
<tr>
<td>6</td>
<td>Junction improvement</td>
<td>25</td>
<td>6.3</td>
<td>0.3</td>
<td>£229,305</td>
<td>£912,508</td>
</tr>
</tbody>
</table>
• With Year 1 and Year 3 projects producing an out-turn FYRR of 78% and 74% respectively, and Year 2 producing an out-turn FYRR of 151%, overall safety schemes are performing well, with an average out-turn FYRR of 99% against a predicted corrected FYRR of 72%.

• There are now a number of scheme type categories with large enough sample sizes to start to draw meaningful conclusions, namely signing/lining and other improvements, junction improvements, gap closures and speed limit reduction schemes.

• Speed limit reduction schemes are ranked highest in terms of out-turn FYRR (226%) and out-turn benefits per scheme (£288,104) as shown in Table 4.4. Speed limit reduction schemes also have the most significant effect on accidents.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Scheme Types</th>
<th>No. of schemes</th>
<th>Outturn Benefits</th>
<th>Outturn Costs</th>
<th>Average FYRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Junction closure</td>
<td>1</td>
<td>£399,040.08</td>
<td>£1,720,990.05</td>
<td>23%</td>
</tr>
<tr>
<td>2</td>
<td>Speed limit reduction</td>
<td>13</td>
<td>£288,104.48</td>
<td>£127,277.01</td>
<td>226%</td>
</tr>
<tr>
<td>3</td>
<td>Provision of right turning ghost island</td>
<td>3</td>
<td>£226,433.34</td>
<td>£51,004.10</td>
<td>444%</td>
</tr>
<tr>
<td>4</td>
<td>Junction improvement</td>
<td>25</td>
<td>£202,780.23</td>
<td>£229,305.34</td>
<td>88%</td>
</tr>
<tr>
<td>5</td>
<td>Signing/lining and other improvements</td>
<td>43</td>
<td>£164,639.99</td>
<td>£77,538.01</td>
<td>212%</td>
</tr>
<tr>
<td>6</td>
<td>Speed cameras</td>
<td>3</td>
<td>£126,635.34</td>
<td>£91,395.09</td>
<td>139%</td>
</tr>
<tr>
<td>7</td>
<td>Adjusting road surface level</td>
<td>1</td>
<td>£117,706.88</td>
<td>£153,390.13</td>
<td>77%</td>
</tr>
<tr>
<td>8</td>
<td>Gap closure and/or right turn ban</td>
<td>11</td>
<td>£106,746.90</td>
<td>£175,879.01</td>
<td>61%</td>
</tr>
<tr>
<td>9</td>
<td>Crossing improvements</td>
<td>3</td>
<td>£102,516.59</td>
<td>£96,193.24</td>
<td>107%</td>
</tr>
<tr>
<td>10</td>
<td>Layby closure and/or improvement</td>
<td>3</td>
<td>£96,277.90</td>
<td>£61,116.62</td>
<td>158%</td>
</tr>
<tr>
<td>11</td>
<td>Safety Fencing</td>
<td>3</td>
<td>£88,084.72</td>
<td>£248,917.20</td>
<td>35%</td>
</tr>
<tr>
<td>12</td>
<td>Cycle/footway scheme</td>
<td>2</td>
<td>£60,423.46</td>
<td>£161,878.51</td>
<td>37%</td>
</tr>
<tr>
<td>13</td>
<td>Lighting</td>
<td>3</td>
<td>£46,257.34</td>
<td>£636,241.17</td>
<td>7%</td>
</tr>
<tr>
<td>14</td>
<td>Vegetation clearance</td>
<td>1</td>
<td>£32,588.56</td>
<td>£14,506.67</td>
<td>225%</td>
</tr>
<tr>
<td>15</td>
<td>Signing and lining</td>
<td>41</td>
<td>£23,278.86</td>
<td>£50,829.60</td>
<td>46%</td>
</tr>
<tr>
<td>16</td>
<td>Drainage improvement</td>
<td>1</td>
<td>–£58,859.83</td>
<td>£30,782.61</td>
<td>–191%</td>
</tr>
<tr>
<td>17</td>
<td>Traffic Calming</td>
<td>1</td>
<td>–£209,582.06</td>
<td>£111,012.85</td>
<td>–189%</td>
</tr>
</tbody>
</table>

Table 4.5: Average FYRR (reproduced from the Highways Agency MBU report (Highways Agency/Atkins, 2006))
that result in KSI casualties and are the most cost effective at reducing KSI, with an average of 1.6 KSI being reduced per scheme in the opening year, at a cost of just £79,539

- Simple signing and lining schemes over £100,000 are ranked lowest in terms of out-turn FYRR (46%), and out-turn benefits per scheme (£23,279). They also produced a reduction in KSI per scheme of just 0.1 accidents at a relatively high cost of £652,227.

Although the report deals only with Highway Agency schemes on trunk routes, it is likely that this report provides a good indicator of potential returns on rural schemes in other high-speed situations.

4.2.5 Comparing rates of return

By comparing the MOLASSES records to 1999 and the latest work by TRL for 2005/06, they suggest that there has been a modest fall in the achieved rates of return for safety schemes (from 372% to 305%) on LHA schemes. However, these numbers are not directly comparable as they do not relate to the same geographic areas and are not comparative databases. These figures do, however, suggest a level of confidence that rates of return are likely to remain above 200% for at least the period to 2020. This is true of rural and urban interventions. The Highways Agency’s pool of schemes is smaller and centred on rural locations. The Highways Agency’s monitoring has not been continuous for long enough to indicate an overall trend. However, it is our opinion that there is a plentiful supply of Highways Agency schemes in the FYRR 50% and above range.

The selection of expected FYRR is very important when selecting a new target. Selecting a value too high may place unreasonable expectations on those delivering the target. Selecting a value too low may lead to unrealistically high cost estimate assumptions with respect to the level of funding that may be needed to be invested. The evidence suggests that FYRR of at least 100% is achievable, with 200% also possible. Sensitivity analysis can be performed on this issue to inform the decisions taken for the new target. The following is an example calculation: for FYRR 200% and annual spend of £100 million in Year 1, assuming the cost of an accident to be £64,440 (see Highways Economic Note 1 (HEN 1) (Department for Transport, 2007e), excluding damage-only incidents), it would be possible to save 3,100 accidents in each year.

It is interesting to note that the cost of accidents does not include a component of delay costs to road users. While this underestimation of the benefit of reducing accidents is not of primary importance, the allocation of funding between different road types may well be important to the travelling public. This factor may also be influential for authorities when dividing finite budgets between different budget headings. The Department for Transport could consider the make-up of ‘accident
costs’ in HEN 1 (Department for Transport, 2007e), with a view to including an allowance for user delays.

4.2.6 Summary

Both the Highways Agency MBU database and MOLASSES give details of a variety of individual schemes that ‘work’. In order to work, a scheme has to reduce road casualties and reduce them at an economic cost. It would be possible to employ significant resources to develop the work done by Lines and Woodgate (2000) to update their report in full. However, the assumptions would still be subjective. Furthermore, each project has a range of costs and benefits depending on the local circumstances. It seems to be better to look at the summation of the efforts given in the tables above to estimate what a programme of road safety engineering works could give. All these issues are surrounded by the fact that LHAs currently have some autonomy to deliver what they see as best value solutions. From time to time the Department for Transport issues advice on current good practice, such as Traffic Advisory Leaflets. Where significant accident causation exists, there is a potential market for more centralised frameworks to allow consistent treatment. For example, in managing speeds, the Department for Transport issued Road Circular 1/06 (Department for Transport, 2006a) that created responsibilities for LHAs to act by 2011, but without tying them to definitive solutions. This tactic could be extended to other road casualty causations.

The Department for Transport could consider updating their publication *Road Safety Good Practice Guide* (DTLR, 2001) so that LHAs continue to target their resources most effectively. Further, the Department for Transport could consider whether there is a gap in the advice they issue this could be filled by ‘framework’ type advice (similar to the Road Circular 1/06 model) on how to tackle specific issues that occur nationally, but in a local context.

4.3 Road safety management on rural roads

Three reports have been provided to the Department for Transport, describing the current casualty patterns on rural roads:

- *STATS19 Analysis of Rural Road Casualties from 2000–2004* (Walter, 2006);
- *Contributory Factors in Rural Accidents* (Broughton, 2006); and

Lynam (2007b) builds on the data in the first two reports, extending it to look in more detail at local authority rural roads, and discusses the potential countermeasures available to reduce casualties further on these roads, their likely cost effectiveness in different circumstances, and suggests the way in which the
Department for Transport might develop future policy for these roads. The report covers all aspects, not merely road infrastructure issues.

Lynam (2007b) also draws heavily on a review of rural road safety carried out by Hamilton and Kennedy in 2005, for the Scottish Executive. Although the scope for the application of measures is different on English roads, the general information on accident causation factors and reported effectiveness of measures is highly relevant.

This current report now builds on some of the themes developed Lynam (2007b), but adds information on possible urban infrastructure interventions.

### 4.3.1 The problems

The problem faced by highway authorities is that many of the accidents are, in a sense, predictable, although the precise location is not. Significant research investment allows detailed analysis on a year-by-year basis on accident statistics. As accident rates reduce, it becomes more difficult to identify true clusters. So much so that the Highways Agency has produced draft guidance on how best to identify clusters using various computerised techniques. While there is a level of confidence in the traditional approach of seeking clusters, the time will soon arrive where this is not useful. As an example, the trunk road network exhibits an accident density of around 0.5 KSI/km per annum, but because any single accident in a year at any point on the network would skew the local average, finding the true locations where investment is needed over a 10- to 20-year period may be difficult using current techniques. In our view it is imperative that highway authorities concentrate on route treatments, as over time it is more likely that the quantum of casualty reduction would be greater. This approach also allows greater emphasis on concentrating on those routes where total accident reduction would be greatest. At present, if a highway authority reports a relatively homogeneous accident rate along its single carriageways or even along its motorways, it may not invest significantly, particularly if the accident rate was near the national average. Is this appropriate? Designing ‘to the average’ will generally perpetuate the average. While it is natural to direct resources to the most deserving sites (and it is noted that this provides a good legal defence), it may be time to challenge some of the historical theories used by the road safety industry. Work is ongoing by the Highways Agency and EuroRAP that could allow safety engineers to analyse both Road Protection “star scores” RPS star scores and accident rates side by side for roads that have been surveyed for Road Protection Score (RPS). This will allow more data to inform the decisions on where investment is placed. This procedure is still data led and therefore defensible.

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1 RPS (also known as “star rating”) is a measure (scored 1 to 4) of a road’s inherent ‘protection’. For example divided carriageways score higher than undivided carriageways, with any road type gaining a higher score if roadside objects are protected. Details are provided at www.eurorap.org.
4.3.2 Implications of European legislation

The European legislation for road safety infrastructure management (Directive 2008/96/EC) offers a sound grounding for highway authorities and covers:

- road safety impact assessment;
- road safety audit;
- the management of high-risk road sections, including data management; and
- road inspections.

In reality the likely mix of successful ingredients for casualty reduction is wider than this list, but the headings of the European legislation offer a good starting point for infrastructure issues. The legislation, when published in November 2008, but effective from November 2011, will apply only to the Trans-European network (TERN). The current view of the Department for Transport is that the legislation will offer little or no reduction in casualties on TERN in the UK because the procedures contained within the Directive are already adhered to. In formulating a position on the Directive, the Department for Transport did not investigate to what extent LHAs comply with the legislation as that was outside the scope of work at the time, which was limited to the TERN. Earlier drafts of the Directive suggested that all road authorities should be encouraged to comply with the Directive, even if not directly covered by its scope. There is a possibility that future European legislation may re-introduce the issue and within a timescale that would affect casualty reduction prior to 2020. However, the scope for improving casualty reduction by re-brigading and updating road safety management across LHAs is likely to be limited. If the Department for Transport was minded to include LHAs within the locus of the new legislation, then this could be done either on a compulsory or encouragement basis. It is recommended that, of the four essential ingredients, priority should be given to the road safety audit. This process has been shown to represent good value for money and offers a good safety net at intermediate decision points during project progression. While it is widely understood that most LHA projects are audited, this is by no means universal. The Department for Transport may be able to link funding decisions to the requirements of audit for projects.

Consideration should be given to mandating the use of the road safety audit for all LHA projects that involve permanent change to the highway.

4.3.3 Structure and function of the rural road network

Rural roads are defined as in Walter (2006). Previous analyses of rural road safety have defined rural roads as those with a speed limit greater than 40 mph (non-built-up roads). Speed limits have been lowered on many rural roads in recent years and this approach had become increasingly inappropriate, so a new GIS-based system
was implemented in 2002. About 60% of traffic, 65% of fatalities, 48% of KSI injuries and 39% of all casualties occur on these roads.

4.3.3.1 Trunk roads

Trunk roads have a clear function to facilitate strategic traffic movements throughout Britain. This objective needs to be achieved as safely as possible and with minimum environmental disturbance, but minimising congestion and maintaining higher traffic speed is a key part of the trunk road function. These roads should therefore be engineered to a quality where high speeds can be achieved safely. Improvement programmes for this network are developed and managed by national governments who have set their own strategic objectives to deliver the 2010 casualty reduction targets.

Over recent years, the English trunk road network has been reduced in size (Table 4.6), with a substantial proportion of previous single-carriageway trunk roads being handed back to local authority management. The Highways Agency has made considerable safety improvements to these roads during this transition period.

<table>
<thead>
<tr>
<th>Table 4.6: Change in size and characteristics of the English trunk road network between 1999 and 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Highways Agency network</strong></td>
</tr>
<tr>
<td>1999 network</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Length (km)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Casualties per km</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Casualties per vehicle km</strong></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

It is our understanding that the Highways Agency is on target to meet the 2010 casualty reduction targets for trunk roads (including trunk motorways) in England. The trunk road targets are slightly less ambitious to reflect the generally lower starting accident rates. It should be noted that it is our experience that the delivery of casualty reduction is intrinsically linked to the availability of budgets. This is not surprising as a good management system would divert funds to other projects if the safety target was projected to be ‘met’. Conversely, the fact that the Highways Agency is on target, rather than substantially over-delivering, may be an indicator that the target itself could be hindering the reduction in casualties.
4.3.3.2 Non-trunk roads

The functions of the non-trunk road network are much more diverse, ranging from regional distributors to local access roads. The dual carriageways and many of the more major single carriageways play a major role in carrying through traffic and this role has been increased with the transfer of part of the previous trunk road network. One of the most important needs, therefore, is to define clear categories of road within this overall network, each having a clear function. This is made difficult however by the very varied levels of development and landscape through which these roads pass. The challenge for the future is to bring a more ordered structure to this network which improves the safety of its use, while recognising this diversity.

4.3.3.3 Current practice

For many years local authorities have implemented low-cost local safety schemes on non-trunk local roads, both at individual sites and along more major routes. The level of intervention has varied between authorities, but a general reduction in casualty rate can be seen throughout the network. Typical first-year rates of return vary from scheme to scheme, but rates in excess of 200% are not uncommon.

In earlier periods these programmes often focused on urban roads where the density of casualties was higher, but considerable attention has also been given to rural roads, particularly to accidents at bends and junctions, since 1990 (Barker et al., 1999). Specific programmes have also targeted major roads passing through villages (Wheeler and Taylor, 1999) and the development of ‘Quiet Lanes’ (Kennedy and Wheeler, 2004a, 2004b).

For the last 10 years, the desirability of a better rural road hierarchy on which to base a more consistent speed management process has been discussed. This has culminated in a revision of the Roads Circular on setting speed limits on single-carriageway rural roads, with the same advice being issued by the Highways Agency for speed management on their local roads).

Speed camera enforcement programmes have also included sites on rural roads, although these are in the minority and mainly limited to major roads.

4.3.4 Elements in an overall strategy

Future policy for rural roads needs to accept that the low density of casualties on rural roads other than those that are heavily trafficked means that, in cost-benefit terms, the returns on engineering measures could be low. However, this very much depends on the cost of measures. Although single carriageways can be straightened or dualled, realistically these type of projects only affect a very small percentage of the English network, even in a 10-year horizon. These projects will continue to offer a small contribution to overall casualty numbers, but can be ignored for the purposes
of target setting. Indeed, it may be asked why substantial proportions of limited resource are targeted at large schemes that, while worthwhile in economic terms, are unlikely to deliver the same attractive return that smaller schemes or mass action schemes could deliver.

Methods must be found of changing the behaviour of drivers on rural roads, and of mitigating the severity of injuries when accidents do occur.

Lynam (2007b) suggested that a future strategy would need to include the following elements:

- Clearer separation of road functions the safety quality of the network of high-speed roads needs to be more consistent and more clearly separated from those roads with more diverse functions.

- Self-explaining roads the safety of rural roads relies heavily on driver behaviour, and there is more scope for drivers to be better informed about the function of a road, and the driving style necessary for safe use of that road.

- Safe road system the key aspects of road design contributing to severe injury (roadside, junction, median treatment) need to be reconsidered to mitigate injuries to those involved in accidents. This needs to be done by balancing vehicle speed and potential impact severity, integrating the contributions that can be made from both vehicle and infrastructure design. Injury protection needs to be seen alongside accident likelihood as routes to improved safety.

- Modifying driver behaviour general improvement in driver behaviour on all roads should be reflected in casualty reductions on rural roads, but in addition the limited investment justified on engineering and enforcement measures on many of the lower trafficked roads means that a specific focus on road-user perception of safe behaviour on these roads is necessary.

While the theory of these bullet points cannot be disputed, our belief is that models that rely on ‘fixing the driver’ are susceptible to failure. The appetite for taking feckless drivers out of the system (e.g. by custodial sentences) is seemingly low. This places a high degree of dependence on the education of ‘average’ road users. While this is a worthwhile activity, it is unlikely to produce a sizable shift in driver behaviour that could be measured in terms of overall safety impacts. This approach seems most relevant to ensure compliance with the law, for example on seat belts, drink-driving and, to a degree, speed limits. However, many road crashes are caused by genuine driver errors rather than reckless behaviour. While campaigns that encourage greater attention at junctions have merit to reduce ‘looked but failed to see’ type accidents, it is better road layouts that would ultimately lead to reduced casualties in the longer term, given that a percentage of mistakes will always occur at layouts that have conflict points.
4.3.5 Rural road casualties

These are largely based on Walter (2006), Broughton (2006) and Hamilton and Kennedy (2005):

- Rural roads accounted for 66% of fatalities and 49% of KSIs in Great Britain in 2004.
- The proportion of KSI casualties on rural roads decreased at a lower rate than on urban roads in recent years.
- Roads with high traffic flows have a higher density of casualties, but a lower risk in terms of rate per vehicle kilometre.
- For all casualty severities, the largest proportion occurs on single-carriageway Class A roads, ranging from 48% of fatalities to 38% of all injury casualties.
- About 61% of fatalities and KSI casualties on rural roads are car occupants and 19% are motorcyclists. About three-quarters of car occupant fatalities and two-thirds of motorcycle fatalities occur on rural roads.
- Single-vehicle accidents account for over 30% of all rural non-motorway accidents and 37% of fatal accidents; they are most likely to occur on B or C class roads at night, on bends, and involve young drivers.

Of the 65% of fatal casualties occurring on rural roads in Great Britain, the large majority (53% of the total, 81% of the rural road fatalities) are on non-trunk roads. A rather smaller proportion (48%) of KSI casualties occur on rural roads, but again the majority of these (41%) occur on non-trunk roads. In relation to road length, however, the density of KSI casualties on rural non-trunk roads is only about a quarter that on trunk roads (Table 4.7).

<table>
<thead>
<tr>
<th>Table 4.7: Distribution of casualties by road type in Great Britain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Killed</strong></td>
</tr>
<tr>
<td><strong>Trunk</strong></td>
</tr>
<tr>
<td>2,524 (12%)</td>
</tr>
<tr>
<td>16,707 (7%)</td>
</tr>
<tr>
<td>12,119</td>
</tr>
<tr>
<td>0.23</td>
</tr>
</tbody>
</table>

Table 4.8 shows the distribution of the rural non-trunk road casualties in Great Britain between 2000 and 2005 by road type (excluding a small number with unknown road type). The density of KSI casualties varies from about 0.02 per kilometre on B, C and U class roads to 0.6 per kilometre on dual A class roads. Average rates per vehicle kilometre are similar for both major and minor roads.
Table 4.8: Distribution of rural non-trunk road casualties in Great Britain

<table>
<thead>
<tr>
<th>Road type</th>
<th>K (2000–05)</th>
<th>KSI (2000–05)</th>
<th>Length (2004) km</th>
<th>Traffic (2004) billion vehicle km</th>
<th>KSI per year per km</th>
<th>KSI per billion vehicle km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorway and dual A</td>
<td>987</td>
<td>6,295</td>
<td>1,738</td>
<td>81.6*</td>
<td>0.6</td>
<td>99.1</td>
</tr>
<tr>
<td>Single A</td>
<td>5,682</td>
<td>42,233</td>
<td>25,197</td>
<td>65.9</td>
<td>0.24</td>
<td>106.7</td>
</tr>
<tr>
<td>B</td>
<td>1,952</td>
<td>17,643</td>
<td>24,640</td>
<td></td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>847</td>
<td>8,731</td>
<td>73,363</td>
<td></td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>1,237</td>
<td>15,833</td>
<td>109,561</td>
<td></td>
<td>0.02</td>
<td></td>
</tr>
</tbody>
</table>

* Excludes local authority motorways.

Table 4.9 shows the distribution of casualties at bends and junctions by road type for rural non-trunk roads. For example, 17.3% of all fatalities on rural non-trunk motorway and dual carriageway A roads occur at or near a bend.

Table 4.9 Percentages of casualties at bends and junctions on rural non-trunk roads

<table>
<thead>
<tr>
<th>Road type</th>
<th>Percentage of all killed</th>
<th>Percentage of all KSI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At bend</td>
<td>At junction</td>
</tr>
<tr>
<td>Motorway and dual A</td>
<td>17.3</td>
<td>32.2</td>
</tr>
<tr>
<td>Single A</td>
<td>36.4</td>
<td>26.5</td>
</tr>
<tr>
<td>B</td>
<td>45.3</td>
<td>25.1</td>
</tr>
<tr>
<td>C</td>
<td>46.6</td>
<td>17.8</td>
</tr>
<tr>
<td>U</td>
<td>39.2</td>
<td>25.5</td>
</tr>
</tbody>
</table>

4.3.5.1 Involvement of vulnerable road users

- **Young drivers/passengers**  young drivers are over-represented in accidents in relation to their vehicle mileage on all types of road. Both Hughes and Amis (1996) and Barker et al. (1999) noted that younger drivers, particularly males, were over-represented in accidents involving the ‘faster’ manoeuvres, such as going ahead and overtaking, on rural single-carriageways.

- **Motorcyclists**  Sexton et al. (2004) found, for motorcyclist accidents on rural roads in Scotland, that these tended to be more often the fault of the motorcyclist, resulted from loss of control, involved sports bikes and occurred on single carriageways with 60mph limits. The Highways Research Group (2007), working for the Highways Agency, showed that motorcyclists are significantly under-represented in accidents at trees, indicative of risk perception in certain circumstances.

- **Children**  Christie et al. (2002) found that a minority of accidents involving children occurred on non-built-up roads and these tended to be child passengers and had a lower severity ratio than adult car-occupants. There were also many fewer child pedestrian and child cyclist accidents than in built-up areas. The
only issues highlighted were children walking with their back to traffic and child cyclists being vulnerable at private driveways.

- **Pedestrians** 18% of KSI pedestrian casualties and 30% of pedestrian fatalities occur on rural roads.

- **Cyclists** 27% of KSI cyclist casualties and 48% of cyclist deaths occur on rural roads. Gardner and Gray (1998) found the rate of fatal cycling accidents per vehicle kilometre is almost three times that on built-up roads, and the severity of cycling accidents increase with speed limit.

- **Tourists/visitors** Sharples and Fletcher (2001) examined whether tourists and visitors contributed disproportionately to casualties on rural roads in Scotland; while the increased traffic results in more accidents, it is difficult to establish higher levels of risk.

### 4.3.5.2 Behavioural factors

- **Speed** identifying the role of speed in accidents through contributory factor studies is difficult as it depends on an assumption of appropriate speed for the location. Earlier contributory factor data (Broughton, 2005) has shown that up to 30% of fatal accidents are associated with excessive or inappropriate speed. More recently, Broughton (2006) noted about 15% of fatal accidents and 11% of serious accidents were recorded as having excessive speed as a contributory factor. The proportions are slightly higher for lower class (B to U) roads. Broughton also showed that this factor was associated with about 40% of KSI casualties in single-vehicle car accidents involving loss of control and 30% of single-vehicle motorcycle accidents involving loss of control. The influence of speed on accidents has been identified through cross-sectional studies (Taylor *et al.*, 2002) as resulting in between 4% and 7% extra accidents per 1 mph above the average speed for the road, with the larger effects on lower-quality roads.

- **Alcohol** Broughton (2006) showed that similar proportions (about 5%) of fatal and serious accidents on rural roads were recorded with alcohol as a contributory factor, with no large variation between road types. The comparable percentages for urban roads are 8% of fatal and 6% of serious accidents. The Highways Research Group (2007) showed that accidents at trees had a higher involvement of alcohol.

- **Fatigue** evidence of fatigue from contributory factor studies is very limited. It can be expected to be a larger factor on rural roads than on urban roads, and on lightly trafficked roads than on heavily trafficked. (e.g. Reyner *et al.*, 2001; Flatley *et al.*, 2004). Incidence may be high (up to 30%) on high-quality high-speed roads when flows are low, typically linked to night-time driving, young males and also to drivers in the course of work. However, involvement is likely to be low on lower-class roads (the above references suggest 3% for rural B roads), particularly those whose features are continually changing, for example winding roads. The Highways Agency has commenced two studies that,
in time, may reduce fatigue accidents: one study relates to potential improvements to engineering measures on, or near, hard shoulders (e.g. better rumble strips); another study relates to low-cost interventions that may reduce the effects of tiredness by maintaining a greater driver interest in his/her surroundings.

- **Distraction/inattention**  Broughton (2006) showed that 7–8% of fatal and serious accidents on rural roads were related to inattention, with the lowest proportions (5%) on unclassified roads. Mobile phone use is often cited as one cause of inattention, with even the use of hands-free phones having a significant effect on concentration on the driving task (Burns *et al.*, 2002). Wallace (2003) failed to find any substantial effect from external distractions, such as advertising boards, although the presumption is that the Department for Transport will continue to work with planning authorities to remove distracting advertisements.

- **Careless/aggressive driving** careless/thoughtless/reckless behaviour was recorded in about 9% of fatal and serious accidents (Broughton, 2006), with little variation between road types. Aggressive driving was recorded in another 2–3% of accidents.

- **Failure to judge** failure to judge one’s own or another’s path or speed was noted as a contributory factor in 16% of both fatal and serious accidents on all rural roads on average, but only about 10% on lower class (B to U roads).

- **Observational issues:** Failure to look and failed to see were noted as factors in 7% of fatal accidents and 10% of serious accidents on rural roads.

- **Inexperience** Broughton (2006) showed that this was recorded in 9% of all loss of control accidents on rural roads, with the highest involvement on C and unclassified roads.

- **Seat-belt use** wearing rates are generally higher on high-speed rural roads. However, a proportion of fatal and seriously injured casualties involve occupants not wearing seat belts. The size of this group is not known accurately, but estimates of up to 50% of fatalities have been suggested in Sweden. Data for Great Britain from the CCIS (Co-operative Crash Injury Study) project indicate that 25% of fatalities are unbelted, with a further 15% unknown.

### 4.3.5.3 Engineering factors

The main sources of information for this section are Walmsley and Summersgill (1998), Hughes and Amis (1996), Barker *et al.* (1999), Hamilton and Kennedy (2005) and Broughton (2006). The OECD (1999) states that about 80% of fatal accidents on rural roads are related to four accident types—accidents involving vulnerable road users, accidents associated with intersections, single vehicles running off the road, and head-on collisions. Further analyses, as part of EuroRAP (Lynam and Lawson., 2005) have shown how the proportions of each of these accident types vary in Great Britain for different road types and different traffic flows:
• **Road width**  increased road width is generally associated with lower accident rates, although estimates of the size of the effect vary in different studies. Significant carriageway or lane narrowing potentially leads to lower speeds, particularly in urban settings, but seemingly not enough to balance the increased risk of driving along the narrower roads.

• **Horizontal and vertical alignment**  Walmsley and Summersgill (1998) found that bendiness and hilliness have only a small effect on accident risk on rural trunk roads, but these are engineered to fairly high standards. On non-trunk roads, Barker *et al.* (1999) and Hughes and Amis (1996) both found that increased bendiness led to increased accident risk. Taylor *et al.* (2002) also showed that, across a variety of non-trunk rural road types, more sharp bends per kilometre were associated with higher accident risk. Broughton (2006) showed that about 10% of fatal and serious accidents involving loss of control were at bends or on winding roads. Broughton also showed that this factor was associated with a similar proportion of all single-vehicle motorcycle accidents.

• **Roadside characteristics**  the width of the safety zone (i.e. the area in which vehicles can recover or stop without serious impact) on the side of the road has a significant effect on casualty outcome. The influence of this area is also affected by the slope and nature of the ground and the presence of ditches. Carriageway edge treatments can help the driver avoid leaving the road. Klassen *et al.* has shown that large parts of even the most highly engineered UK roads (motorways) do not comply with the latest standard for roadside protection.

• **Junctions and accesses**  the influence of junctions depends on the number of conflicting movements allowed and the speed and angle at which these can take place. Additional major junctions (roundabouts and traffic signals) typically only increase accident rates by a small amount. Movements controlled by give way markings only, without the need for main road speeds to be reduced, lead to potentially greater increases in risk. Significant proportions of accidents have been recorded at private accesses on single-carriageway roads. Projects that consider replacing priority junctions with roundabouts are often difficult to justify due to the monetarised disbenefits (user delays) caused to mainline traffic. This policy may be a future obstacle to the reduction of KSI accidents which are prevalent at high-speed priority junctions. We are aware that, in urban areas, the user delay disbenefits are often disregarded in economic assessments when considering speed reduction schemes. This disparity may become more apparent if urban casualties continue to fall. If KSI rural casualties are to fall at priority junctions, then the economic model which includes user delays at roundabouts may need to be reviewed. Current practice between rural and urban scheme assessment is inconsistent.

### 4.3.5.4 Other factors

• **Emergency medical response**  Hamilton and Kennedy (2005) quote emergency service response time as an important issue in relation to casualty
outcome in Scotland; similar situations may be found in the most rural areas in England and Wales.

- **Agricultural vehicles** Knight (2001) suggested that these vehicle drivers are less likely to be responsible for their accident involvements than other drivers, but they may pose a specific risk to motorcyclists on rural roads.

- **Wild animals** collisions with these are not recorded in national road casualty statistics.

### 4.4 Future engineering interventions on rural roads

Studies have shown that simple engineering using signs, lines and junction enhancements has the capacity to reduce casualties. These schemes will be at point sites and also along routes. It is not thought necessary to report here the wide variety of these potential interventions. However, we have selected some interventions where the potential for casualty reduction may be initially considered high and where the technique is not widely in current use (Table 4.10). A series of

| Table 4.10: Selected interventions and potential casualty reductions on rural roads |
|-----------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| Intervention                                  | Scale/severity of casualties currently affected | Potential casualty reduction at treated sites | Likely number of sites treated | Overall contribution to 2020 casualty targets |
| Speed management                              | High            | Very good       | High            | High            |
| Road Restraint Systems                        | High            | Very good       | High            | High            |
| Bends and WYLIWYG*                            | High            | Very good       | High            | High            |
| Vehicle-activated signs                       | High            | Very good       | High            | High            |
| ‘Crash friendly’ signposts/lighting columns   | High            | Very good       | High            | High            |
| Treatment options for bends                  | High            | Very good       | High            | High            |
| MIDAS                                         | High            | Average         | High            | Medium          |
| Junction specific issues                      | High            | Very good       | Medium          | Medium          |
| Markings and surfaces (good maintenance)      | Medium          | Medium          | Medium          | Medium          |
| Double white lines and similar                | High            | Good            | Low             | Medium          |
| Village treatments                            | Low             | Good            | Low             | Medium          |
| Psychological traffic calming                 | Low             | Good            | Low             | Low             |
| Controlled motorway                           | High            | Average         | Low             | Low             |
| Hard-shoulder running                         | High            | Average         | Low             | Low             |
| Quiet Lanes                                   | Low             | Medium          | Low             | Low             |
| Wide single carriageway 2 + 1 roads           | High            | Good            | Very low        | Low             |
| Vehicle separation markings                   | High            | Low             | Very low        | Low             |
| Large-scale link upgrades by changing road type | High          | Very good       | Very low        | Low             |

* WYLIWYG stands for ‘Where You Look Is Where You Go’. Traditionally, hazard markers are placed to highlight the ‘crown’ of a bend. However, WYLIWYG takes the marker posts further round the bend to the point where the ‘vanishing’ point starts moving away from the road user’s view, which is often into the straight. In addition, the posts are placed closer together so that they keep appearing into the road-user’s view, focusing on a point around the bend allowing the rider to negotiate the hazard safely (description adapted from Roadsafe (2005)).
recommendations are made as to the actual likely impact of these measures. The assessment of future impact is relatively coarse and subjective, but is usefully included as a method of identifying the highest priorities. More detail can be provided on each of these interventions.

4.4.1 *Summary of interventions with the potential for high impact on rural road casualties*

The interventions that have been classed as having the potential for high impact on casualty reduction targets are speed management, road restraint systems, WYLIWYG, vehicle-activated signs (VAS) and crash-friendly signposts/columns. These exclude some of the more traditional measures which are expected to generally continue with associated high rates of return.

4.5 *Future engineering interventions on urban roads*

In the urban domain, there are a wide range of types of road, from urban motorway, through strategic routes, shopping and town centre streets, district and local distributors to minor access roads and culs-de-sac, each requiring a different approach and a unique combination of measures which are appropriate to the location and accident scenario.

We have selected some interventions where the potential for future casualty reduction may initially be considered high and/or novel (Table 4.11). A series of recommendations are made as to the actual likely impact of these measures. The

<table>
<thead>
<tr>
<th>Table 4.11: Selected interventions and potential casualty reductions on urban roads</th>
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<tbody>
<tr>
<td><strong>Intervention</strong></td>
</tr>
<tr>
<td>Passive sign supports, lighting columns and signal poles</td>
</tr>
<tr>
<td>20 mph zones</td>
</tr>
<tr>
<td>Speed cushions</td>
</tr>
<tr>
<td>Entry treatment</td>
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<tr>
<td>Lateral deflection</td>
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<tr>
<td>Carriageway narrowing</td>
</tr>
<tr>
<td>Pedestrian refuges/central islands</td>
</tr>
<tr>
<td>SafeNET</td>
</tr>
<tr>
<td>MOVA and other signal control improvements</td>
</tr>
<tr>
<td>SCOOT</td>
</tr>
<tr>
<td>Automatic/rising bollards</td>
</tr>
<tr>
<td>Speed/vehicle activated signs</td>
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<tr>
<td>Pedestrianisation</td>
</tr>
<tr>
<td>‘H’ and ‘S’ shaped speed humps</td>
</tr>
<tr>
<td>Home zones</td>
</tr>
<tr>
<td>Shared areas</td>
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<tr>
<td>Rumblewave surfacing</td>
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</tbody>
</table>
assessment of future impact is relatively coarse and subjective, but is usefully included as a method of identifying the highest priorities.

4.5.1 Summary of interventions with the potential for high impact on urban road casualties

Many of the interventions presented in Table 4.11 are appropriate for urban areas and comprise tried and tested means, with only a few new additions. Traffic-calming measures have been in common use for the past 30 to 40 years, but have been constantly refined over that period.

The interventions that have been classed as having the potential for high impact on casualty reduction targets are passive furniture, speed cushions and 20 mph zones.

4.6 Possible engineering action plans

4.6.1 Rural roads

This section is largely based on work reported by Lynam (2007a) for rural roads. Roads have been historically classified as A, B, C and Unclassified, depending on their perceived importance. As their usage has changed over time, some reclassification takes place, but does not fully reflect the changes in function taking place. One of the most important indicators of function is the level of traffic flow, usually measured as annual average daily traffic (AADT). The higher flow roads, which typically serve more through movements, are also those where pressure to maintain higher speeds is greatest. As flow increases, the justification for major improvements, such as dualling or more segregated junction movements, becomes greater. For the purpose of this analysis, dual and single carriageways will be discussed separately, and single carriageways will be considered as major or minor. There are no clear criteria for defining the major/minor split; it can be done assuming major are all A and B roads, or all roads carrying more than a specified AADT. As part of their response to the revised Roads Circular on speed limits (Department for Transport, 2006a), highway authorities are required to review speed limits on single-carriageway rural roads and categorise these as major or minor.

The implementation of specific measures will depend on detailed route investigations, targeting the specific problems at sites along the route. This section is concerned only with discussing the general application and effectiveness of policies on different road types.

4.6.1.1 Motorways

The use of MIDAS (or mandatory variable speed limits) has high potential for motorway safety, including shunt accidents. The business case for the former is now
well established and roll-out to the remaining qualifying sections of the motorway network is a reasonable probability.

Measures that reduce the effects of run-off accidents, such as passive street furniture or the increased use of nearside barriers, appear to be very cost effective and reasonably affordable, particularly when compared with other motorway network interventions that are not specifically focused on safety. Both rates of return and cost effectiveness will be maximised if the whole network is upgraded.

4.6.1.2 Trunk roads

About 15% of rural KSI casualties and 19% of rural road fatalities occur on the trunk road network. Engineering standards on these roads are already high, but the remaining high casualty density, averaging 0.23 per kilometre per year, means that further measures to improve junctions, roadsides and medians on these roads, similar to those recommended for local authority class A roads, are still likely to be cost effective. Again, cost effectiveness will be maximised by co-ordinated programmes of work rather than piecemeal improvements.

4.6.1.3 Non-trunk dual carriageways

Including the small length of motorways managed by local highway authorities, only 7% of all rural road KSI casualties (3% of national KSI casualties) occur on these roads. However, the density of these accidents, at 0.6 per year per kilometre, means that engineering measures are likely to remain cost effective. The largest behavioural issue on these roads is close following, coupled with high vehicle speeds.

Almost half the KSI casualties in accidents on dual carriageways with at-grade junctions occur at these junctions, with most at priority-controlled access points. Large reductions in these casualties can probably only be made by much greater limitations to the number of access points, although significant savings might be made by limiting the movements allowed at access points that were retained. Ideally, only merging movements, at similar speeds should be allowed.

Between 10% and 20% of KSI casualties result from single vehicle run-offs, most of which, presumably, will be related to fatigue or inattention and speed. These could be tackled through increasing driver awareness, or through removing aggressive objects from the roadside. LHAs are currently extending the use of passive infrastructure, but this will have little effect unless large-scale replacement programmes are pursued. On local authority roads, many objects other than those installed by the highway authority are likely to exacerbate the problem.
4.6.1.4 Non-trunk major road single-carriageways

This is the largest potential target group, involving two-thirds of all rural KSI casualties (over a quarter of all national KSI casualties). The average density of KSI casualties on these roads (0.24 and 0.11 per year per kilometre on A and B roads, respectively) is still relatively high, and will be typically twice as high on the highest risk sections.

There has been considerable attention to speed management on rural single-carriageways in recent years, but contributory factor data continue to show scope to reduce casualties through the safer choice of speed by some drivers. Further awareness and enforcement campaigns supported by the continuing implementation of low-cost engineering, perhaps particularly through signing hazards and clarifying road function, are likely to be necessary. More consistent use of speed limits will play a part in this, although around 15% of the fatalities on these roads already occur on roads with 20–40 mph limits.

Only around 10% of KSI casualties on these roads are associated with shunt accidents. The largest KSI casualty group (about 40% on class A roads) occurs in the vicinity of junctions. Some of these might be saved by low-cost improvements, but large casualty savings are likely to require major programmes of junction improvement, with more focus on eliminating high-speed steep-angled conflicts.

Improvement of the roadside on these roads only affects 14% of the KSI casualties, and is likely to need to be well targeted to be cost effective. Again, major programmes involving large lengths of road will be more cost effective than piecemeal changes.

A major problem seen in other countries is the incidence of head-on accidents on these roads; this appears to be less of a problem in Britain, but still results in over 20% of the KSI casualties. Measures to discourage overtaking further or the provision of a greater length of dedicated overtaking lanes (‘2 + 1 lanes’, with and without central safety barriers) should be considered.

About 30% of KSI casualties on A roads and 40% on B roads occur at bends; these may occur in both run-off and head-on accidents. Effective signing and marking should continue to be developed to reduce these accidents. About 35% of KSI casualties occur at junctions on these roads; around half of these involve both bends and junctions. Interactive signing has proved effective at some of these junctions, but at others more major layout changes may be justified. A hierarchy is suggested and WYLIWG (Where You Look Is Where You Go) appears to be a future candidate intervention that offers good value.

About 60% of pedestrian and cyclist KSI casualties on non-trunk rural roads occur on these roads, and 36% occur at speed limits of 60 mph. It is unlikely that low
speeds can be introduced over large parts of this network. Department for Transport Circular 1/06 recommends 50 or 60 mph except where there is significant development (Department for Transport, 2006a). Therefore modification of the environment to give greater risk awareness to both drivers and vulnerable road-users at key points where conflicts with higher-speed vehicles occur appears the only low-cost measure. The development of more segregated facilities should be investigated, but is only likely to be cost effective in limited situations.

### 4.6.1.5 Minor two-lane roads

About 20% of all fatalities on non-trunk rural roads and 27% of KSI casualties occur on these roads. However, the density of KSI casualties is low at 0.02 per year per kilometre, making it unlikely that any general engineering treatment is justified. But 40% of fatalities on these roads occur on bends, and 30% at junctions, and there could be scope to make drivers more aware of the risks at these sites, particularly where the cost of intervention is low (such as WYLIWYG). The frequency of such sites on these roads suggests that road users are not aware of the high-risk locations or are not behaving in a way that adapts for the different risks of different locations.

The proportion of fatal and serious accidents with excessive speed on these roads is slightly higher than the average for all rural roads, and Department for Transport Circular 1/06 recommends speeds of 40 or 50 mph for minor rural roads (Department for Transport, 2006a). Half of the pedestrian fatalities on these roads, 35% of cyclist fatalities and 20% of car occupant fatalities occur on sections which already have speed limits no higher than 40 mph.

Overall, about a quarter of all rural non-trunk road pedestrian fatalities and a third of cyclist fatalities occur on these roads.

### 4.6.2 Urban roads

We envisage continuing refinement of Urban Safety Management (USM), including modification by *Manual for Streets* (DfT, 2007) (and successor documents). USM will increasingly involve hierarchical considerations and these are constantly evolving. For example, there is likely to be continuing development of the mixed priority use (MPU) streets approach, often coupled with accessibility and regeneration projects.

More specifically, we envisage increased emphasis on providing walking and cycling facilities in urban centres. For example:

- on-street cycle parking provision and bike parks;
- cycle routes particularly as part of Travel Plans;
- cycle-only access/contra-flow;
• cycle centres;
• Bikerail;
• the extensive use of cycle audits;
• refinement of pedestrian crossings Toucan and Puffin;
• pedestrianisation increased town and city centre redevelopment shared areas;
• increased priority for pedestrians ‘less is more’ signing;
• Disability Discrimination Act compliance; and
• non-motorised user audits.

For urban speed management (reduction) we envisage:
• the increased use of cameras and other measures;
• less reliance on humps;
• more use of perceived danger signals, for example chicanes, build-outs, horizontal realignment;
• VAS;
• an increase in the use of Home Zones; and
• mini-roundabouts.

4.7 Costs, benefits and funding

4.7.1 Introduction

In historic terms road safety engineers have used first-year rate of return (FYRR) as an indicator of economic success. This is because, in the past, schemes were always local and, in many cases, short lived. Additionally, the indicator is slightly crude, but this does not matter because it is still used as a relative tool to identify best projects and best options where there are a high number of candidate sites and options.

Major interventions on the network are expressed using benefit to cost ratios (BCRs) over a 30- or 60-year appraisal period. This method of cost benefit analysis may be more relevant to mass action programmes with longer time-frames. This method would aid policy makers in identifying where investment would be best placed, as it would allow direct comparison with other major programmes, such as road widening. Additionally, the use of FYRR does not immediately allow decision takers to overtly understand what return ratio they will receive for the investment. This feature might be particularly useful when looking across different government areas when more strategic decisions are made between different public-sector areas.
Of interest to policy makers is the longevity of safety schemes, that is, how long do they continue to deliver safety benefits once constructed. This is important as sensible investment would rely on the portfolio of schemes that delivered the most effective casualty reduction when summed over the longer term. To our knowledge no studies have looked at this issue, presumably because high rates of return over short periods (say one to two years) in themselves do not require further assessment. However, as safety targets become harder to meet, this area may require a critical review. Such a review might usefully create categories of scheme with reference to the longevity of effects to allow the possible re-basing of priorities, for example a white lining scheme with FYRR of 100% that is effective for one to two years may currently receive funding ahead of a safety barrier scheme with FYRR of 40% that delivers greater casualty reduction over 30 years. This system of re-basing need not be overcomplicated and may involve designating a small number of scheme-life categories that allow better comparison of benefits.

As different safety schemes have different life-spans, it would be useful to rank priorities in such a way that gave better information on the overall casualty reduction that is likely. This could improve value for money in the long term.

### 4.7.2 Funding mechanisms

There are various methods of securing funding for road safety investment. It is our understanding that certain projects enjoy ring-fenced funding based on the approval of a business case and sufficiently robust economics. However, this is understood not to be the case at a national level. If the projects concerned represent excellent value for money compared with the overall road safety portfolio, then ring fencing is sensible. If, however, mass programmes are based on weaker economics than projects that emerge on a routine annual basis, then there may be concern that historic business cases could weaken the overall positive effect on spending on road safety.

Mass action has economies of scale due to its repetitive nature. If any of the interventions (e.g. WYLIWG) are shown to enjoy high levels of return (say FYRR over 200%), there may be merit in top-slicing budgets or allocating additional funding to high worth programmes in order to ensure plans can be put in place with confidence. Although it is anticipated that most road safety interventions will be based on local knowledge, it is possible that the isolated use of ‘instructed’ mass action from the central department may have some worth.

Further work could be carried out to investigate whether different funding arrangements, for the same overall expenditure, could maximise casualty reductions. This review could include assessment of any existing ring-fenced programmes to ensure that value for money was still high.
4.7.3 Possible savings through engineering schemes

It has been shown that at current expenditure levels it might be possible to save 3,100 accidents in each year through engineering intervention, with a FYRR of 200%. Assuming an average of 1.36 casualties per accident (derived from Department for Transport (2007c)), this gives a saving of 4,234 casualties or 1.63% of the total per year at the current rate of expenditure. Increases in expenditure of low multiples (between one and two) would be expected to increase the number of casualty reductions by an amount broadly pro-rata to the funding granted.

4.7.4 Timing/programming

It is important to consider whether it is possible to deliver the target casualty reduction in a particular time frame (e.g. between 2010 and 2020) if funding was available and political will existed. A realistic timescale would be based on industry capacity and agreement on an acceptable amount of roadworks. Let us assume that working on three sites per LHA is possible at one time, with a four-month site occupation per site means that it would be possible to remedy nine sites in one year per LHA. Nationally this would equate to around 1,400 sites per year. This implies that each site would need to save just over two accidents. This is consistent with historical performance.

Any decisions in support of targets for 2020 that assume increased expenditure would have to be taken to allow the acceleration of construction works to start early in the next decade. Any ambitious target may be unachievable if roadwork restrictions or unavailability of designers or contractors were a problem.

Targets should consider the capability of the delivery system to ensure that the volume and type of skills and resources required to implement road safety engineering are available within the target time-frame. If they are not, then consideration should be given to how the required levels of implementation might otherwise be delivered.
This section begins with a brief discussion of the limitations of this work and a description of how vehicle safety can be categorised. It then reviews recent developments in the design of vehicles and how they have influenced the number of accidents and casualties as well as what changes are expected as a result of growing market penetration of those designs. A discussion of what major new developments are expected in each area of vehicle safety is presented, alongside predictions of the casualty effects, where available, and the risks and barriers to introduction.

5.1 Limitations of the analysis

The analysis undertaken for this project was of limited scope and duration. The report, therefore, briefly summarises what is a very wide-ranging technical subject area and does not consider any of the aspects involved in great detail. In particular, there are a number of limitations with respect to estimates of the casualty effects, as summarised below:

- However, for some, particularly primary, safety features, the ability to measure or predict the effects is severely limited by the data available. Thus, casualty reduction estimates were not available for all measures.

- Many vehicle safety features will be the subject of multiple studies of casualty reduction potential. These often predict widely varying levels of effectiveness based on a wide variety of assumptions, data sources and different countries with varying quality of analyses.

- Casualty reduction estimates for individual systems tend to be undertaken in isolation and are usually based on historic accident data rather than forecasts of future accident numbers. This can overestimate the effects because the effects of other measures implemented at similar times are ignored. This means that the predictions of benefits for different systems cannot be added together. In fact, if all of the predictions contained in this section were added together, it would imply that more than 100% of fatalities could be prevented.

- Different literature often expresses the benefits as percentages of different groups of casualties in different countries. This means that it can be difficult to compare all the effects on a uniform scale.

The time and resources for this work were such that no attempt has been made to overcome these limitations and many of the estimates presented were quoted from a single reference source without critical analysis of the techniques used. This means that the predictions quoted in this report should be taken as no more than an initial indication of the potential future casualty effects that might be expected from vehicle safety measures. Considerable further work would be required to produce a more accurate quantification of the overall net effect of a suite of vehicle safety
measures, introduced at various times and combined with other measures described elsewhere in this report.

5.2 Vehicle safety definitions

A wide variety of definitions and methods of categorising vehicle safety are in existence. Those used in this report are based on an interpretation of the European Automobile Manufacturers’ Association (ACEA) safety model, an adapted schematic of which is shown in Figure 5.1.

![Figure 5.1: ACEA safety model](image)

Primary safety features are defined as those primarily intended to avoid an accident, although such features can also reduce the severity of an accident. Secondary safety features are those intended to avoid or reduce the severity of injuries when an accident does occur. Tertiary safety is related to features that help reduce the consequences of injury by making it easier and/or quicker for the casualty to receive medical treatment.

In many parts of the world, particularly in Europe, the term active safety is often used as a direct alternative to primary safety, and passive safety is used as a replacement for secondary safety. However, active and passive can also be used to describe the mode of operation of a feature. This can lead to confusion. For the purposes of this report, a passive safety feature is defined as one that has a single fixed characteristic or response, while an active safety feature is one that measures one or more parameters and makes a decision as to which of two or more responses is appropriate. In this way both active and passive features can contribute to either primary or secondary safety. For example, a standard seat belt (without pre-tensioner) is defined as a passive system contributing to secondary safety, an airbag is an active system contributing to secondary safety, the foundation brakes are a passive system contributing to primary safety and an antilock braking system (ABS) is an active system contributing to primary safety.
Historically, the fields of primary and secondary safety have been considered in isolation. However, in recent years the boundaries between these two areas have been blurred, largely because of the development of advanced sensor technologies that have made a much wider range of system functionality possible. This is reflected in Figure 5.1 by the diagonal boundary in the unavoidable collision phase of the ACEA safety model. This is intended to represent the possibility that the vehicle can monitor the likelihood of a collision before it occurs and can then use primary safety systems to either avoid the collision, or if the collision has become unavoidable, reduce the collision speed in order to reduce its severity. The information from this monitoring can then also be used to optimise or pre-arm secondary safety systems in order to better protect the occupant when the collision does occur. For the purpose of this report, systems representing interaction between primary and secondary safety have been defined as integrated safety systems.

Elsewhere in this section the ‘market penetration’ of vehicle design features is also referred to. This is defined as the proportion of all vehicles registered on the UK’s roads that are equipped with the feature in question at a particular point in time.

5.3 Primary safety

Primary safety includes subjects such as:

- braking and braking stability;
- handling;
- lighting and conspicuity;
- field of view;
- vehicle loading; and
- ergonomics and human machine interaction (HMI).

5.3.1 Recent developments

The main objective of this work was to consider what might be expected to happen after 2010, the date at which current casualty reduction targets are set. However, when considering the future effects of vehicle safety features it is particularly important to review the actions taken over recent years. This is because for almost all vehicle safety features there will be an approximately linear relationship between the market penetration and the casualty effects for a given system’s effectiveness. Most vehicle safety features are introduced through the type approval system or, increasingly, voluntary action by the manufacturers. In either case, the changes are only applied to new vehicles and it can take a long time, 10 years or more, for such a measure to fully penetrate the vehicle fleet. Thus, new measures implemented on new vehicles in the last 10 years may not yet have fully penetrated the vehicle fleet.
and may, therefore, continue to have an increased effect on the number or severity of casualties.

In recent years there have been some developments that could be considered to have an adverse effect, tending to increase the frequency of accidents. These include the following:

- **Increased A-pillar thickness** the A-pillar is the part of the car to each side of the windscreen that supports the roof and provides the forward part of the front door frame. This structure can obscure the vision of the driver. One method used to improve car secondary safety (see Section 5.4.1) has been to increase the size and stiffness of the A-pillar. There is evidence to suggest that the obscuration caused has been a contributory factor in some accidents (Millington et al., 2006). This is a very common feature on newer cars performing well in New Car Assessment Programme (NCAP) tests, but older cars in the current fleet would not be affected.

- **Taller vehicles** in recent years there has been a trend for passenger cars to be taller, particularly for SUVs, people carriers and small ‘town’ cars. This has the effect of reducing the static stability of the vehicle, thus making a rollover accident more likely. This has been a relatively recent trend and may not yet have fully penetrated the vehicle fleet.

- **Increased use of two-wheeled motor vehicles (TWMV)** motorcycles and other TWMV tend to have lower levels of primary safety because of lower conspicuity, higher speed capability, lesser stability and less sophisticated braking systems. Thus, increased use of such vehicles tends to increase the frequency of accidents and there has been an increase of approximately 25% in the number of TWMV fatalities (Department for Transport, 2006b).

However, there have also been a range of measures introduced that have acted to reduce the frequency of accidents. These include the following:

- **Reduced stopping distances** brake performance has improved, particularly for passenger cars, such that higher decelerations and shorter stopping distances are achievable. Market penetration will be relatively high, but not 100% for passenger cars and much lower on heavy vehicles.

- **ABS** ABS prevents wheel lock and the associated instability under braking and permits some steering during emergency braking, thus increasing the ability of the vehicle to avoid an accident. For vehicle/trailer combinations it also greatly reduces the chance of jacknife and trailer swing. Market penetration will be relatively high particularly for larger goods vehicles (greater than 12 tonnes) and long distance touring buses where it has been mandatory since 1991. It is now fitted to all new passenger cars, HGVs and buses, and is fitted to many new light commercial vehicles (LCVs). However, there is still likely to be a
substantial proportion of older vehicles in the current fleet that are not so equipped.

- **Brake Assist System (BAS)** it has been shown (Lawrence et al., 2006) that ordinary drivers often do not use the maximum braking available to them in an emergency situation. BAS detects when a driver intends an emergency brake application and acts to increase the amount of braking applied such that maximum braking is reached earlier in the stop, thus reducing stopping distance. ECORYS (2006) estimated that BAS could avoid 4% of fatal accidents and that, in 2005, 5% of vehicles in the EU were equipped with it already. If no further action was taken, it was estimated that market penetration would be 20% in 2025. However, it is likely to be incorporated as an option within the pedestrian Directive which would be expected to greatly increase its uptake.

- **Electronic Stability Control (ESC)** loss of control can be shown to be a significant cause of accidents, particularly those of higher severity. ESC detects when a vehicle is not following the path that the driver demands (as measured by the steering wheel angle) and acts to control the instability by applying the brake at individual wheels in order to create a restoring moment. Frampton and Thomas (2007) state that, in the UK, ESC reduces the risk of becoming involved in a crash by 7%, but that the risk of a serious crash is 11% lower in ESC-equipped cars and the risk of a fatal crash is 25% lower. ECORYS (2006) suggest that 9% of the EU vehicle fleet is equipped with ESC, but there is evidence (EuroNCAP, 2007) to suggest that fitment in the UK is lower than most other European countries. In addition to this, systems are available that also aim to prevent rollover of heavy vehicles. ESC is likely to be mandated for new vehicles across Europe very soon and this will greatly increase the rate of market penetration.

- **Brake light displays** traditionally, brake lights are a very simple signal to show that a vehicle is braking and the signal remains the same regardless of whether they are braking to remain at a constant speed on a downhill stretch of road or emergency braking. More advanced brake light displays have been developed to illuminate additional signals (typically flashing brake lights or hazard warning lamps) when the vehicle deceleration exceeds a certain level. Research has shown that some such systems can result in small improvements in the reactions of following drivers. Systems were, until recently, considered to be illegal by some approval authorities and, therefore, the market penetration is low.

- **Improved field of view from mirrors** regulations were amended in 2003 to provide a greater visible area from mirrors to help eliminate blind spots around HGVs (Fenn et al., 2005). This is expected to provide substantial benefits to a small group of casualties. Most changes were applied to new vehicles only such that market penetration remains low, but a regulation requiring some of the increased mirrors to be retro-fitted to some vehicles is due to be implemented soon, greatly increasing market penetration.
5.3.2 Potential future developments

There are a wide range of potential future developments in primary safety. A selection of the more fundamental primary safety systems are presented below, but many more advanced systems are based on pre-crash sensing and are presented in the section describing integrated safety (Section 5.5):

- **Adaptive front lighting** traditional headlamp systems provide a beam that is a compromise intended to fulfil as many conflicting requirements as possible. Adaptive front headlamp systems adapt to the manoeuvre or type of driving being undertaken by the vehicle at the time in order to provide the correct illumination in the right areas at all times. For example, they will form a long narrow beam when driving on high-speed roads and a shorter, wider beam on lower-speed roads and will move through an angle to remain focused on the road ahead during bends and corners.

- **Daytime running lights** there is evidence (Knight and Broughton, 2006) to suggest that operating daytime running lights (DRL) would result in a net casualty reduction in the region of 5%. However, there is a risk, depending on the details of implementation, that this would have an adverse effect on the number of motorcyclist casualties. It had been proposed that DRL would become mandatory across the EU, but that proposal has been dropped. It is still possible that the use of headlamps and/or dedicated daytime running lights will increase because a proposal to fit DRL to new cars is still under consideration.

- **Increased minimum brake standards** although, on the whole, brake performance has improved substantially, the improvements have been much smaller for heavy vehicles and some light vehicles perform at substantially lower levels than the best. It is possible, therefore, that the minimum regulatory standards for braking will be increased in order to bring vehicles with a lower performance standard more into line with the best vehicles.

- **Combined brake system for TWMV** currently, most motorcycles have separate brake controls for the front and rear brakes. This means that the driver controls the brake balance, which means that the optimum performance is not always achieved. Developing a combined brake control with an optimised brake balance system should result in an increase in the average deceleration in emergency brake manoeuvres for typical riders.

- **TWMV ABS** very few motorcycles are equipped with ABS despite the fact that it has been proven to be technically feasible for some time and the consequences of a locked wheel, particularly at the front, can be much harder for the rider to deal with. It is possible that the use of ABS on motorcycles will increase.

- **TWMV BAS** this represents another transfer of technology from passenger cars which could potentially improve the performance of typical riders in emergency braking manoeuvres.
• Alcohol interlocks estimates suggested that, in 2004, 17% of all road deaths occurred when someone involved was driving while over the legal limit for alcohol (Department for Transport, 2006b). Alcohol interlocks are devices that are intended to prevent drivers from being able to start an equipped vehicle if they are over the alcohol limit. The upper limit of their effect in the UK would be to eliminate all of the 17% of road deaths where alcohol was a factor. However, in reality their effectiveness will be substantially lower than this because persistent offenders may find ways around the system and some drivers may drink more than previously because the alcohol limit in the UK is relatively high and drivers will be more confident of avoiding prosecution if they use the system. In addition to this, it is possible that some of the 17% of fatalities would still have occurred even if none of the parties involved had been over the legal alcohol limit.

5.3.3 Risks and barriers

Knight and Broughton (2006), among many others, show that accurately quantifying the casualty effects of primary safety features can be very difficult. The fundamental problem is similar to other safety areas, in that if a measure is successful then there is no accident and, thus no data for comparison. While techniques are available to provide estimations of effects that can be used in cost benefit analyses, these are the subject of a number of limitations that contribute greatly to varying estimates from different researchers and different countries. Vehicle primary safety features interact strongly with driver behaviour, and the effectiveness of such systems rely on drivers having the knowledge and skill to use the systems correctly in an emergency situation and not to adapt their behaviour in a negative way during normal driving. This possibility requires careful design in its own right, but is very difficult to model in a prediction of casualty benefits. Thus, arguments of behavioural adaptation can often be easily used to undermine such analyses without any evidence to support the argument. These factors combine to make it difficult for policy makers to be confident in cost benefit analyses for new measures, particularly those that may only have small, but still beneficial, effects.

A range of potential enhancements to data sources and techniques were recommended by Knight and Broughton (2006). These included:

• improving the quality of information recorded in accident databases about the exact vehicle motion and driver behaviour immediately preceding a collision;
• more widespread use of standardised event data recorders;
• the development of enhanced exposure data, principally developing travel data disaggregated by vehicle make and model to improve the ability to carry out statistical comparisons of the accident involvement of different vehicles equipped with different system;
• compilation of a database identifying the safety equipment fitted to particular vehicles and potentially even some performance data relating to those vehicles again, this is required to improve the capability of statistical analysis of accident data; and

• increased use of human factor experiments in conjunction with predictive and retrospective accident analysis in order to increase confidence about the effects of behavioural adaptation.

The implementation of these recommendations would be expected to greatly enhance the ability to ensure that the most effective potential new measures are those that are encouraged toward full market penetration most quickly, thus maximising the potential casualty reduction effects within any particular time frame.

5.4 Secondary safety

Secondary safety includes subjects such as:

• structural crashworthiness;
• occupant protection and restraints;
• vulnerable road-user protection;
• child occupant protection; and
• TWMV rider protection.

5.4.1 Recent developments

Secondary safety has been the main focus of vehicle safety research and regulation over recent years and a great many major changes have been made. Some examples of these are given below:

• Mandatory use of seat belts  this was probably the most significant single measure taken to protect the occupants of vehicles. It was implemented for passenger cars in the 1980s and from this point of view cannot necessarily be considered a recent measure. However, it has only been introduced on other vehicle types, such as HGVs, more recently and there is some limited evidence (Whitehead and Knight, 2001) to suggest that wearing rates for this category of vehicle are relatively low. In addition, the small proportion of passenger car-occupants that do not wear their belt form a relatively large proportion of the killed and seriously injured casualties recorded by the CCIS (Co-operative Crash Injury Study) database, as shown in Figure 5.2.
- **Front and side impact Directives**: these greatly increased the minimum standards of protection offered to occupants of passenger cars. They were believed to have had a substantial effect, but measurements of the casualty effect could not be found within the limits of this study. The Directives have been in force for some time now so the market penetration is expected to be relatively high. However, it is also likely that there is a substantial minority of cars still in use that pre-date the regulations.

- **EuroNCAP**: the EuroNCAP consumer information scheme has encouraged improvements in passenger car structural crashworthiness substantially over and above the minimum standards required by type approval regulations. The market penetration of cars that perform well in these evaluations will be substantial, but a long way from 100% because the first five star cars were tested in 2001 and are only six years old now. Several evaluations of the effectiveness of EuroNCAP have been made. The Swedish National Road Administration and Monash University estimated that each additional star in the EuroNCAP rating represented a 12% reduction in serious and fatal injuries (Lie and Tingall, 2002).

- **Pedestrian protection Directive**: the first phase of the Directive has been implemented. This aims to ensure that the front ends of passenger cars are designed in a way that reduces the severity of injuries received by pedestrians colliding with that part of the car. It was predicted (Hannawald and Krauer, 2004) that this would reduce the number of pedestrian fatalities by between 0.5% and 10%. This is a recent change and few manufacturers were voluntarily complying before it was introduced, so the market penetration is expected to remain very low.

- **Front underrun protection for trucks**: this was introduced in 2003 and was intended to reduce the severity of injury sustained by car occupants in head-on collisions.
collisions with trucks. Gwehenberger et al. (2004) estimated that this protection could prevent the deaths of 11% of those car occupants killed in a collision with a truck (24% of those killed in a head-on collision with a truck).

- **Improved crash helmets** regulations controlling the design of helmets were introduced in 2002. Although it is difficult to predict the effects reliably, the COST 327 study (Chinn, 2003) identified that a 30% increase in the energy absorbed by a helmet could reduce Abbreviated Injury Score (AIS) 5–6 injuries by 50%.

- **ISOFIX** is a standardised system for providing mounting points for child seats in cars. This is now fitted to new vehicles, but the market penetration remains relatively low. The benefits have not been quantified and could be undermined by unforeseen risks associated with the fitment of different child seats.

- **Mandatory child restraint use for children less than 12 years old or 135 cm tall** this is likely to reduce abdominal injury in frontal collisions and provide some measure of side impact protection. However, there is the potential for some adverse consequences, for example, in a collision from the rear where no head restraints are fitted to the seat.

### 5.4.2 Potential future developments

Secondary safety has reached a very high standard in recent years such that major step changes in performance are now less likely. However, there are still a wide range of areas that could see beneficial improvements. These include the following:

- **Improved front impact protection** this involves the development of new and improved crash test procedures to make them more representative of real-world collisions and to avoid the optimisation of structures and restraints to one crash pulse and occupant size. The subject can be divided into two categories:
  - the ability of a car to protect its own occupants (self-protection) a first order of magnitude estimate is that a further 2–3% of car occupant fatalities could be saved by improved self-protection; and
  - the ability of a car to interact with other vehicles in a way that increases the protection offered to the occupants of the other vehicle (partner protection or compatibility). Edwards et al. (2007) predict reductions of 5–8% of UK car-occupant fatalities and reductions of 5–13% of seriously injured car-occupants. It should be noted that both elements may require the development of improved crash test dummies.

- **Improved side impact protection** further improvements in this area are being researched under the auspices of the European Enhanced Vehicle Committee (EEVC) Working Group 13, but no casualty effect predictions are available yet. Measures under consideration include:
  - New Mobile Deformable Barrier (MDB) test the Advanced European MDB (AE-MDB);
• pole test;
• interior head-form test; and
• side-impact compatibility (partner protection) measures are a longer-term aim with little research carried out to date.

• **Rear-impact protection** measures to improve car-occupant protection in the event of a collision from the rear are under assessment, with particular emphasis on the reduction of whiplash injuries. Thus, these measures will have little impact on fatality figures.

• **Rollover protection** The rollover of passenger cars is perceived to be a growing problem; for example, in 2000, 4,146 vehicles overturned (DTLR, 2001) and, in 2007, 11,010 vehicles overturned (TSO, 2008). This has been highlighted as a potential area for new research, but little action has been taken to date.

• **Frontal design of HGVs** increased protection could be offered to car occupants in head-on collisions if an extended zone of energy absorption was positioned to the front of an HGV at a low level. Pedestrians are the second largest group of road users killed by HGVs and modifying the structure of the front to deform by several centimetres at head height has the potential to prevent a substantial proportion of these fatalities. A further significant group of pedestrians are killed when standing in front of a stationary HGV in the frontal blind spot when the HGV starts moving forward from rest. Eliminating this blind spot could eliminate this type of casualty. All three of these problems could be substantially improved by changing the shape of the front end of an HGV, such that it had some form of ‘nose-cone’ extending from the front of the vehicle. Smith *et al.* (2007) predicted that this could have prevented 53 fatalities per year if it had been fully implemented in the UK between 2003 and 2005. However, if current fatality trends continued, this would reduce to a prediction of 24 fatalities per year if implemented in 2021.

• **Improved crash helmet design** 80% of injured motorcyclists suffer a head injury. Advanced crash helmet designs have been shown to offer substantial benefits over current designs, but in the absence of any additional action to promote these systems the penetration of the market would be expected to be slow because of the additional cost. However, a consumer rating scheme for crash helmets, known as SHARP, was launched in November 2007 and claims that if all motorcyclists wore the safest helmet it could prevent 50 TWMV fatalities per year in the UK (DfT, 2008).

• **Neck restraints** a quarter of all motorcyclists that suffered a fatal head injury were found to have also suffered a neck injury serious enough to prove fatal even if the head injury had not occurred. New neck restraint products have been introduced to the market. These aim to prevent these neck injuries by limiting hyperextension or flexion of the neck. However, the benefits of these devices have not as yet been independently assessed.
5.4.3 Risks and barriers

One of the most significant risks in terms of secondary safety is the UK’s ageing population. Most of the recent improvements in this field have been developed based on protecting medium-sized adults. These designs are not necessarily very effective at protecting elderly adults, which can be considerably more difficult because they are generally less tolerant to injury. An increase in the proportion of vehicle occupants that are elderly could result in an increase in the numbers of killed or seriously injured casualties. Further research and technical development will be required to offer these occupants better protection. This will need to include the development of new injury criteria specifically for elderly people that can be used in tests to assess the likelihood of injury.

As secondary safety has developed, thoracic injury has become increasingly important. However, current anthropometric test dummies do not measure the probability of chest injury very well. Improved dummies, such as the THOR device, have been developed to improve the measurement of thoracic injury and this may need to be incorporated in test and assessment regimes to drive developments intended to improve protection.

Currently, the protocol for the assessment of child seats extends up to 10-year-olds, but currently there is not an adequate dummy available to represent 10-year-old children. This will be required to fully implement the protocols and to achieve the maximum potential benefits.

There is also a need for improvements in the way that measures that are implemented are monitored. For example, when the mandatory requirement for children to use child restraints was introduced, this resulted in some children using booster seats and adult seat-belts. However, the booster seats meant that the child’s head height was comparable with that of an adult. In cars where rear head restraints are not fitted, this could result in an increase in neck injuries, particularly in rear impacts. The improved monitoring of measures would enable unintended consequences such as this to be identified, quantified and remedied more easily.

5.5 Integrated safety

5.5.1 Recent developments

The concept of integrated safety is a relatively new field that has been enabled mainly by the development of advanced sensors that can detect the current state of a vehicle and can also predict the likelihood of a collision occurring. This enables actions to be taken before the collision to reduce the likelihood of it occurring at all, reduce the severity of the collision and/or reduce the severity of injuries resulting from the collision. Recent developments include the following:
- **Lane departure warning (LDW)**  many accidents occur where a driver fails to pay sufficient attention, typically due to fatigue or distraction, and drifts out of their travelling lane, colliding with either oncoming traffic or roadside furniture. LDW systems use sensors capable of identifying lane markings on the road and warning the driver if these are crossed without the direction indicators being activated to show that the driver intended the manoeuvre. The nature of the warning is typically either a vibration in the driver’s seat and/or a warning sound played through the car’s stereo system loudspeaker on the side of the car crossing the marking. ECORYS (2006) estimates that the risk of a collision is reduced by approximately 12.5% (25% reduction in risk for 50% of all accidents) by this technology.

- **Lane change assist (LCA)**  this system uses sensors to monitor the area to the side and rear of a vehicle and, in combination with lane departure warning sensors, identifies whether a vehicle is in a position likely to result in a collision when the driver attempts to change lane. Warnings are provided to the driver if the lane change manoeuvre carries a risk of a collision. It has not been possible to identify predictions of casualty effects in the course of this project, but it is known that the European Commission is planning a study of this technology which will include a cost–benefit analysis and it has been suggested that this system could be used as a replacement for door mirrors, thus offering the potential to reduce aerodynamic drag and thus improve fuel economy.

- **Forward collision warning (FCW)**  this uses sensors such as radar or lidar to monitor the relative position of other vehicles and obstacles to the front of the vehicle. Combined with other sensors from systems such as ESC to predict the intended path of the vehicle, the probability of a forward collision is monitored and if the probability exceeds certain thresholds then the driver is given some form of warning, which could be audible, visual or tactile (e.g. tightening of the seat belt). First generation systems are now fitted to a range of new vehicles mainly at the more expensive end of the market. These first generation systems are typically only reliable in front to rear shunt collisions with other vehicles and with rigid fixed objects on the carriageway, which is a relatively small group of accidents. Estimates of casualty effect for these early sensors were not identified.

- **Brake Assist Plus**  standard brake assist systems rely on the measurement of the driver’s brake application characteristics to determine whether or not a driver intended an emergency stop and amends the brake performance arbitrarily dependent on those inputs. Brake Assist Plus builds on the function offered by forward collision warning systems in order to use the radar sensor to determine the amount of braking required to avoid the obstacle ahead. This level of braking is then applied as soon as the driver presses the brake pedal, regardless of how hard the driver presses the pedal. The functionality is, therefore, subject to the same limitations of scope as the FCW sensors and, thus, early versions only function in front to rear collisions with other vehicles or rigid fixed objects.
• **Collision Mitigation Braking System (CMBS)** this system again uses the forward collision sensors to determine the likelihood of a collision. If the driver does not react to an impending collision and the collision becomes unavoidable, then the system automatically applies heavy braking in order to reduce the collision speed. Again, the functionality is limited to that of the FCW sensors. Grover *et al.* (2008) estimated that first generation systems would reduce the number of fatalities occurring in front to rear shunt collisions with other vehicles by between 25% and 75%.

• **Pre-crash adaptation/optimisation of restraints** these systems can be installed in combination with any of the above systems using the FCW sensors. The information from the sensors is used to adapt the characteristics of the restraint systems before the collision occurs. For example, the seat belt can be pre-tensioned before the crash such that the forward excursion of the occupant within the vehicle is further reduced.

The introduction of this type of system is very recent and although the vehicles being equipped with the systems and the functionality being offered are growing rapidly, the market penetration remains very low because fitment is mainly to lower volume, more expensive models of car. For many of these first generation systems, the benefit to cost ratio is likely to be better for heavy vehicles than it is for passenger cars. This is because the type of collision benefiting tends to be more severe with heavy vehicles and the number of vehicles to which the system must be fitted is considerably lower. The large potential of such systems does make it likely that at least some of them will become mandatory in future, greatly increasing market penetration. However, given the current state of technical development and cost as well as the time required to develop appropriate regulations and test and evaluation regimes, it is considered that this is unlikely to happen until five to ten years have passed.

Although the different functions are named and described separately above, in reality most of them represent additional functionality for the same hardware and they will, therefore, usually be packaged together. For example, a vehicle equipped with CMBS will be equipped with FCW and Brake Assist Plus, such that when sensors detect a possible collision (approximately three seconds before impact), then the driver will get an audible/visual warning. If no action is taken, then the warning will be repeated and emphasised with the addition of a tactile warning. If action is taken, then the system will use Brake Assist Plus characteristics to ensure that the driver achieves the level of deceleration required to prevent the collision. If the driver still fails to react, then the brakes will be applied automatically.

### 5.5.2 Potential future developments

The rapidly developing sensor technology in this field means that a huge range of potential applications may become possible in the future. Some examples of this are described briefly below:
• **Intelligent speed adaptation**  excessive speed is known to be a contributory factor in many accidents. The technology is now available, either through GPS systems or on-board sensors, to enable the vehicle to know the speed limit of the section of road on which the vehicle is travelling. This enables a system that either warns the driver that they are breaking the speed limit or automatically limits the speed to the relevant maximum for that road.

• **Pop-up bonnets**  one of the difficulties associated with designing the front of a vehicle such that it is less likely to cause injuries to pedestrians is that it can be difficult to package everything to avoid hard and/or pointed objects associated with the engine lying just below the bonnet of the vehicle. The concept of pop-up bonnets is that they activate on contact with a pedestrian and raise themselves clear of any such obstructions, such that the bonnet can crush appropriately without the pedestrian contacting hostile objects.

• **CMBS (pedestrian)**  this is a further development of the CMBS described above, but with the functionality expanded such that the autonomous braking can be applied to reduce the severity of pedestrian collisions. The first such systems are now about to be introduced to the market and will greatly increase the casualty effects of CMBS.

• **CMBS (head-on)**  as above, but functionality expanded so that the system functions in head-on collisions. This is more difficult to achieve from a technical perspective and may be further from market introduction, but will represent a substantial increase in the casualty effects.

• **CMBS (junction)**  again a further development of functionality to include collisions where one vehicle pulls out across the path of the equipped vehicle. This is also more difficult technically and may require vehicle to vehicle and/or vehicle to infrastructure communication systems as well as the on-board sensors of other systems.

• **Adaptive restraints**  the ability of restraint systems to adapt to the particular characteristics of the occupants and the collision is expected to continue to develop, providing further casualty prevention effects.

• **Adaptive structures**  it is possible that the same pre-crash sensors could be used to adapt the structure of the vehicle immediately prior to the crash such that the structure crumples easily in lower-speed collisions, but becomes stiffer in higher-speed collisions.

• **Collision avoidance**  as the sensing technology develops and steer by wire systems become available, then it is likely that CMBS will be developed in order to automatically brake and steer in order to fully avoid certain types of collision.

• **Autonomous driving**  ultimately, the type of technology being developed has the potential to enable fully automated driving where the vehicle controls all of the necessary navigation and safety functions. However, this remains a long-term possibility and systems are unlikely to reach the market in the next 10 years.
New technology is being developed all the time and the information presented here is an outline of what might occur. However, it is likely that elements of some systems discussed will be combined with other systems. For example, it is possible that some elements of collision avoidance systems could be implemented within CMBS in a shorter time-frame than required for the full systems.

5.5.3 Risks and barriers

As can be seen from the preceding sections, there is a wide variety of quite complex control and information systems either being implemented or under consideration. Even in the list of examples above it can be seen that a vehicle equipped with several of these systems could have at least four separate warning systems (lane departure, lane change, speed limit exceeded, forward collision). This is in addition to the warning signals from existing systems such as parking sensors and seat-belt reminders. It is clear that if the human machine interface of these systems is not correctly designed, then the driver could find it very difficult to know quickly and instinctively what any particular warning meant, thus devaluing the systems. In addition to this, it is possible that if warnings became common place then important signals could be ignored completely. In the worst case, the warnings from, and control of, these systems could become a major distraction, thus contributing to an increase in they type of dangerous occurrence that the systems are designed to prevent.

The development of integrated safety systems has been very rapid and has out-paced the development of the regulatory system. This means that, in some cases, existing regulation could become a barrier to the implementation of beneficial technology. Combined with difficulty in accurately quantifying the accident benefits of such systems (the same difficulties as described for primary safety in Section 5.3.3) this can also lead to the following risks:

- voluntarily fitted systems may be confined to high specification and high price vehicles with low market share;
- work vehicles where specification is largely cost driven, such as trucks and buses, may have slower uptake of technology; and
- systems may be prioritised or optimised on the basis of marketing and/or comfort rather than safety.

Wherever a vehicle control system is taking control away from the driver there is a concern about the liability for any accident that may occur. From one perspective this risk should help ensure that any such system implemented is robust and reliable. However, the concern over the risk may also hold back some potentially beneficial technologies. It is possible that regulating the performance and characteristics of systems would help to resolve these concerns.
### 5.6 Summary of technologies

The vehicle safety features that have been implemented recently or are expected to be implemented in the future are summarised in Tables 5.1 - 5.6.

#### Table 5.1: Recent primary safety developments

<table>
<thead>
<tr>
<th>Development</th>
<th>Direction of effect</th>
<th>Magnitude of effect</th>
<th>Market penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduces stopping distance</td>
<td>Positive</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Antilock brakes (ABS)</td>
<td>Positive</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Brake Assist System (BAS)</td>
<td>Positive</td>
<td>c. 4% all fatalities</td>
<td>5%</td>
</tr>
<tr>
<td>Electronic stability control</td>
<td>Positive</td>
<td>25% fatalities 11% serious 7% slight</td>
<td>9% (EU study – may be different in UK)</td>
</tr>
<tr>
<td>Brake light displays</td>
<td>Positive</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Improved mirrors (HGV)</td>
<td>Positive</td>
<td>Medium (HGV)</td>
<td>Low</td>
</tr>
</tbody>
</table>

#### Table 5.2: Recent secondary safety developments

<table>
<thead>
<tr>
<th>Development</th>
<th>Magnitude of effect</th>
<th>Market penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal/side impact Directive</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>EuroNCAP</td>
<td>KSI reduction 12% pedestrian fatalities</td>
<td>Medium – first five star cars in 2001</td>
</tr>
<tr>
<td>Pedestrian protection Directive phase 1</td>
<td>1–10% pedestrian fatalities</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Seat belts</td>
<td>High</td>
<td>High but the small per cent that do not wear seat belts represent c. 30% of those seriously injured in cars</td>
</tr>
<tr>
<td>Front under-run protection (HGVs)</td>
<td>c.11% car to HGV fatalities</td>
<td>Low</td>
</tr>
<tr>
<td>Improved crash helmets</td>
<td>Medium</td>
<td>Low (consumer rating scheme 2007/08, regulation post-2008)</td>
</tr>
<tr>
<td>ISOFix (improved child-seat attachment)</td>
<td>Unknown (potential benefits but unforeseen risks)</td>
<td>Low</td>
</tr>
<tr>
<td>Mandatory child restraint use &lt; 12 years old or 135 cm</td>
<td>Reduced abdominal injury plus some side impact protection</td>
<td>High</td>
</tr>
</tbody>
</table>
### Table 5.3: Recent integrated safety developments

<table>
<thead>
<tr>
<th>Development</th>
<th>Magnitude of effort</th>
<th>Market penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward collision warning</td>
<td>c. 12% fatalities</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Lane departure warning</td>
<td>10–20% fatalities</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Lane change assist</td>
<td>Unknown</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Brake Assist Plus</td>
<td>Unknown – less than CMBS</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Collision mitigation braking system</td>
<td>25–75% of those KSI in front to rear shunt collisions</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Adaptive (pre-crash) restraints</td>
<td>Unknown</td>
<td>&lt; 1%</td>
</tr>
</tbody>
</table>

### Table 5.4: Possible future primary safety developments

<table>
<thead>
<tr>
<th>Development</th>
<th>Expected casualty effects</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive lighting</td>
<td>Low</td>
<td>Cars and TWMVs, truck and bus possible</td>
</tr>
<tr>
<td>Brake/steer by wire</td>
<td>Low</td>
<td>Enabling technology for more advanced systems</td>
</tr>
<tr>
<td>Daytime running lights</td>
<td>c. 5% of all casualties</td>
<td>Possible adverse environmental consequences and possible increased risk to TWMV users</td>
</tr>
<tr>
<td>Higher minimum brake standards</td>
<td>Low</td>
<td>Brings a small number of poor vehicles to the standard of the large proportion of good vehicles – more effect for HGVs</td>
</tr>
<tr>
<td>TWMV combined braking system</td>
<td>Unknown</td>
<td>Links front and rear brakes to provide optimum balance and reduce stopping distance</td>
</tr>
<tr>
<td>TWMV ABS</td>
<td>Unknown</td>
<td>In existence but market penetration very low</td>
</tr>
<tr>
<td>TWMV BAS</td>
<td>Unknown</td>
<td>Possible issues with user acceptance</td>
</tr>
<tr>
<td>Alcohol interlock</td>
<td>No more than 17% fatalities</td>
<td>Applicable to all vehicle types, but effectiveness will vary by vehicle type and level of compliance</td>
</tr>
</tbody>
</table>
### Table 5.5: Possible future secondary safety developments

<table>
<thead>
<tr>
<th>Development</th>
<th>Expected casualty effects</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved front-impact protection</td>
<td>2–3% car occupant fatalities</td>
<td></td>
</tr>
<tr>
<td>Improved frontal crash compatibility</td>
<td>5–8% car occupant fatalities</td>
<td></td>
</tr>
<tr>
<td>Improved side-impact protection</td>
<td>Unknown</td>
<td>EEVC WG13* currently assessing this</td>
</tr>
<tr>
<td>Improved side-impact compatibility</td>
<td>Unknown</td>
<td>Little research to date</td>
</tr>
<tr>
<td>Rear-impact protection</td>
<td>Low</td>
<td>Focused on whiplash injury</td>
</tr>
<tr>
<td>Rollover protection</td>
<td>Unknown</td>
<td>Scale of problem needs assessment</td>
</tr>
<tr>
<td>Rear-seat occupants</td>
<td>Low</td>
<td>Low seat-belt use a major constraint</td>
</tr>
<tr>
<td>HGV nose cone</td>
<td>c. 9% fatalities from HGV</td>
<td>Will require regulatory change to permit – adds environmental benefits too</td>
</tr>
<tr>
<td>TWMV neck restraints</td>
<td>Unknown</td>
<td>25% of those with serious head injury also had serious neck injury</td>
</tr>
<tr>
<td>NPACS – consumer information</td>
<td>High (child occupant KSI)</td>
<td>Improved child seats through more robust test standards and ease of use</td>
</tr>
<tr>
<td>Advanced helmet design</td>
<td>c. 20% TWMV fatalities</td>
<td>Take up likely to be slow</td>
</tr>
</tbody>
</table>

*European Enhanced Vehicle Committee Working Group 13 (Side Impact)

### Table 5.6: Possible future developments in integrated safety

<table>
<thead>
<tr>
<th>Development</th>
<th>Expected casualty effects</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pop-up bonnets</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Adaptive structures</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>Adaptive restraints</td>
<td>High</td>
<td>Benefits for 5th/95th percentiles and elderly (but need improved test tools and injury criteria)</td>
</tr>
<tr>
<td>CMBS (pedestrian)</td>
<td>High</td>
<td>First generation expected to enter market soon</td>
</tr>
<tr>
<td>CMBS (head-on)</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>CMBS (junction)</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Collision avoidance</td>
<td>Very high</td>
<td>Not likely to be prevalent in fleet for many years</td>
</tr>
<tr>
<td>Autonomous driving</td>
<td>Very high</td>
<td>Very long-term measure</td>
</tr>
</tbody>
</table>
5.7 Conclusions

A large number of new vehicle safety measures have been implemented in recent years and many of these have not yet fully penetrated the UK vehicle fleet. Thus further casualty reductions are expected to be derived from these measures in future. One of the measures expected to have the highest future benefit is electronic stability control (ESC).

Further improvements are expected to be derived from new secondary safety measures. However, an ageing population could make this task more difficult and carries a risk of casualty increases.

Active and integrated safety systems have a very large potential for casualty reductions. Systems such as intelligent speed adaptation, collision mitigation braking and collision avoidance are expected to produce substantial benefits. However, there are also a range of risks and barriers to introduction that need to be adequately resolved before the full benefit of such systems could be achieved.
6 THE CONTRIBUTION OF NEW IN-VEHICLE TECHNOLOGIES

6.1 Introduction

This work is intended to assist the Department for Transport in formulating its road safety strategy post-2010. The task was to focus on new in-vehicle technologies, particularly those relating to primary safety. The most promising near-market systems have been discussed. The potential of eCall, which affects the rapidity of post-crash emergency service response is also discussed.

6.2 What are the vehicle manufacturers offering and developing?

6.2.1 Systems currently on the market

Table 6.1 shows that driver assistance systems are already widely available on current vehicles offered by European manufacturers. It can also be noted that such systems are offered on mass-market vehicles such as the VW Golf and the Ford Mondeo.

<table>
<thead>
<tr>
<th>Brand</th>
<th>Model</th>
<th>Class</th>
<th>ACC</th>
<th>LDW</th>
<th>BSD</th>
</tr>
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<tbody>
<tr>
<td><strong>PASSENGER CARS</strong></td>
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<tr>
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<td>✓</td>
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<td>✓</td>
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<td>HM</td>
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<td>✓</td>
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<tr>
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<tr>
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<td>✓</td>
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<tr>
<td></td>
<td>‘3</td>
<td>LM</td>
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<td>✓</td>
<td>✓</td>
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<td>Chrysler</td>
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<td>LM</td>
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<td></td>
<td>Mondeo</td>
<td>LM</td>
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<tr>
<td>Honda</td>
<td>Legend</td>
<td>HM</td>
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<tr>
<td></td>
<td>CRV</td>
<td>S</td>
<td>✓</td>
<td></td>
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<td>Accord</td>
<td>LM</td>
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</table>

(continued)
### Table 6.1: (continued)

<table>
<thead>
<tr>
<th>Brand</th>
<th>Model</th>
<th>Class</th>
<th>ACC</th>
<th>LDW</th>
<th>BSD</th>
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<tbody>
<tr>
<td><strong>PASSENGER CARS</strong></td>
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<td>Jaguar</td>
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<td></td>
<td>E-Class</td>
<td>HM</td>
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<td>Touareg</td>
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<td></td>
<td>Passat</td>
<td>LM</td>
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<tr>
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<td>Phaeton</td>
<td>L</td>
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<td>✔</td>
<td>✔</td>
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<tr>
<td></td>
<td>Golf</td>
<td>C</td>
<td>✔</td>
<td></td>
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<tr>
<td>Volvo</td>
<td>S 80</td>
<td>HM</td>
<td>✔</td>
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<td>✔</td>
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<tr>
<td></td>
<td>V70</td>
<td>LM</td>
<td>✔</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td></td>
<td>XC 90</td>
<td>S</td>
<td>✔</td>
<td></td>
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<tr>
<td><strong>TRUCKS</strong></td>
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</tr>
<tr>
<td>MAN</td>
<td>TGA</td>
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<td>✔</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>TGX</td>
<td></td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Merc. Benz</td>
<td>TGS</td>
<td></td>
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<tr>
<td>Volvo</td>
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<td>Iveco</td>
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<td>Stralis</td>
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<td>✔</td>
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</tr>
<tr>
<td></td>
<td>R-Series</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

Notes:
C: Compact; L: Luxury class; M: Medium class; H: High class; S: Sport-Utility
ACC: Adaptive Cruise Control; LDW: Lane Departure Warning; BSD: Blind Spot Detection.

### 6.2.2 An integrated safety truck

The Volvo concept truck shown at the PReVENT project exhibition in Versailles in September 2007 illustrates the plethora of driver assistance systems that are currently available or will shortly be available. The vehicle was developed through a number of European projects and, in particular, PReVENT, AIDE (Adaptive Integrated Driver-vehicle Interface) and GST (Global System for Telematics). It features the following:

- An enhanced interface with a configurable instrument panel, multifunction buttons on the steering wheel, the capability for voice control of various functions, and a system for filtering and prioritising information provision to the driver, so that, for example, incoming phone calls can be delayed when driver workload is estimated to be high. The system also features eye-movement cameras to monitor driver fatigue and distraction.

- A lane keeping system which warns the driver about straying out of lane through steering wheel vibration. The driver is assisted to steer by the truck helping to turn the wheel in the correct direction.
• A lane change assistant with blind spot monitoring. The driver is warned if there is a risk of collision with an overtaking vehicle in the adjacent lane.

• All round monitoring indicates to the driver if there are objects or people in the vehicle’s blind spots.

• Curve speed warning informs the driver if he/she is approaching a horizontal curve at excessive speed.

• A forward collision avoidance system that applies automatic braking if the truck is detected as approaching a lead vehicle too fast. At the same time the driver is warned with a buzzer and lights.

• A start inhibit to prevent starting from rest when a person or object is detected right in front of the vehicle. Such a person or object is likely to be out of the driver’s view.

6.2.3 The manufacturers’ roadmap

In the Advanced Driver Assistance System in Europe (ADASE) and ADASEII projects, the European vehicle manufacturers have created a roadmap for the introduction of new driver assistance systems. That roadmap was initially detailed in Zwaneleveld et al. (1999) and subsequently reconfirmed in Ehmanns and Spanheimer (2004). The 1999 version is show in Figure 6.1.

The vehicle manufacturers perhaps no longer view the ultimate goal as one of autonomous (i.e. automated) driving, but the bottom two development paths in Figure 6.1, i.e. those in red and orange, are still evidently valid, with the rapid development of warning and assistance systems for both longitudinal and lateral control.

6.3 Field operational tests

6.3.1 Introduction

At a European level, there is currently a focus on the need to demonstrate the concrete benefits of Advanced Driver Assistance Systems (ADAS) and Cooperative Vehicle Highways Systems (CVHS) through so-called Field Operational Tests (FOTs). Such tests are intended to prove the real-world impacts of using various systems by conducting rigorous large-scale trials using participants who use the vehicles in their everyday driving. Equipping the vehicles can either be done by adding the relevant system to the participant’s or the fleet’s vehicles, but is more typically done by loaning equipped vehicles to the participants. Such FOTs have been quite common in recent years in North America, with examples being a trial of Adaptive Cruise Control (Fancher et al., 1998) and a trial of Forward Collision Warning (University of Michigan Transportation Research Institute and General Motors Research and Development Center, 2005). However, with the notable
Figure 6.1: ADASE roadmap

- **Longitudinal Control**
  - AGC
  - LDWS
  - FCW
  - IV Com
  - VV Com
  - Map
  - OR
  - RC
  - TSR
  - DM
  - Actuators: Smart Actuators, X-by-Wire

- **+ Lateral Control**
  - S&G
  - RDWS
  - PAss
  - BSM
  - LCA
  - CrossA
  - TrajCal
  - Sensors: Vel, dist., Wider Range, Trajectory, Object Classification, Lane Recogn., Curve Prediction, Speed Limit, Curve, Crossing Signs, Physiological Charact., Driver Reaction Interpretation

- Autonomous driving
exception of trials of Intelligent Speed Adaptation, they have been much less common in Europe. The resulting lack of solid empirical evidence on the impacts of new technologies has been identified as a critical weakness by a report from the eSafety Forum setting out the research priorities for the European Seventh Framework Programme (FP7) (eSafety Forum, 2006, p. 27):

‘[T]here is still a great need to investigate the behaviour of the user in the real traffic environment when being equipped with new ICT systems for safety and efficiency as compared to the user’s behaviour without the ICT systems. The short and long term effect of the use of such systems is also of great importance to assess as a justification of the systems.

Field Operational Tests (FOTs) have during later years developed as a powerful tool to gain insight into how new functions and systems suit the user when operated in the real context under sufficiently long time to reach the “daily operational and behaviour level”.

FOTs for ICT-based traffic safety and efficiency functions and systems are viewed as very important for understanding the users’ ability to use these and to make cost/benefit assessments, as well as to evaluate the impact on safety, traffic efficiency, environmental aspects, and the behaviour of drivers and other road users. FOTs are also important in the technical development since they can provide valuable feedback regarding the performance and improvement of the technical system (eSafety Forum, 2006, p. 27).

The ICT research programme in FP7 had a call for FOTs on a driver assistance system that closed in October 2007. Both the vehicle manufacturers (in the form of EUCAR (the European Council for Automotive R&D) and the administrations and infrastructure owners (in the form of ERTICO (Europe’s intelligent transportation system organisation)) have submitted proposals. These proposals provide a useful guide to the views of the different parties as to which near-market systems they view as beneficial.

6.3.2 Vehicle manufacturers

The EUCAR-organised consortium is led by Ford Germany and is called EuroFOT. The consortium includes most of the major European vehicle manufacturers. Trials of ADAS systems for both cars and trucks are envisaged. The systems to be tested are:

- Forward Collision Warning with and without Brake Assist;
- Adaptive Cruise Control;
- Speed Limiter (driver-set);
- Lane Departure Warning and Impairment Warning;
- Blind Sport Information System;
- Curve Speed Warning;
- Safe Human Machine Interaction (HMI); and
- Fuel Efficiency Advisor.

Of these, the last is not directly targeted at safety, but may have some safety impact in that it encourages calmer driving. With regard to the Safe HMI application, it may be difficult to validate its safety impact in a relatively small-scale trial. All the others are clearly likely to have an impact on crashes and the project may be able to demonstrate their impact if it goes ahead. However, it should be noted that relatively a small number of trial vehicles are envisaged.

6.3.3 **Infrastructure owners**

The ERITICO-led consortium was called SMARTFOT and included as partners the Swedish Road Administration, the Dutch Ministry of Transport (RWS), the Czech Ministry of Transport, the Flemish Ministry of Transport and Transport for London. The systems to be tested were:

- eCall with 750 to 1,000 vehicles; and
- Speed and Hazard Alert with more than 2,600 vehicles for Hazard Alert, the in-vehicle digital map is enhanced so that it can identify hazardous locations as well as speed limits.

6.3.4 **Summary**

The vehicle manufacturers can be seen to be concentrating on various warning systems and information systems such as forward collision warning, lane departure warning, curve speed warning and blind spot information. They are also proposing to prove the safety impact of Adaptive Cruise Control. The systems to be tested affect both longitudinal and lateral control. With regard to systems that affect vehicle maximum speed, Speed Alert (warning Intelligent Speed Adaptation (ISA)) and other forms of ISA are not included. However, the speed limiter function in which the driver sets vehicle top speed manually is to be examined. This function is somewhat analogous to the limiting function in a cruise control, but differs in that, with the speed limiter, only a maximum speed is set, whereas with cruise control the vehicle is set to be driven at the set speed and the driver removes his/her foot from the accelerator pedal.

On the other hand, the infrastructure owners are proposing to test functions which clearly have safety potential. One of these functions is Warning ISA, affecting crash risk and crash severity, and the other is eCall affecting post-crash emergency
services. The next few sections summarise the evidence to date for the safety impact of these functions.

### 6.4 Adaptive cruise control

There have been a number of FOTs of adaptive cruise control (ACC), particularly in the United States. The first of these was conducted in the late 1990s (Fancher et al., 1998). In this trial 10 cars were equipped with ACC and handed to drivers to use for their normal driving. Eighty-four drivers drove for two weeks with the ACC available to them in the second week. Twenty-four drivers drove for five weeks with the ACC available in the last four weeks. Thus there were 3.6 person years of driving with ACC available for use. ACC was in use for a total of 56,380 km (31% of the distance travelled) and 534 hours (18% of driving time).

The final report of the study states: ‘The data gathered in the FOT could be used to argue both for and against safety benefits. More headway time and a deceleration type of warning, if the driver is inattentive, certainly appear to be safety benefits. The possibility of inattention due to over reliance and over confidence as well as the possibility of slower or delayed reactions certainly appear to pose disbenefits. Given the limitations of presently available data, the net impacts on safety are unknown’ (Fancher et al., 1998). Further on the authors specifically address the engineering hypotheses and state: ‘To the extent that safety is associated with longer headways and more uniform traffic, driving with this ACC system provides safety benefits.’ The qualification of ‘this ACC system’ should be noted: the drivers had the choice of three headways 1.1 seconds, 1.5 seconds and 2.1 seconds so that the shortest headway was longer than that chosen by many drivers in manual driving. The system tested was a pre-production prototype; production systems may have shorter minimum headways.

ACC was further investigated in the US study of automotive collision avoidance systems (University of Michigan Transportation Research Institute and General Motors Research and Development Center, 2005). Automotive collision avoidance systems (ACAS) are the combination of ACC and forward collision warning (FCW). The study found that with ACC: ‘The percent of driving time spent below one-second time headways was reduced by 60 percent to 70 percent across sparse and heavy traffic freeway conditions, respectively’ (General Motors Corporation, 2005a; p. 95).

It was concluded that there were a number of specific contexts in which the ACC system appeared to provide the same or better safety qualities than conventional driving. Apart from longer headways, there was a reduced tendency to overtake. Since much of the driving with ACC was on freeways, this was thought to reduce exposure to the hazards associated with lane changing. In terms of overtaking where there was a potential for conflict with opposing traffic, this tended to be initiated at considerably longer range, resulting in lower levels of conflict than in either of the
other modes of control (normal driving and driving with a traditional cruise control). There were comparable levels of peak deceleration between ACC driving on the one hand and normal and cruise control driving on the other. Equally, the conflict severity levels at the moment of braking onset were not significantly different from those observed in non-ACC driving. ACC driving also resulted in a lower overall rate of imminent alerts from the FCW systems, suggesting that the ACC controller may serve to moderate conflict severity better than the driver operating the vehicle manually.

There were, however, some aspects of ACC driving that do not suggest safety improvements when compared with non-ACC driving. These aspects concern drivers’ decisions about when it was appropriate to engage the ACC. Perhaps not altogether surprisingly (since one of the selling points of ACC is that it can be used in congested conditions), ACC was utilised at several times the rate of conventional cruise control under heavy traffic conditions. The report states: ‘Since heavy traffic calls for a higher rate of significant braking intervention by the ACC driver, this practice poses a significant requirement upon the driver’s skill and readiness to intervene, (although conflict levels encountered during ACC control intervention were not higher than those seen in the manual or CCC modes of control)’ (General Motors Corporation, 2005b; p. 8 85) Equally, ACC was utilised at twice the rate of conventional cruise control on local roads, even though these roads are liable to more intense and more frequent conflicts. However, the decline in ACC usage in this environment over time suggests that this effect wears off with experience. Finally, the observations of drivers indicated that, under ACC control, they engaged in significantly more secondary tasks than were seen under normal cruise control. Although these tasks were mainly conversations with passengers, this does perhaps indicate some potential for drivers to perceive the regulation of longitudinal control by the ACC as giving them more scope to engage in non-driving-related tasks.

As a qualifier to this discussion, it should be noted that the minimum time headway for the studied ACC system was one second. It should also be noted that the study was not able to investigate the potential benefits from the smoothing of motorway flows at high levels of ACC penetration.

### 6.5 Forward collision warning

Reliable predictions of the effectiveness of FCW systems are rare. An additional problem is that the various specific versions that have been investigated are not alike: they have different alarm algorithms and different warning thresholds. They also have different rates of false and missed alarms. An important issue with FCW is whether drivers become over-reliant on the system or will adapt their behaviour to take additional risks because they are confident that the system will help to prevent major incidents.
Perrett and Stevens (1996) carried out a top-down review of the potential impacts of various telematic systems and estimated that longitudinal collision avoidance would save 20% of motorway accidents, which was equivalent to 0.8% of all injury accidents. The analysis of the effect of FCW alone carried out for the US ACAS FOT (University of Michigan Transportation Research Institute and General Motors Research and Development Center, 2005) found only a relatively small effect: ‘ACAS does not appear to influence either the frequency or the severity of forward conflicts that drivers experience during manual driving. ACAS does appear, however, to reduce the time that drivers spend with short headway times (less than 1.0 second)’ (University of Michigan Transportation Research Institute and General Motors Research and Development Center, 2005; p. 7 61). The same report found little evidence of unintended negative consequence of the FCW, for example in terms of behavioural adaptation of increased involvement in secondary tasks.

Subsequently, as part of the same study, a further analysis was carried out in order to determine the safety benefits of ACC and FCW in tandem (Najm et al., 2006). The conclusions from this work were as follows:

‘ACAS, as an integrated system of FCW and ACC functions, has the potential to prevent about 6 to 15 percent of all rear-end crashes depending on the source of crash data used for safety benefits estimation. This system effectiveness ranges between 3 and 26 percent according to 95 percent confidence bounds. By averaging estimates from the four sources of crash data, ACAS might prevent about 10 percent of all rear-end crashes with variability between 3 and 17 percent based on 95 percent confidence bounds.’ (Najm et al., 2006; p. 4 75)

The same study also examined the potential of the ACAS system to affect severe conflicts, which were termed ‘severe near-crashes’. These were defined as events with a minimum time-to-collision of less than three seconds and a peak deceleration level by the host vehicle of over 0.3 g. The near-crashes were further split into low-intensity and high-intensity events depending on the time-to-collision thresholds. The conclusion was that ‘ACAS has the potential to reduce the number of severe near-crashes per 1,000 km traveled by 10 percent and 20 percent respectively for low-and high-intensity levels based on aggregate FOT data from all subjects’ (Najm et al., 2006; p. 4 82).

Some qualification of these results is required. First of all they only apply to forward events involving other vehicles and not to all crashes or conflicts. The overall impact of an ACAS or FCW depends on the proportion of such rear-end events among total crashes. The effectiveness of such a system is also dependent on the driving styles prevalent in Michigan, where the FOT was conducted, compared with the UK. Thus the results are not immediately transferable to the UK. However, they do indicate that FCW, with or without ACC, has considerable promise.
6.6 Speed-related systems

6.6.1 Manual speed limiter

The driver-set speed limiter is common on a number of French-manufactured cars, particularly those from Renault, where it is available as an option on virtually every model. As part of the AIDE integrated project, a small study was carried out on the impact of speed limiter use on speeding. This study is reported in Saad et al. (2006). In the study, six French drivers drove with a Renault Laguna equipped with a speed limiter along an 80 kilometre route that included a variety of road types. Data were recorded automatically. The results are shown in Table 6.2 and they show that the use of the limiter substantially decreased speeding. Admittedly this is a small study and one in which the participants may have felt somewhat obligated to engage the system, but it indicates a surprisingly large effect of the speed limiter. If these results are confirmed by additional studies, then it may indeed be appropriate to promote the introduction of this system.

<table>
<thead>
<tr>
<th>Table 6.2: Results of AIDE trial of the speed limiter</th>
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<tbody>
<tr>
<td>Per cent of distance over the limit</td>
</tr>
<tr>
<td>Before (%)</td>
</tr>
<tr>
<td>Urban roads</td>
</tr>
<tr>
<td>Rural roads</td>
</tr>
</tbody>
</table>

6.6.2 Voluntary ISA and speed alert

The recent ISA project for the Department for Transport has produced estimates of the casualty savings that can be achieved with ISA on different road categories (Carsten et al., 2008). This work is being further developed in the current project for the Commission for Integrated Transport (CfIT) entitled ‘Speed Limit Adherence and its Effect on Road Safety and Climate Change’ (Motorists’ Forum/CfIT, 2008). The estimates are based on:

- an analysis of accident numbers by road category;
- observed changes in speed choice with ISA; and
- relationships between speed choice and risk of accident involvement at various levels of severity from the scientific literature.

Voluntary ISA is the version with a direct link between speed limit information and vehicle drivetrain, but which the driver can nevertheless override when he or she chooses. Table 6.3 shows the maximum estimated change in risk of involvement in an injury accident for a vehicle equipped with a voluntary ISA compared with the
same vehicle without ISA. These predicted impacts of ISA are very substantial, indicating that ISA is one of the most effective safety interventions on offer.

| Table 6.3: Change in risk for a vehicle equipped with voluntary ISA |
|----------------------|----------------------|
| Speed limit (mph)    | Risk impact (%)      |
| 30                   | −43                  |
| 40                   | −40                  |
| 50                   | −29                  |
| 60                   | −14                  |
| 70                   | −8                   |

Advisory or warning ISA, i.e. an ISA without any link to the vehicle drivetrain, is sometimes known as Speed Alert. There is relatively little information in the literature on the effectiveness of such systems. In the French LAVIA trials, the advisory ISA only had a fifth of the impact of the voluntary ISA in terms of the amount of time spent driving above the speed limit on 50 km/h roads (Ehrlich et al., 2006). Thus, one can conclude that purely advisory ISA without additional incentives to comply with the warnings will have far smaller impacts on the risk of accident involvement than will voluntary ISA.

6.7 Lane departure warning

Lane Departure Warning Systems (LDWS) are now available on many vehicles. They have been heavily promoted by Citroen in particular. Even more sophisticated are Lane Keeping Systems (LKS) such as those offered by Honda. These provide steering jerks or steering resistance to steering input (or lack of it) that is likely to lead to lane departure.

Such systems are relevant to a number of crash situations, but in particular to single-vehicle road departure crashes and also to some head-on collisions. There is a large overlap with fatigue and impairment warning systems. Here prototype systems use steering behaviour as one of the determinants of driver state.

There have been few systematic studies of the effect of LDWS on driving. The Michigan FOT of road departure crash warning (LeBlanc et al., 2006) looked at a combination of lane departure warning and curve speed warning. Seventy-eight drivers drove for one week in the baseline (no system condition) and for three weeks with the combination of systems active. The study found a 9% reduction in the standard deviation of lane position on freeways and a 12% reduction on surface roads. It also found a larger reduction in encroachment on lane edge: the time spent with one tyre within four inches of the lane edge or beyond the lane edge was reduced by 63%. However, it is not possible to deduce an estimated impact on crashes from these results.
It should be noted that the system did work satisfactorily at night and thus might be especially relevant to young driver crashes. The study did not look systematically at any changes in exposure with the system, but at least one participant made some worrying comments that hint that it might encourage driving while drowsy:

‘I’ve gotten behind the wheel and stayed behind the wheel 13, 14 hours at a stretch, you know, at a certain point that you are getting a little off kilter and I’ve been in the car with other people driving back and forth. I’ve gone there many times and somebody drifted off, dozed off a little bit and the rumble strips on the road made the noise and they corrected themselves and stuff. If they had something like this activated they would never have gotten that close to leaving the road. I think it’s very effective.’
(LeBlanc et al., 2006; p. 961)

6.8 eCALL

eCall is the system that automatically notifies the emergency services in the event of a serious crash. The European Commission is planning its fitment in new cars from 2009 as part of a full-scale rollout. Counterpart equipment in emergency centres is required and the European Commission is putting pressure on the Member States to provide that infrastructure. Viviane Reding, the European Commissioner for Information Society and Media, has stated of eCall: ‘It has huge potential. Every year it can save 2,500 lives in Europe, with very large socio-economic benefits. We cannot wait any longer: we have to work together and sort out the barriers remaining to the implementation of eCall’ (European Commission, 2005). It is suggested that up to €26 billion annually could be saved with eCall, were all cars equipped. The claimed savings in fatalities would amount to a reduction of over 6%.

It is therefore important to examine the actual evidence for the benefit of eCall. There have been a number of European projects which have studied the service. Of these, the most prominent are E-MERGE and GST RESCUE. Both projects concentrated on technical validation of the system at various test sites, but they also produced safety predictions. The prediction of E-MERGE was based on a questionnaire survey sent out to the PSAPs (Public Service Answering Points, i.e. emergency call centres) in the project test sites (there were six test sites, one in each of six countries; Geels, 2004). The report states: ‘The replies show a positive view for the additional value of an E-MERGE system. The foreseen live savings are estimated on an average between 5% 10% which means 2000 to 4000 lives given the current number of fatalities of approx. 40000 and the reduction of the severity of injuries is estimated at the same number 5% 10%. None of the PSAPs foresees large procedural or technical problems with implementing the E-MERGE solution’ (Geels, 2004; p. 47).

The E-MERGE final report adjusts these conclusions somewhat (Nielsen et al., 2004). Drawing on the same questionnaire, it states:
‘Based on the project’s investigations, a full-scale deployment of the E-MERGE system is expected to lead to a decrease in fatalities and severe injuries in traffic accidents as follows:

- Fatality: 5% reduction;
- Severe Injuries: 10% reduction to light injuries;
- Light Injuries: No positive effect foreseen.

That level of reduction would mean 2000 lives saved each year and a saving of nearly €4 billion each year in related social and health costs and lost “public” income calculated for the European Community.’ (Nielsen et al., 2004; p. 49)

This is most probably the source for the European Commission’s predictions. It is not clear where the €26 billion in claimed savings came from. The SEiSS project on the socio-economic impact of intelligent safety systems, drawing on the E-MERGE results, estimated that the annual accident savings at €12.4 to €21.9 billion (Abele et al., 2005). Overall, it is remarkably thin evidence for making an important decision on the Europe-wide implementation of a safety system.

GST RESCUE also conducted a questionnaire, this time among project participants and outsiders. There was no question on potential casualty savings, but there was a question on the predicted reduction in rescue time with respondents being asked to state their prediction on a scale between 0% and 100% with increments of 10% (Eijkelenbergh, 2007). The most common predicted reduction was 30%. The number of respondents and their type is not stated.

Only one detailed study from a European country on the impact of eCall has been found (Virtanen et al., 2006a and 2006b). This study was carried out in Finland and used in-depth accident reports on fatal accidents. In Finland, all road accidents that result in a fatality within three days are investigated by an in-depth team. For the study, cases covering 1,180 fatalities were used, of whom 919 were motor-vehicle occupants. The time delay between accident occurrence and the notification of the emergency response centre was calculated. Two trauma specialists were on the study team and their task was to assess whether a fatality would have been prevented had there been no delay in accident notification. The conclusion was that eCall would have saved 3.6% of the fatalities, but it was also found that eCall would have been most effective in accidents involving vehicles for which eCall is not designed, i.e. motorcycles and mopeds. The likely effect of eCall could not be authenticated for any fatality to a pedestrian or cyclist.

There were also cases where the system might possibly have prevented the fatality. This proportion was approximately 5% for motor-vehicle occupants and 1% for pedestrians and cyclists. Thus the overall conclusion was that eCall could have
prevented approximately 4–8% of the road fatalities that occurred in Finland during 2001–03. It was also calculated that benefits would most likely exceed the costs.

In thinking about the transferability of these results to Great Britain, it should be noted that, in Finland, 70% of fatal accidents occur outside urban areas and single-vehicle accidents account for 47% of all fatal accidents. In Great Britain, 58% of fatal accidents occur on rural roads, and single-vehicle accidents constitute 26% of fatal accidents (Road Casualties Great Britain: 2006 (Department for Transport, 2007c)). In addition, the country is much more densely populated than Finland and British roads carry heavier traffic. There is thus less scope for eCall, although there are no doubts that for part of the road network, such as the Scottish Highlands, eCall would affect rescue times and hence severity outcomes.

6.9 Discussion and conclusions

Overall it can be concluded that some of the systems discussed have significant safety potential. The systems related to longitudinal vehicle control, affecting speed and rear-end conflict situations are perhaps the most mature in technical terms and offer the greatest benefit. ISA, in particular, has been evaluated extensively and offers significant benefits (Carsten et al., 2008). Systems addressing road departure are less mature (certainly less reliable from a technical point of view with many more missed situations and false alarms) and are relevant to fewer accident situations, although such events can have very serious outcomes. The proposition that eCall will have a large impact on fatalities is not convincing, and there are doubts about the benefit-to-cost ratio for the system.

It should also be acknowledged that there is overlap in terms of the accident types to be addressed by the various systems. For example, the systems that affect speed and those that affect headway, such as FCW, may affect some of the same situations.

The discussion above of the safety potential of various systems can be compared with the conclusions the eIMPACT project (Wilmink et al., 2008). The project applied a common procedure to examine the safety potential of twelve systems, and carried out a cost–benefit analysis for those systems. The systems were:

1. Electronic Stability Control
2. Full Speed Range Adaptive Cruise Control, i.e. Stop and Go
3. Emergency Braking (fully automated braking to avoid or mitigate longitudinal crashes)
4. Pre-Crash Protection of Vulnerable Road Users (automated braking to avoid or mitigate collisions with vulnerable road users)
5. Lane Change Assistant (warning of relevant vehicles when changing lane)
6. Lane Keeping Support (active steering to keep in lane)
7. Night Vision Warn (enhanced vision at night through near or far infrared sensors, including obstacle warning)

8. Driver Drowsiness Monitoring and Warning

9. eCall

10. Intersection Safety (red light warning, right of way information at signalised intersections and stop signs, and right-turn\(^2\) assistance)

11. Wireless Local Danger Warning (inter-vehicle communication distributing early warnings of accidents, obstacles, reduced friction and bad visibility)

12. SpeedAlert, i.e. advisory Intelligent Speed Adaptation

Table 6.4 shows the estimated changes in injuries and fatalities with 100% penetration of each system. ESC and Lane Keeping Support have the greatest impact (though perhaps to some extent affecting the same types of accident) followed by SpeedAlert and Emergency Braking. These estimates reinforce the message that new in-vehicle technologies have the potential to deliver considerable safety benefits.

<table>
<thead>
<tr>
<th>System</th>
<th>Change in injuries (%)</th>
<th>Change in fatalities (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic Stability Control</td>
<td>6.6</td>
<td>16.6</td>
</tr>
<tr>
<td>Full Speed Range Adaptive Cruise Control</td>
<td>3.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Emergency Braking</td>
<td>7.3</td>
<td>7.0</td>
</tr>
<tr>
<td>Pre-Crash Protection of VRUs</td>
<td>1.9</td>
<td>1.8</td>
</tr>
<tr>
<td>Lane Change Assistant</td>
<td>4.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Lane Keeping Support</td>
<td>8.9</td>
<td>15.2</td>
</tr>
<tr>
<td>Night Vision Warn</td>
<td>2.0</td>
<td>2.9</td>
</tr>
<tr>
<td>Driver Drowsiness Monitoring and Warning</td>
<td>3.6</td>
<td>5.0</td>
</tr>
<tr>
<td>eCall</td>
<td>+0.1</td>
<td>5.8</td>
</tr>
<tr>
<td>Intersection Safety</td>
<td>7.3</td>
<td>3.9</td>
</tr>
<tr>
<td>Wireless Local Danger Warning</td>
<td>2.8</td>
<td>4.5</td>
</tr>
<tr>
<td>SpeedAlert</td>
<td>6.2</td>
<td>8.7</td>
</tr>
</tbody>
</table>

\(^2\) For driving on the left.
7 DISCUSSION

In the light of the foregoing content of this report, this discussion begins by considering reasons for adopting a vision for road safety in Great Britain, what kind of vision would be appropriate, and what the preconditions are for the adoption of a vision to be effective. It goes on to address some issues concerning cost-effectiveness, especially in relation to local road safety engineering schemes. Some comments are made on the potential contributions of highway engineering and vehicle technology to continued casualty reduction, and the need for corresponding assessment of the contribution of changes in road-user behaviour other than those that are induced by changes to the road or the vehicle. Aspects of the choice of performance indicators are discussed, and road safety policy is related to issues that seem likely to be influencing transport policy and wider government policy during the development of road safety strategy beyond 2010.

7.1 Reasons for adopting a vision for road safety in Great Britain

Section 3 sets out the potential value of a vision for road safety as a promotional tool, in guiding policy by providing a focus upon a desirable future road safety scenario, and in gaining acceptance for controversial initiatives. It goes on to emphasise that adopting a vision is not a substitute for developing and implementing a safety strategy.

Experience in Sweden, the Netherlands and New Zealand is seen as indicating the importance of securing parliamentary commitment on grounds that are hard to refute, demonstrating that there are cost-effective measures through which the vision can be pursued, and securing the engagement of stakeholders and the public through careful development of readily comprehensible concepts, principles and lines of action. The value of overt high-level political commitment is highlighted by experience in recent years in France.

In Sweden and the Netherlands the practical strategies backing up their respective visions have much in common with the Tomorrow’s Roads strategy for Britain (DETR, 2000), but with differences in emphasis on various kinds of safety measure. In both countries, implementing the chosen range of measures in a decentralised administrative environment has been supported by a quality assurance mechanism. This is accompanied in Sweden by a mechanism for collaboration between all agencies and businesses involved in the provision of the land transport system and services, and in the Netherlands by explicit consideration of financing work towards the adopted vision. In France, the main stimulus for casualty reduction in the last few years has been a change in the culture and practice of enforcement of traffic law.
Section 3 goes on to identify a need in Britain for something going beyond a target-focused strategy—an extra something that might embrace, but has to be more than, a quantification of a low aggregate level of risk in the desired scenario as advocated by the Motorists’ Forum of the Commission for Integrated Transport (CfIT) (2003), Allsop (2005) and PACTS (Crawford, 2007). It has to address public acceptance of required changes in behaviour, how far policy can move ahead of public opinion, and obstacles to progress that exist either within institutions and agencies or in the mind of the public. This is seen as pointing to the need for dialogue with the public and strengthening of institutional commitment in the process of adopting a vision, and then the setting of targets and identification of performance indicators within the context of the adopted vision, followed by independent auditing of delivery.

7.2 What kind of vision?

What then are the attributes of a vision for road safety that is right for Britain?

It should speak convincingly to a public that is sceptical of anything that smacks of pie in the sky or pre-election promises, but is responsive to down-to-earth commonsense.

It should reflect and be backed by a renewal of already recognised stakeholder commitment to a transparent programme of action, matched by credible and verifiable commitment to that programme by new and previously less committed stakeholders in government and business.

Its pursuit should be manifestly cost-effective and involving of the public.

Its essence should be expressed in a credible, challenging, appealing and memorable headline and strapline, which make it irrefutably clear that road safety is life-enhancing.

7.3 Preconditions for such a vision

Three preconditions for the effective adoption of such a vision need to be satisfied sequentially:

1. Breadth of institutional and stakeholder commitment to the concept of a vision.
2. Fresh public understanding of existing risk on the roads and the possibility of change.
3. Public and stakeholder engagement in the formulated vision.

Some key facts that should help to underpin the realisation of these preconditions are as follows:
• The risk of death per hour spent using the roads is higher than in the rest of everyday life in Britain by a factor of about eight (for all except elderly people who are at an increased risk of fatal falls in the home).
• Serious traffic offences like drink-driving, red light running, overtaking across double white lines and speeding kill like murder, maim like grievous bodily harm and cause damage like arson and breaking and entering.
• Basically law-abiding motorists have nothing to fear from the enforcement of traffic law to detect and deter these serious offences.
• We nearly all wear seat belts in the front seats and most of us do in the back seats so the many deaths among those who do not are avoidable tragedies that we can all help to reduce by encouraging anyone we know who does not belt up to do so.

7.3.1 Breadth of institutional and stakeholder commitment

The context for road safety policy in Britain has hitherto been seen largely as the achievement by the road transport system and its users of access and mobility for the users who are the whole population, both while engaged in economic activity and in their social and personal lives. Broad though that context is, it is only one of five current and likely continuing areas of policy in which there are substantial synergies and trade-offs with the reduction of risk on the roads. These are:

• access and mobility for all purposes;
• public health in the workplace and other organised activity and in private life;
• liveability of urban and rural surroundings;
• social inclusion or equality of opportunity; and
• sustainability in terms of carbon and other contributors to global warning.

The formulation of a vision for road safety needs to involve and thereby engage stakeholders, including politicians, central and local government, in all these areas, such as, respectively:

• highway authorities, transport authorities, transport operators, educators and trainers in road use, and the police and the courts;
• health authorities, health and safety organisations, and health professionals;
• transport and development planners, developers, architects of buildings and landscapes, and designers;
• professionals in social work, community development, education and other related professions; and
• those concerned with energy policy, fuel supply systems, and the fuel efficiency of road vehicles, of other transport systems and of their use.

The aim should be the verifiable commitment of the most relevant stakeholders from each of these sectors, accompanied by widespread awareness among all actors in these sectors of the synergies and trade-offs between their work and road safety. The first step in this direction should be to obtain commitment at the ministerial level in all relevant departments in Westminster, Edinburgh and Cardiff, made explicit in Parliament, the Scottish Parliament and the Welsh Assembly. The support of the Prime Minister and First Ministers should be sought as required.

If a vision were to be adopted without the prerequisite commitment from public and stakeholders, and were then to come into contempt, the potential benefits to society of adopting a vision effectively would be postponed for many years.

7.3.2 Public understanding

Having secured stakeholder commitment, the prerequisite for effective consultation with the public in formulating and adopting a vision for road safety is widespread public understanding of:

• the disproportionate level of risk that is tolerated in road-use compared with risk tolerated in any other large-scale everyday activity that is necessary for participation in economic and social life;

• the fact that this level of risk can be reduced substantially by measures that are cost effective and offer the prospect of widespread public acceptance after appropriate consultation and sensitive implementation;

• the fact that road safety measures can contribute to other desirable objectives for society and that pursuit of other objectives can contribute to road safety; and

• the readiness of relevant stakeholders to work together to achieve such synergies and to address and find good resolutions of inherent trade-offs between road safety and other objectives.

To achieve this understanding calls for a brisk and powerful, yet sensitive, programme of public information ahead of consultation about the vision itself. It will call for close cooperation between national and local channels of information, both governmental and sympathetic non-governmental, in England, Scotland and Wales. It may well also benefit from exceptionally high-level sharing of the substance and purpose of the exercise face-to-face with key figures in the media and other exceptionally influential opinion-formers.
7.3.3 **Public and stakeholder engagement**

The verifiable commitment of the wide range of stakeholders and the foregoing programme of public information should provide the foundation for extensive consultation with stakeholders and the public about a proposed vision and the specifics of an institutional framework and a strategy and programme of action in pursuit of the vision. These specifics should include:

- timetabled action by stakeholders, costed in both financial and human resource terms;
- contributions looked for from the public;
- headline targets for casualty reduction as the primary outcome;
- key performance indicators measuring other outcomes and directly relevant inputs; and
- arrangements for oversight of the programme and independent auditing of progress.

A positive outcome from this consultation, including sensitive taking on-board of the balance of the responses elicited, will pave the way for a suitably timed and orchestrated adoption of the vision and supporting strategy and launching of the targeted and monitored programme of action.

7.4 **Cost-effectiveness**

Both as taxpayers and as road users who may be asked for some adaptation of behaviour, sometimes entailing some inconvenience or extra cost, people will expect the implementation of the programme of action (whether in pursuit of an adopted vision or simply to implement a strategy) to be cost effective, at least in so far as this can be estimated. In the language of New Zealand legislation, people will be looking for safety at a reasonable cost.

It is widely recognised that there are aspects of road safety work that should be undertaken indeed that it would be irresponsible not to undertake even though their effectiveness in terms of numbers of casualties prevented can hardly be estimated. Examples are road safety education in schools, training, testing and licensing of drivers, and many other kinds of public information. Their effectiveness can sometimes be measured in terms of levels of knowledge or awareness, and sometimes in terms of observed behaviour. Interested members of the public, involved professionals and those responsible for the related allocation of resources will expect this to be done, but will recognise that the principal benefit to society of such work in terms of casualty reduction remains unquantified.

However, in road safety work where research, often supported by the monitoring of experience, provides estimates of the effects of particular interventions upon the
occurrence of collisions, injury and death, it has rightly been the practice in Britain to estimate cost-effectiveness in terms of the valuation of the prevention of collisions, injury and death (Department for Transport, 2007e) together with other measurable benefits and costs. This applies notably to the building of and major alterations to roads, and to more modest road safety engineering schemes. It also applies to requirements concerning the design and equipment of vehicles that are imposed by regulation (as distinct from being provided in response to market demand), and to requirements placed upon road users to change their behaviour in ways that impose costs on them. But requirements of these two kinds call for analysis less frequently and routinely than do road construction and road safety engineering.

Road construction and major alteration schemes are subject to cost-benefit analysis based upon estimates of costs and benefits arising over the lifetime of the scheme, and this can be done for different variants of the scheme, each with its own safety features included in the cost. In these analyses, the effects on numbers of collisions and casualties are estimated by established methods and the associated benefits are included on the basis of standard valuations.

As discussed in Section 4.7 the assessment of cost-effectiveness of local road safety engineering schemes has commonly been based on the first-year rate of return (FYRR), which is the estimated value of the benefits arising in the first year of operation expressed as a percentage of the estimated cost of the scheme. High values of FYRR have rightly been used to support the case for investment in local safety schemes. An up-to-date review of this process (Evans, 2007) has recently been carried out for the CfIT.

The discussion in Section 4.7, Evans’ work and issues raised by the Audit Commission (2007) call for the foundations of the economic case for local safety schemes to be revisited, perhaps in consultation with the CfIT, not because the case is likely thereby to be weakened, but to strengthen and clarify it in order to support its implications for investment levels to be followed through more fully than hitherto. This revisiting need not be an unduly expensive or protracted piece of research, but should address the following issues:

• Given the ways in which programmes of local safety schemes are managed by highway authorities and by consultants acting for them, what are the long-term avoidable costs of running such programmes, and how should the whole of these costs be allocated among implemented schemes (including the costs of investigation and preparation of schemes which are for various sound reasons abandoned or postponed for long periods)?

• What are the lifetimes of schemes of various kinds in terms of persistence of the resulting reduction in collisions and casualties, or the time until the investment needs to be repeated or followed up by major renewal, or the scheme is superseded by some further alterations affecting the site?
Just how should the lifetime and any need for subsequent investment to keep the scheme effective be interpreted in terms of the benefit to cost ratio (BCR) at present values that correspond to any estimated value of FYRR?

How should the values of FYRR, or probably and preferably BCR, of candidate local safety schemes be interpreted in terms of financial and human resources allocated to programmes of such schemes in competition with other calls on these resources?

How can opinions, like those reported by the Audit Commission (2007) that returns from local safety schemes are diminishing, be reconciled with evidence from Local Transport Plans, such as that cited by Evans (2007), that FYRR from implemented schemes remain at similar levels to hitherto?

To what extent should high threshold values of FYRR or BCR currently required to be reached in order for schemes to proceed be seen not only as a sign of the cost-effectiveness of implemented schemes, but also as a sign of underinvestment, resulting in the foregoing of benefit that could have been obtained by implementing, in addition, some further cost-effective schemes whose values of FYRR or BCR lie below current thresholds?

In relation to the last point, a useful comparator may be the threshold value of BCR that prevails in relation to candidate road construction schemes.

### 7.5 Contributions from highway engineering

Section 4 provides an extensive review of many ways in which highway engineering can continue to contribute to casualty reduction. The main determinants of its overall contribution are likely to be:

- the extent of road construction and major alteration;
- the scale of financial and human resources allocated to local safety schemes (including route and area schemes and mass action); and
- the ingenuity of highway and traffic engineers, working with town planners, countryside planners and developers, in identifying and responding to opportunities for creating safer local road networks.

In interpreting Section 4 in terms of local safety schemes, it may be helpful, alongside the implications of any revised and strengthened basis for assessing cost-effectiveness, to bear in mind:

- the potential offered by the current review of local speed limits;
- the relevance of the forgiving roadside to the current high and rising incidence of run-off-road accidents;
• the potential of mixed priority route treatments for casualty reduction on main roads in urban areas in parallel with that of 20 mph zones and Home Zones for residential and other lightly trafficked areas;

• the yet to be ascertained effect of the application of the Manual for Streets (Department for Transport et al, 2008) upon numbers of casualties in residential areas to which it is applied; and

• the relevance of the safety of routes for walking and cycling, of routes to and surroundings bus stops, and of routes to railway stations and light rail stops to the promotion of active travel in support of public health and sustainability objectives.

7.6 The contribution of vehicle technology

Sections 5 and 6 review the ways in which new or enhanced technology in vehicles has the potential to contribute to collision prevention and casualty reduction, and downsides in this respect of some tendencies in vehicle design and consumers’ choices of vehicle.

Some of the developments are incremental extensions to previous and proven technologies, and in these cases the routes to application and the potential for casualty reduction can be explored and assessed in established ways. This does not remove uncertainties about timescale and take-up, but it is known territory in terms of assessing these.

Others of the emerging technologies are more radical, both technically and in terms of their potential effects. They also bring with them greater uncertainty about their rate of development and take-up, about the size of their casualty reduction potential, and about the extent to which that potential may be realised simply by the working of the market, or realising it may require accompanying investment in the public sector or regulations requiring fitment and use of the last especially to extend benefits to users of less expensive cars.

This greater uncertainty arises in the context of accelerating technical development, so that the prospects for casualty reduction are much more difficult to forecast than they have been hitherto for the progressive development of occupant protection and almost grudging steps towards pedestrian protection over recent decades.

Occupant protection faces two particular challenges: the greater of these is demographic – the increasing number and proportion of older and therefore physically frailer car-users. The other is a matter of consumer choice: the tendency for the proportions of the largest and smallest types of car on the road to increase at the expense of the medium-sized. In collisions between cars of appreciably different masses, compared with those between cars of similar mass, the increased severity of injury in the smaller cars outweighs the reduction in severity in the larger cars.
In the area of active safety, innovation is particularly rapid and is running ahead of systematic and objective monitoring of effects on the occurrence of collisions, death and injury. This leads to a particular risk of initial overestimation of casualty reduction potential, not least because changes in driver behaviour, in order to take part of the benefit of the technology in the form of greater freedom to drive riskily instead of in the form of reduced risk, may take time to materialise.

7.7 The contribution of road-user behaviour

Many highway engineering measures and developments in vehicle technology affect the occurrence of collisions and casualties at least partly by modifying the behaviour of road users, especially drivers. And the degree to which the safety measure or technology reduces casualties often depends on how road users modify their behaviour in response to it, whether or not their response is part of the intended mechanism for casualty reduction. These aspects of the contribution of road-user behaviour to potential casualty reduction have been addressed in Sections 4, 5 and 6, and have been commented upon in Sections 7.5 and 7.6.

However, this report has not addressed the potential for casualty reduction by influencing road-user behaviour by other means than modifying the road or the vehicle. The other principal means of doing so are:

- education;
- training;
- information;
- regulation; and
- incentivisation.

Education is the lifelong cultivation of understanding of the phenomena of roads and traffic and the responsibilities inherent in using the roads. Training is the development of the capability for the specific tasks involved in doing so. Information ranges from general updating abut the evolving road system and its use, through targeted awareness-raising about particular aspects of road use or prevailing conditions, to site- or time-specific guidance or warnings at relevant points during the use of the roads. Regulation requires the education of road users about what compliance is required of them and why, and enforcement action against those who inadvertently or deliberately fail to comply. Incentivisation is the rewarding of behaviour that is helpful to the operation and use of the road system, including, but not confined to, the compliance with regulations.

The understanding offered by behavioural psychology has an important part to play in assessing the further contribution that these means of influencing behaviour can make to casualty reduction. The work reported here should be supplemented by a
review by perhaps three leading contributors to the study of road-user behaviour in relation to safety.

7.8 Key performance indicators

The use of performance indicators in road safety policy needs to be considered in the light of recent professional experience and public perceptions of their role in this and other areas of policy. On the one hand, the current national casualty reduction targets and their predecessor have achieved general professional acceptance as appropriate and helpful in motivating and managing road safety work. This is reflected in their widespread adoption at the local level, and they seem to be understood by the media and the public. On the other hand, some choices of targets and performance indicators used in other public services have been accused of leading to the diversion of attention from the main objectives of service delivery, and this has led to the use of targets and performance indicators being viewed with scepticism, especially in the media.

To retain the benefit for road safety of widely accepted and well-understood targets, it is therefore important that future road safety targets and performance indicators be well conceived, carefully chosen and widely understood.

Sections 2 and 3.8.3 discussed the scope for headline outcome targets for certain future years (such as annual numbers of deaths or seriously injured, in total and among specific groups of road user) to be accompanied by secondary performance indicators related to particular aspects of road-user behaviour or road safety activity (such as the proportion of vehicle occupants wearing seat belts or the percentage of length of main roads that has been systematically treated to make the roadside more forgiving). Targets for such secondary indicators are sometimes described as intermediate targets because they relate to some achievement partway through the process of casualty reduction, but use of this term in communication with the public is not recommended because it is too readily confused with targets for intermediate dates within the period covered by the headline targets.

Such secondary indicators as used to inform the public about the progress in implementing road safety policy should preferably be few in number and should be tested strictly against the following criteria:

- the level of the indicator should be transparently susceptible to improvement through cost-effective road safety activity and proof against influence by activity that has no beneficial impact on road safety;
- improving the level of the indicator should contribute incontrovertibly to casualty reduction; and
- the indicator should be measurable unambiguously and reliably in ways that are understandable by the public and at a cost which is clearly only a very small
proportion of the resource devoted to road safety activity to improve the level of the indicator.

This is not to say that highway authorities and other stakeholders should not be free to use any indicators that they find helpful in the management of their road safety activities. Nor should the public be denied information about any indicators that stakeholders are using. However, there should be no requirement to use or publish any secondary indicator that does not satisfy the above criteria.

7.9 Road safety policy in the context of wider policies

The timescale for developing a road safety strategy beyond 2010 set out on page 85 of the second three-year review of the current strategy (Department for Transport, 2007d) is such that the work will be carried out in the early stages of the process of revisiting transport policy in the light of the Eddington and Stern reports that is envisaged in the White Paper Towards a Sustainable Transport System (Department for Transport, 2007a).

Any road safety strategy, whether or not in pursuit of a vision for road safety, should therefore reflect the need to understand and improve road safety in the context of the full end-to-end journeys of people and movements of goods, and to do so in ways that are consistent with the overall reduction in emissions and support for economic growth. Additionally, links need to be drawn beyond the wider transport policy with, for example, health, education and urban regeneration.

In seeking and winning commitment across and beyond government to vision and strategy for road safety, it will be helpful to emphasise the contribution that radically enhanced road safety with radically reduced death and injury on the roads can make to the five broad goals set out in the White Paper:

- **The competitiveness and productivity of the economy** will be helped by reducing not only the grievous toll of death and long-term disablement, but also the disruption resulting from the scale of shorter-term injury, material damage and delay that stem from the levels of risk currently accepted on the roads.

- **Addressing climate change** will be helped by reducing the risk associated with travel on foot or by pedal cycle (either right to the destination or to and from public transport) and by enhancing the safety of motor-vehicles and their use in ways that encourage, or are at least consistent with, increased fuel efficiency.

- **Improving people’s safety, security and health** will be supported not only by tackling risk on the road as one of the largest single sources of injury and premature death, but also by encouraging the use of the streets on foot through the reduction in risk from traffic and thus helping to improve people’s security in the public realm and their health through physical activity.
• **The quality of life**, as enriched by the ability to travel both locally and over longer distances, will be further enhanced by reducing one of the major negative impacts of road transport—the toll of death and injury, and the anxiety that stems from it.

• **Promotion of greater equality of opportunity** will be helped by diminishing the risk of death and injury on the roads which impinges disproportionately on disadvantaged groups, and most notably on their children.

In all of these ways, a newly invigorated determination to bring down the risk of death and injury on the roads from its still disproportionate level will contribute directly and substantially to evolving transport policy and the wider quest for sustainable prosperity and equity.
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