INTERVENTIONS TO PREVENT UNINTENTIONAL INJURY IN CHILDREN ON THE ROAD

Report 3:

Cost-effectiveness modelling of road and street design-based interventions aimed at reducing unintentional injuries in children

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About the Peninsula Technology Assessment Group (PenTAG)

The Peninsula Technology Assessment Group is part of the Institute of Health Service Research at the Peninsula Medical School. PenTAG was established in 2000 and carries out independent Health Technology Assessments for the UK HTA Programme, systematic reviews and economic analyses for NICE (Technology Appraisal and Centre for Public Health Excellence) and systematic reviews as part of the Cochrane Collaboration Heart Group, as well as for other local and national decision-makers. The group is multi-disciplinary and draws on individuals' backgrounds in public health, health services research, computing and decision analysis, systematic reviewing, statistics and health economics. The Peninsula Medical School is a school within the Universities of Plymouth and Exeter. The Institute of Health Services Research is made up of discrete but methodologically related research groups, among which Health Technology Assessment is a strong and recurring theme.

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Collaborations

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No authors have competing interests.

List of abbreviations

Abbreviation	Meaning
CBA	Cost-benefit analysis
CEAC	Cost-effectiveness acceptability curve
CUA	Cost-utility analysis
DfT	Department for Transport
GAD	Government Actuary's Department
GB	Great Britain
GDP	Gross domestic product
km	Kilometre
mph	Miles per hour
NB	Net benefit
NPV	Net present value
ONS	Office for National Statistics
PenTAG	Peninsula Technology Assessment Group
PSA	Probabilistic Sensitivity Analysis
QALY	Quality-adjusted life year
RCGB	Road Casualties Great Britain
RR	Rate of return
TAG	Transport Analysis Guidance
UK	United Kingdom
USA	United States of America
WMHTAC	West Midlands Health Technology Assessment Collaboration

Glossary

Term	Definition
Cost-benefit analysis	An analysis comparing the incremental resources used by an intervention to the incremental benefits gained, valued in monetary terms, over another intervention
Cost-utility analysis	An analysis comparing the incremental resources used by an intervention to the incremental health benefits gained as expressed in quality-adjusted life-years, over another intervention (and where the quality of life weighting for added/lost years of life is based on people's preferences for those health states relative to full health (=1) or being dead (=0))
EQ-5D	A preference-based instrument for measurement of non-disease-specific health-related quality of life
Incremental cost-effectiveness ratio	The incremental cost of an intervention divided by the incremental benefit of that intervention compared to an alternative intervention
Incremental benefit	The difference in benefits between two interventions
Incremental cost	The difference in cost between two interventions
Net benefit or net present value	The total monetary benefit of an intervention less its costs (compared with an alternative intervention) when discounted to its present value.
Quality-adjusted life year	Year of life adjusted for quality of life
Rate of return	The total benefits of an intervention as a percentage of the total costs of the intervention in a given time period
STATS19	Injury accident data collection system used by the police
Utility	Preferences groups or individuals have for a particular set of health states
Willingness to pay	The amount a provider is willing to pay to obtain the specified benefits

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1. Summary

1.1. Introduction

This report describes economic modelling which explores the cost-effectiveness and cost-benefits of selected road/street design interventions (e.g. traffic calming) which have a primary or significant purpose of reducing road injuries. It is the third of three reports to support the development of NICE public health intervention guidance on preventing unintentional injuries to children and young people (aged less than 15) on the road, using road/street design-based schemes.

Only 13 previously published economic evaluations of interventions for the prevention of unintentional injuries on the road are available, all of which have been conducted using the approaches to cost-benefit analysis favoured by transport economists (see review of economic evaluations in Report 1). Of these interventions, only those involving the installation of 'Mixed Priority Route' schemes, or the installation of mandatory or advisory 20 mph zones were conducted in the UK after 2000. These interventions became the main focus of the modelling analyses in this report.

All of the previous studies used cost-benefit analysis, where the value society places on preventing fatal and non-fatal casualties (in monetary terms) are estimated and compared with scheme implementation costs. These values are the casualty or injury-related costs of medical services, lost productive output and 'human costs' (including pain, grief and suffering). In contrast, for policy making relating to health, NICE recommends cost-utility analysis where quality-adjusted life years (QALYs) are used to assess incremental health gains which are then compared with incremental costs as a ratio (National Institute for Health and Clinical Excellence 2006). Furthermore, only one of the previous economic evaluations (Grundy et al. 2008) considers costs and benefits of a scheme beyond the first year. This further justifies the need for a modelling-based approach; to extend these previous analyses to longer time horizons, to permit more extensive sensitivity analysis, and also to assess the interventions using a cost-utility as well as a cost-benefit analytical approach.

1.2. Aim

The aim of the economic modelling was to conduct both a cost-benefit analysis and a cost-utility analysis of the lifetime costs and effectiveness of relevant traffic calming and related interventions. The following comparisons, based on recent economic evaluations in the UK (so that there are relevant in terms of costs, effects and benefits to NICE) were evaluated:

- Mixed Priority Route schemes vs. no intervention
- Advisory 20 mph zones vs. no intervention
- Mandatory 20 mph zones vs. no intervention

Similar analyses comparing advisory 20 mph zones vs. mandatory 20 mph zones are also presented. However, these should be interpreted with caution due to uncertainties about the transferability of evidence about advisory 20 mph zones to England (and also about the similarity of areas in which they have been, or would be, located).

1.3. Methods

In our model, all road casualties are categorised into one of four levels of severity: fatal, serious permanent injuries, serious short-term injuries and slight injuries. The cost-utility analysis is from the perspective of the public sector and accounts for all quality-adjusted life-years (QALYs) and medical, police, local authority and DfT costs invested or saved from the prevention of casualties due to the intervention. The cost-benefit analysis is from a broader societal perspective and accounts for medical and human costs saved and lost output saved, from the prevention of casualties due to the intervention. Other potential benefits, such as changes in health and well-being due to physical activity and/or those associated with reduced congestion or pollution, which may be a consequence of the road interventions are not considered in this evaluation (see Discussion Section 6).

All costs associated with the construction, planning, design and maintenance of an intervention were estimated. One-way deterministic sensitivity analysis and probabilistic sensitivity analyses were undertaken to explore parameter uncertainty in the model. Results from the cost-benefit analysis are presented in terms of Net Present Value (NPV) (and First Year Rate of Return, for camparison with previous studies), while the incremental cost per QALY is reported from the cost-utility analyses (this is the Incremental Cost-Effectiveness Ratio, or 'ICER'). In the base case analyses, all results from both types of analysis are presented for an assumed 10 years from the construction/installation of the intervention, to cover the assumed effective life of the intervention. In the CUA, all lifetime health costs and benefits (QALYs) associated with casualties saved due to the intervention are estimated.

1.4. Findings

The table on the following page shows the base case and mean PSA results for the main intervention comparisons made, and using both cost-benefit analysis (using DfT-recommended methods) and cost-utility analysis (using NICE-recommended methods). We do not, however, summarise the comparison between advisory 20 mph speed limits and 20 mph zones, because of concerns about the comparability of the source study road sites and results .

Overall, the cost-effectiveness analysis suggests that the installation of advisory 20 mph zones is highly cost-effective, at least on the type of road and with prior rates of casualties that they have been previously implemented on. On the basis of the cost-utility analyses, only advisory 20 mph speed limits would be judged as cost-effective using the decision rules typically applied by NICE for the adoption of health technologies by the NHS. All interventions are more cost-effective when assessed in high casualty areas, as would be expected. Since the CBA accounts for broad societal costs whereas the cost-utility analysis only accounts for health and other public sector costs, interventions tend to be shown as cost-effective more with CBA than with CUA.

There is, however, a lack of data regarding certain costs, such as maintenance costs, and benefits (e.g. utility gains) associated with interventions on the road. There is therefore a great deal of uncertainty associated with the cost-effectiveness analyses as identified by the PSA (see standard deviations of mean PSA results in the following table). Good data on the long-term quality-of-life and public sector cost impacts of non-fatal road injuries is currently lacking.

Main cost-benefit and cost-utility results

Intervention	Cost-Benefit	Cost-Utility		
	NPV	**ICER in £/QALY**	**Incremental Cost**	**Incremental Benefit in QALYs**
Mixed Priority Routes:				
Base case	-207,073	304,823	2,511,650	8.24
PSA	-222,345 (1,258,476)	369,996 (186,734)	2,490,681 (795,253)	7.55 (2.48)
Mandatory 20 mph zones, Low casualty areas:				
Base case	-25,480	457,762	66,943	0.15
PSA	-25,526 (25,596)	511,299 (182,482)	66,596 (18,292)	0.14 (0.03)
Mandatory 20 mph zones, High casualty areas:				
Base case	90,625	89,700	62,708	0.70
PSA	91,106 (58,288)	93,409 (34,925)	62,595 (18,906)	0.70 (0.14)
Advisory 20 mph speed limits:				
Base case	32,354	22,952	2,577	0.11
PSA	32,073 (11,896)	25,996 (12,445)	2,591 (1,095)	0.10 (0.02)

Numbers in brackets are standard deviations around the mean PSA results.

1.5. Discussion points

- We believe this may be the first economic analysis to have simultaneously conducted cost-benefit analyses and cost-utility analyses of the same transport/road safety interventions. This gives rise to the possibility that (as with mandatory 20 mph zones in high casualty areas) that an intervention would be deemed cost-effective by one method but not by the other. Importantly, however, this approach has allowed us to estimate the benefits and costs of these interventions over more realistic time horizons and from the perspective of the public sector.

- There is a great deal of uncertainty in many of the important parameter estimates. As much as possible within the time and resources available we have explored this uncertainty using the current approaches to sensitivity analysis in health care economic evaluation.
- In addition, as discussed in Report 1, there is clearly much heterogeneity in the effectiveness of these interventions from place to place, and when implemented at different scales and with different intensity of component features. These variations will also inevitably impact on cost.
- Most traffic calming schemes have multiple objectives, and only partly aim to reduce injuries. Moreover, they tend to reduce injuries amongst all road users, including both adults and children – hence the broader perspective taken in our analyses.
- There is a paucity of good quality and recent evaluations which provide detailed cost and effectiveness estimates from the same sample of road safety or traffic calming schemes. In addition, there is very little research-based information to inform potentially important cost variables such as the additional maintenance costs of road engineering-based measures, or the expected effective life of these types of intervention.

2. Introduction

The systematic reviews in Report 1 on the prevention of unintentional injuries to children on the road, using road/street design-based interventions, has shown evidence that a number of traffic calming and other speed-reduction schemes are effective at reducing injuries and injury accidents in children. Moreover, although often based only on reported First Year Rates of Return (from cost-benefit analyses), there is moderate evidence that some are also cost-effective – with benefits likely to exceed costs in the medium to long term for many of the interventions for which economic evaluations have been conducted.

This report describes some economic modelling which explores the cost-effectiveness and cost-benefits of selected road and street design interventions (e.g. traffic calming and 20 mph zones) which have a primary or significant purpose of reducing road injuries. It is the third of three reports to support the development of NICE public health intervention guidance of preventing unintentional injuries to children and young people (aged less than 15) on the road, using road/street design-based measures. The other two reports for consideration by NICE's Public Health Intervention Advisory Committee are:

- Report 1: A systematic review of effectiveness studies and a systematic review of economic evaluations of traffic calming and related road design based road injury prevention measures.
- Report 2: A systematic review of qualitative research studies with relevance to understanding the barriers to and facilitators of the planning and implementation of traffic calming and related road design based road injury prevention measures.

A limited number of economic evaluations of interventions for the prevention of unintentional injuries on the road are available, all of which have been conducted using the approaches to cost-benefit analysis favoured by transport economists (Atkins (on behalf of DfT) 2009;Burns et al. 2001;Cheshire County Council & JE Jacobs 2008;Elvik 2003;Erke & Elvik 2007;Gorell & Tootill 2001;Grundy et al. 2008;Mackie et al. 1990;Manchester City Council & JE Jacobs 2008;Meuleners et al. 2008;Norfolk County Council & JE Jacobs 2008;Saelensminde 2004;Wheeler & Taylor 2000) (see review of economic evaluations in Report 1). Of these existing relevant economic evaluations, only those involving the installation of 'Mixed Priority Route' schemes or the installation of mandatory or advisory 20 mph zones were conducted in the UK after 2000 (Burns et al. 2001;Cheshire County Council & JE Jacobs 2008;Gorell & Tootill 2001;Grundy et al. 2008;Manchester City Council & JE Jacobs 2008;Norfolk County Council & JE Jacobs 2008). Further, the study by Gorell and Tootill (2001), while covering a wide range of different local authority road safety schemes did not provide sufficient detail on the reductions in casualties (it only reported percentage changes in accidents).

All of the previously published evaluations from the UK use cost-benefit analysis, where the value society places on preventing fatal and non-fatal casualties (in monetary terms) are evaluated (Department for Transport 2009). These values are the casualty or injury-related costs of medical services, lost productive output and ‘human costs’ (including pain, grief and suffering). In contrast, for policy making relating to health, NICE prefers to inform policy with cost-utility analyses, where quality-adjusted life years (QALYs) are used to assess incremental health gains which are then compared with incremental costs as a ratio (National Institute for Health and Clinical Excellence 2006). Furthermore, only one of the previous economic evaluations (Grundy et al. 2008) considers costs and benefits of a scheme beyond the first year. This further justifies the need for a modelling-based approach; to extend these previous analyses to longer time horizons, permit more extensive sensitivity analysis, and also to assess the interventions using a cost-utility as well as a cost-benefit analytical approach (Buxton et al. 1997;Sculpher et al. 2006).

3. Aims

3.1. Objectives and Rationale

The aim of the economic modelling is to conduct both a cost-benefit analysis (using currently recommended Department for Transport (DfT) methods (Department for Transport 2009)) and a cost-utility analysis (using recommended NICE methods (National Institute for Health and Clinical Excellence 2006)) of the relevant costs and effectiveness of selected traffic calming and related interventions for which good quality UK-based economic evaluations have been found (i.e. those identified and quality assessed in the systematic review of economic evaluations; see Report 1). That is, in addition to extending the published cost-benefit analysis to longer assumed project lifetimes of the measures (up to 20 years), we will be using the same cost and injury outcome data to produce a cost-utility analysis based on the estimated public sector costs and the survival and quality of life impacts which accrue over an injury victim's lifetime.

The following comparisons, based on good quality economic evaluations of interventions in the UK, are evaluated:

- Mixed priority routes schemes in city centres (based on three schemes and their economic evaluations in Manchester (Manchester City Council & JE Jacobs 2008), Norwich (Norfolk County Council & JE Jacobs 2008) and Crewe (Cheshire County Council & JE Jacobs 2008)) vs. no traffic calming
- Advisory 20mph speed limit zones vs. no Advisory 20mph limits (based on Scottish trial by Burns et al (2001))
- Mandatory 20mph speed limit zones vs. no mandatory 20mph speed limit zones (2008) London data
- Mandatory 20mph speed limit zones vs. Advisory 20mph speed limit zones (Burns et al. 2001;Grundy et al. 2008)

These were chosen because they were the higher quality and more recent UK studies which report both effectiveness (fatal and non-fatal injury data) and cost/resource use data.

The economic modelling presented in this report involves modelling road injuries sustained by both children and adults. This is because, the benefits of most road interventions are not separately attributable to either adults or children, and so their costs also should not be. Even if it were possible to apportion intervention costs to children, there is an issue as to how results would be interpreted. Attributing all intervention costs to children and then also comparing the benefits just for children is likely to be fairly arbitrary, and would imply that interventions should only be justified on the basis of the prevention of children's casualties (and therefore that any adult casualties prevented are of secondary importance). Finally, the available DfT values for the prevention of injuries or accidents do not distinguish between children and adults and there is little evidence of effectiveness distinguishing between children and adults. For these reasons, the cost-effectiveness evaluation considers all people affected (whether adults, children, pedestrians, cyclists etc) (Department for Transport 2009).

It is acknowledged that there are a number of benefits to the construction/installation of road interventions, with safety being just one of these. Further benefits include

- Improving congestion/travel flow (increased amenity value, cheaper transport costs)
- Potentially increasing physical activity (increased health)
- Reduced air pollution (increased health, better environment)

These are not considered in the economic evaluation presented here, but are discussed in Section 6.

4. Methods

4.1. Interventions and comparators

As noted in Section 3, mixed priority routes and mandatory and advisory 20 mph zones are the focus of the economic modelling. All three interventions are compared to no intervention, with the mandatory and advisory 20 mph zones also compared with each other. The mixed priority routes scheme is not compared to the 20 mph zones since they are not strictly alternatives as mixed priority routes are likely to be installed on busy, high streets, while 20 mph zones are likely to be installed in more residential areas.

4.1.1. Mixed priority routes

As of January 2009, ten cities and London boroughs individually reported their undertaking of the construction and evaluation of a mixed priory routes scheme (Department for Transportation 2009). (Individual reports are available at www.dft.gov.uk/pgr/roadsafety/dpp/mpr). These schemes involve considerable construction and related high costs with the aim of making roads safer and more pleasant for a wide range of road users (pedestrians, cyclists and motorists), whilst allowing the mixed uses of the roads/area for leisure/shopping, businesses, and public transport (e.g. bus routes); see Report 1 for a fuller description. Economic assessments of three of the mixed priority routes have been undertaken for Crewe (Cheshire County Council & JE Jacobs 2008), Norwich (Norfolk County Council & JE Jacobs 2008) and Manchester (Manchester City Council & JE Jacobs 2008). All three schemes had similar total costs of installation of over £2 million per km of road, with first year rates of return (the value of the prevention of casualties in the first year as a percentage of the total implementation costs of the intervention) from 7% to 34%.

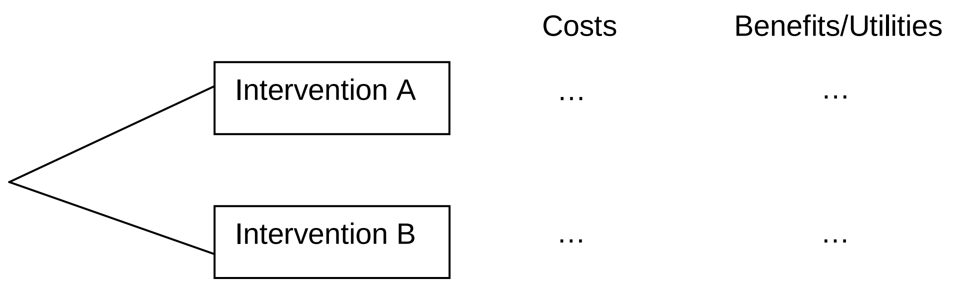
4.1.2. 20 mph zones

Mandatory 20 mph zones are much cheaper to install than the mixed priority routes (see Report 1). An economic evaluation of mandatory 20 mph zones in London (Grundy et al. 2008) found that benefits exceeded costs in areas with more than 0.7 casualties per km of road , while an assessment of advisory 20 mph zones in Scotland (Burns et al. 2001) reported a first year rate of return of 48% .

4.2. Model structure

For each of the different interventions evaluated, although a cost-utility and cost-benefit analysis is undertaken, the model structure remains the same (see Figure 1). Two road safety improvement options are assumed: intervention A and intervention B. The benefits (monetary and quality adjusted life years (QALYs)) and costs are calculated for each intervention and compared. Since the number of potential casualties cannot be known (i.e. we do not know how many individuals use the particular roads we are interested in and therefore have the potential to be casualties), we model the actual number of casualties recorded between the two interventions.

Figure 1. Schematic of economic model



4.3. Cost-utility analysis (CUA)

The cost-utility analysis was conducted from a public sector perspective incorporating all health, local authority, police and DfT costs. The incremental costs of construction, planning and maintenance of the intervention over the comparator are calculated, amortized (spread) over the assumed effective life of the intervention, and health and police service costs saved from the prevention of injuries are estimated.

The Quality-Adjusted Life-Years saved over a lifetime by the prevention of casualties due to the intervention are calculated to obtain the incremental QALYs of the intervention compared with the comparator. For fatalities, the number of QALYs saved is based on the age of the individual at the time of the fatality. Life expectancy tables (Office for National Statistics 2009b) are used to calculate the number of lost life years, which are then adjusted by the quality of life at each age. Calculation of QALYs lost due to non-fatal casualties depends not only on the age of the individual and their quality of life at the time of the casualty, but also on the severity of the injury (the quality of life decrement) and the duration of the impact of the injury. It is assumed that an individual only experiences one casualty.

To calculate the QALYs saved by the intervention, in each year of the effective life of the intervention, the number of casualties is categorised into nine age groups, following the categories used in the 2007 annual report of Road Casualties Great Britain (RCGB) (2008b): 0-15, 16-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80+ years. Within these age groups, each casualty is assumed to be the same age (the mid-point age of each age range, e.g. every child in the 0-15 year age group is assumed to be 8 years old). The age groups and age at the time horizon for the model are shown in Table 1. Since there is no evidence on the number and severity of casualties within each age group for any of the interventions, the proportion of fatal, serious and slight casualties for each age group is based on the proportions reported in the RCGB 2007 annual report (2008b). These are given in Table 2. Where QALY decrements and costs associated with casualties continue after the year of the injury, these QALYs and costs are calculated for the total lifetime of the individual. A life-expectancy of 95 years is assumed with the latest interim life tables (Office for National Statistics 2009b) providing the proportion surviving at each age. These life tables suggest that less than 5% of the population survive beyond 95 years and so, with the model accounting for survival, together with discounting (see Section 4.7), nearly all relevant costs and benefits will have occurred and been accounted for up to 95 years of age.

Table 1. Age groups used in the CUA

Age-band	**Mid-point age (years)**	**Age at each of the assumed effective lifetimes of the intervention**		
		5-year horizon	10-year horizon (base case)	20-year horizon
0-15 years	8	13	18	28
16-19 years	17	22	27	37
20-29 years	24	29	34	44
30-39 years	34	39	44	54
40-49 years	44	49	54	64
50-59 years	54	59	64	74
60-69 years	64	69	74	84
70-79 years	74	79	84	94
80+ years	90	95	death	death

Table 2. Severity profile of casualties within age groups

Age group	Fatal (%)	Serious (%)	Slight (%)
0-15	4	10.9	9.8
16-19	12.5	14.2	13.3
20-29	22.3	22.5	24.6
30-39	15.1	15.7	17.9
40-49	13.7	14.5	15.1
50-59	9.7	9.1	9.2
60-69	7.1	5.6	5.3
70-79	7.5	4.3	3.1
80+	8	3.3	1.7
All ages	100	100	100

Source: RCGB 2007 Annual Report (Department for Transport 2008b) (Table 30a).

4.4. Cost-benefit analysis (CBA)

In the cost-benefit analysis the benefits of the intervention are characterised by the societal value of the prevention of casualties, and then compared to the incremental costs of the intervention. This analysis, taken from a broad societal perspective, is the currently recommended approach by the Department for Transport (2009). Medical and human costs, reflecting pain, grief and suffering, and lost productive output are all considered in the CBA (Department for Transport 2009). The broad societal costs are published by the DfT each year, and are based on calculations originally undertaken by Hopkin and Simpson over 14 years ago (1995). In turn, a number of other studies provided evidence for these calculations, including a survey from 1993 of road accident casualties treated at hospitals in Greater Manchester (Hopkin et al. 1993) which is the basis for calculations on the costs associated with serious casualties. The human costs were estimated using willingness to pay methods - representing the perceived benefits of avoiding accidents, rather than representing the consequences of an accident (Department for Transport 2009).

As QALYs are not accounted for in the CBA and the values associated with a prevented casualty have been calculated and provided by the DfT for the total population, the CBA does not require the age of the individual in the evaluation.

4.5. Economic outcomes

For the CUA the incremental cost (£) per quality-adjusted life year (QALY) gained, also known as the incremental cost-effectiveness ratio (ICER), is reported. For the CBA, the net present value (NPV £) of the intervention over the comparator is reported (note that net present value is equivalent to net benefit). The first year rate of return from the CBA is also reported. All results are calculated and reported on a “per km” scale.

4.6. Time horizons

The time horizon is informed by the effective lifetime of an intervention. It has been indicated that some interventions may have a maximum of 10 years of effectiveness, with different interventions having different effective lifetimes (personal communication Heather Ward, June 2009). In the absence of data, a 10 year effective lifetime is assumed for the base case analysis, so that only casualties prevented in the first ten years of the intervention are simulated in the model. The impact of assuming 5 and 20 year of effective lifetimes is assessed in sensitivity analyses. Regardless of the time horizon for the intervention, the QALYs and costs saved, beyond the year of the injury, due to the intervention are calculated for an individual’s lifetime as described in Section 4.3.

4.7. Discounting

Costs and benefits beyond the first year of the intervention are discounted at a rate of 3.5% per annum (National Institute for Health and Clinical Excellence 2006). In sensitivity analyses, the impact of assuming zero discount rates is assessed, as is the impact of differential discounting: 3.5% for costs and 1.5% for benefits.

4.8. Severity profile of casualties

For the CBA, all casualties are categorised into one of three levels of injury severity. These injury severities are the three-way classification used by the DfT (2009), from the STATS19 data, and are defined as:

- **Fatal**: any death that occurs within 30 days from causes arising out of the accident,

- **Serious**: casualties who require hospital treatment and have lasting injuries, but who do not die within the recording period for a fatality,

- **Slight**: casualties have injuries that do not require hospital treatment, or, if they do, the effects of the injuries quickly subside (Department for Transport 2009).

Since only one of the economic evaluations (mandatory 20 mph zones Grundy et al. 2008) on which the present analyses are based, categorised casualties using the three-way classification from the DfT, an assumption of the proportion of casualties suffering a fatal, serious or slight injury is needed for the remaining interventions/analyses. Data on the severity profile of casualties on built-up roads from the RCGB (Department for Transport 2008b) are used and presented in Table 3. For the CUA, as described in Section 4.3, these proportions are further divided to account for the unbalanced number of casualties within age groups. Unfortunately the split by age group of casualties on built-up roads is not available and so the proportions of casualties within each age group (given in Table 2) are based on all roads data (although the proportion of fatal, serious and slight casualties is taken from data on built-up roads).

Table 3. Severity profile of casualties on built-up roads

	Fatal	**Serious**	**Slight**	**Total**
Total number of casualties	1,160	17,751	149,875	168,786
Percentage of total	0.7%	10.5%	88.8%	100%

Source: RCGB 2007 Annual Report (Department for Transport 2008b) (Table 24).

In order to conduct a cost-utility analysis, since a serious injury could lead to either permanent disability/health impacts or short-term disability/health impacts, the quality of life and costs associated with care could be substantially different within the category of severe casualties. In the calculation of the broad societal costs for the prevention of injuries, this difference is accounted for and the values reported by the DfT are weighted by the proportion of casualties with differing severities of serious injury; so the three severity categories above are used in our CBAs. However, in the CUA, the lifetime health and quality of life impacts need to be accounted for and so this difference in the severity of serious casualties needs to be considered. Therefore, the serious injury category has been sub-divided into serious permanent disability and serious short-term disability to account for these differences. Hence in the CUA, individuals could be those who experience either fatal, serious permanent, serious short-term or slight casualties.

Since all of the reviewed economic evaluations used a CBA, this difference in the severity of serious casualties has not been addressed, and so the proportion of serious casualties who are permanently injured is not documented in the effectiveness literature. However, in the TRL Report 163 by Hopkin and Simpson (1995), where the methods used by the DfT to calculate the broad societal costs are described, data from a survey of hospital treated road casualties in Greater Manchester is used (Hopkin et al. 1993) and serious injury state groups are defined.

These range from casualties who had no overnight stay and recovered in 3-4 months, to those who had permanent brain injury and were dependent on others for most of their physical needs. Hopkin and Simpson (1995) report that 2% of serious casualties were defined as being permanently disabled from the road accident. By extending the injury state group definitions in Hopkin and Simpson (1995) to those casualties having some permanent disability such as “continuing permanent pain, …substantial and permanent restrictions to work and leisure activities”, the percentage of permanently disabled casualties becomes 15%. In base case cost-utility analyses it is therefore assumed that 2% of serious casualties are permanently injured with the remaining 98% having short-term injuries. In sensitivity analyses, the impact of assuming that 15% of serious casualties are permanently injured is assessed as well as the conservative assumption of 1% of serious injuries being permanent.

4.9. Background casualty trends

A reduction in the number of casualties in areas of no intervention (the background trend) have been noted (Grundy et al. 2008). Grundy et al (2008) were able to model the background trend in their economic evaluation of mandatory 20 mph zones in London using regression analyses. They defined background trend as the reduction in casualties in roads where 20 mph zones were not installed. In our base case analyses the background trends reported by Grundy et al are included. This means that for a non-intervention comparator, just the background reduction in casualties is assumed, while for interventions the background reduction and the reduction due to the intervention are modelled. In sensitivity analyses, the assumption of no background trend is made and its impact assessed.

4.10. QALY losses for non-fatal injuries

For slight and serious short-term casualties it is assumed that any QALY loss is experienced in the year of the injury only. Sensitivity analyses are used to assess the assumption of no QALY loss for slight or serious short-term casualties. However, for fatal and serious permanent casualties the QALYs lost are calculated for a lifetime. The basis for these QALY losses is described in Section 4.11.5.

4.11. Model parameters

The parameters relating to the effectiveness of the interventions and the costs and utilities associated with the interventions are described in this section. The base case parameters, their values and data sources are detailed in Table 4 (see next page).

Table 4. Base case parameter values and source details

Parameter	Value (standard error)	Justification/Source
Effective lifetime of intervention	10 years	Personal communication, Heather Ward, June 2009
Discount rate:		
Costs	3.5%	As specified in NICE methods guidance (2006)
Benefits	3.5%	
Effectiveness outcomes		
Number of casualties without intervention	See Table 5	Specific to intervention
% reduction in casualties due to intervention	See Table 5	Specific to intervention
Background reduction in casualties	Fatal: 4.3% (1.4%) Serious permanent: 7.9% (3.5%) Serious short-term: 7.9% (3.5%) Slight: 6.2% (3.0%)	Means and standard errors from Grundy et al (2008)
Utilities (CUA only)		
Utility decrement for individuals with serious permanent injuries until death	4.0% (1.2%)	Mean from Nyman et al (2008). Standard error of 30% of mean assumed for PSA
Loss in utility for individuals with serious short-term injuries (1 year only)	2.4% (0.7%)	Mean from Nyman et al (2008). Standard error of 30% of mean assumed for PSA
First year loss in utility for individuals with slight injuries (1 year only)	1.5% (0.5%)	Mean from Nyman et al (2008). Standard error of 30% of mean assumed for PSA
% of serious casualties with permanent injury	2%	Hopkin & Simpson (1995)
Health utilities (by age)	Under 25 yrs: 0.94 (0.007) 25-34: 0.93 (0.005) 35-44: 0.91 (0.007) 45-54: 0.85 (0.011) 55-64: 0.80 (0.012) 65-74: 0.78 (0.012) Over 74 yrs: 0.73 (0.015)	UK Population Norms – Kind et al (1999). Standard error calculated from standard deviation reported in Kind et al.
Age-specific survival rates	UK Interim Life Tables (Office for National Statistics 2009b)	
Time horizon of model	95 years	UK Interim Life Tables (Office for National Statistics 2009b)
Costs		
Lifetime societal costs associated with injury prevented (CBA only)	Fatal: £1,710,479 (£513,144) Serious: £193,370 (£58,011) Slight: £14,908 (£4,473)	Uprated to 2009 costs from DfT 2007 costs (Department for Transport 2009) using nominal gross domestic product growth of 4.4% from June 2007 to June 2009 (Office for National Statistics 2009a). Standard error of 30% of mean assumed for PSA

Parameter	Value (standard error)		Justification/Source
Lifetime medical costs (CUA only)	Fatal: Serious permanent: Serious short-term: Slight:	£1,013 (£304) £113,723 (£34,117) £11,537 (£3,462) £1,023 (£307)	Uprated to 2009 costs from DfT 2007 costs (Department for Transport 2009) using nominal gross domestic product growth of 4.4% from June 2007 to June 2009 (Office for National Statistics 2009a). See Section 4.11.3 for details on calculation of serious permanent and serious short-term costs.
Police costs (CUA only)	Fatal: Serious permanent: Serious short-term: Slight:	£1,017 (£974) £382 (£366) £382 (£366) £305 (£91)	Calculated as weighted averages from DfT costs for prevention of accidents (see Section 4.11.3 for further details).
Annual cost of construction/installation of intervention	See Table 6		Specific to intervention (annuitized and inflated to 2009 prices, using Road Construction Tender price Index (Department for Transport 2008a)– see Section 4.11.2 for further details)
Annual maintenance costs for intervention	See Table 6		Specific to intervention

4.11.1. Effectiveness outcomes

The effectiveness parameters are i) the number of casualties in the comparator area and ii) the percentage reduction in casualties due to the intervention. The base case effectiveness values for each intervention are given in Table 5.

Table 5. Base case effectiveness outcomes used in the economic model

Intervention	Severity	Number casualties (per km per year) without intervention	% reduction in casualties due to intervention	Source
Mixed priority routes	Fatal	0.17	30%	Crewe (2008), Norwich (2008) and Manchester (2008) reports. Severity of casualties based on severity profile in Table 3
	Serious – permanent	0.03		
	Serious – short-term	1.54		
	Slight	12.26		
Mandatory 20 mph zones – low casualty	Fatal	0.002	57%	From Grundy et al. (2008). 2% of serious casualties are considered permanent.
	Serious – permanent	0.002	26%	
	Serious – short-term	0.074	26%	
	Slight	0.547	22%	
Mandatory 20 mph zones – high casualty	Fatal	0.010	57%	From Grundy et al. (2008). 2% of serious casualties are considered permanent.
	Serious – permanent	0.004	26%	
	Serious – short-term	0.201	26%	
	Slight	1.443	22%	
Advisory 20 mph zones	Fatal	0.003	58%	From Burns et al (2001). Severity of casualties based on severity profile in Table 3.
	Serious – permanent	0.0005		
	Serious – short-term	0.026		
	Slight	0.211		

Mixed priority routes

i) Number of casualties in comparator area

Three economic evaluations of mixed priority routes in Norwich (Norfolk County Council & JE Jacobs 2008), Crewe (Cheshire County Council & JE Jacobs 2008) and Manchester (Manchester City Council & JE Jacobs 2008) are available (see Report 1 for more details). However assessment of all three schemes indicates considerable variation in the number of casualties (in the before period), the effectiveness of the schemes and small differences in the costs of the schemes. For these reasons, the base case analysis uses the total number of casualties in the comparator area from the Norwich scheme (14 per km of road), with sensitivity analyses exploring the values reported in the Crewe and Manchester schemes.

No distinction is made between the severities of the casualties and so the severity profile of casualties given in Table 3 is applied, and the number of casualties in the comparator area, per severity, is shown in Table 5.

ii) Percentage reduction in casualties due to the intervention

There was also some inconsistency concerning the percentage reduction in casualties due to the intervention: Crewe and Manchester report a reduction in casualties due to the intervention of around 25-30%, while in Norwich the reduction is greater than 60%. Therefore, a range of percentage reductions are assumed with 30% being the base case value and the following assessed in sensitivity analyses: 0%, 10%, 20%, 40%, 60% and 80%.

4.11.1.1. Mandatory 20 mph zones

Data for the cost-effectiveness of mandatory 20 mph zones are taken from an economic evaluation of zones in areas of London (Grundy et al. 2008) (see Report 1 for more details).

i) Number of casualties in comparator area

In the Grundy et al (2008) report areas were defined as low casualty (areas with an average of <1 casualty per year per km road) and high casualty (areas with an average of >= 1casualties per year per km road). The numbers of casualties in comparator areas are given in Table 5 for the low and high casualty areas and by casualty severity.

ii) Percentage reduction in casualties due to the intervention

Grundy et al (2008) carried out regression analyses of the yearly data to calculate the reduction in casualties due to the intervention. These percentages are used in this cost-effectiveness analysis and presented in Table 5.

4.11.1.2. Advisory 20 mph zones

The advisory 20 mph speed reduction initiative evaluated by Burns et al (2001) covered 1,525km of carriageway in Scotland and 75 trial sites (see Report 1 for more details). The base case effectiveness parameter values for the evaluation of this intervention can be found in Table 5.

i) Number of casualties in comparator area

Burns et al (2001) report the number of casualties, per year, covering 59 trials sites before the intervention was installed. An average number of casualties per year per km is calculated assuming that each of the 59 trial sites includes an average of 2.2km of road. Again, the severity profile in Table 3 is applied to the Burns et al data and the numbers of casualties, per severity, in the comparator area are shown in Table 5.

ii) Percentage reduction in casualties due to the intervention

Burns et al report the number of casualties in the year after installation of the advisory 20 mph zones, corresponding to a 58% reduction in casualties. In our model it is assumed that all casualty severities are reduced by 58%.

4.11.2. Intervention costs

In economic evaluations in health care it is conventional to spread (or ‘annuitize’) the cost of capital assets or equipment over their useful lifetimes (Drummond et al. 2005). For the CUAs therefore, the costs of the construction and/or installation and design and planning of each intervention are spread out over the effective life of the intervention (for the base case this is 10 years). This is achieved by calculating an 'equivalent annual cost' of the initial capital expenditure (from a formula which used total cost and an annuity factor, based on the number of years of the intervention and an assumed interest rate) (Drummond et al. 2005). For these analyses, the interest rate is assumed to be 1% (reflecting current low rates).

In contrast, the intervention construction costs in the CBA are assumed to occur in the first year of the intervention. This is the way CBAs in the transport economics field handle such costs (see Report 1).

An annual maintenance cost is presented in Burns et al, but as maintenance costs are not given for the mixed priority routes scheme and the mandatory 20 mph zones, it is assumed to be £1000 per year in base case analyses. In sensitivity analyses annual additional maintenance costs of £500 and £2000 are investigated. These maintenance costs are assumed to be the excess costs of maintaining the intervention compared to the comparator.

All cost are inflated to 2007 costs based on the Road Construction Tender Price Index (Department for Transport 2008a) and then inflated to 2009 costs assuming a constant inflation per year as that from 2006-2007 Tender Price Index. Total construction costs, equivalent annual construction costs and annual maintenance costs are shown in Table 6.

Table 6. Design, planning, construction and maintenance costs of road interventions (£ 2009, per km road)

Intervention	Cost of design, planning construction/installation	Equivalent annual construction /installation costs (for the base case of 10 years)	Annual maintenance costs
Mixed priority routes (from Norwich (2008))	£2,924,884	£308,815	£1000 (assumed for base case)
Mandatory 20 mph zones – low casualty (from Grundy (2008))	£67,568	£7,134	£1000 (assumed for base case)
Mandatory 20 mph zones – high casualty (from Grundy (2008))	£68,173	£7,198	£1000 (assumed for base case)
Advisory 20 mph zones (from Burns (2001))	£2,925	£309	£243

4.11.3. CUA public sector costs

As noted in Section 4.3, the medical and police costs for fatal, serious permanent, serious short-term and slight casualties are modelled in the CUA. Both the medical and police costs are obtained from the DfT values for prevention of casualties. The medical costs for fatalities and slight casualties are taken directly from the DfT (Department for Transport 2009) and uprated to 2009 costs as described in the TAG using the assumption of a 4.4% nominal GDP growth between June 2007 and June 2009 (as calculated from National Statistics time series data (Office for National Statistics 2009a)). Medical costs for serious permanent and serious short-term casualties were recalculated using data from Hopkin and Simpson (1995). The authors report the June 1994 medical and support costs for different injury state groups (Table B6 of (Hopkin & Simpson 1995)). Using this information and knowing the percentage of casualties permanently injured, it was possible to calculate the percentage of all serious medical costs that could be attributed to serious short-term and serious permanent casualties. From these analyses, it is assumed that serious short-term casualties have mean medical costs that are 83% of the medical care costs of all serious casualties, and that serious permanent casualties have mean medical costs 8.2 times the cost of all serious casualties. These costs were calculated from the June 2007 costs reported in TAG and uprated to 2009 costs as described above. In the absence of published estimates, for serious permanent casualties, an annual medical cost of £1000 for every year of the individual's life until age 95 is assumed in the base case and varied to £400 and £2000 in sensitivity analyses to evaluate the impact these values have on the results. (NB. £400 per year approximates to the cost of four consultant-led outpatient appointments per year; National Schedule of Reference Costs, 2008)

Although the police costs are reported by the DfT, they are reported per fatal, serious and slight accident, rather than casualty. However, taking the average number of fatal, serious and slight casualties that contribute to a fatal, serious and slight accident (from RCGB (2008b)), it was possible to calculate a weighted average of the police costs associated with a fatal, serious and slight casualty. These were calculated from the DfT values (2009) and uprated to June 2009 costs assuming a nominal gross domestic product percentage growth as above. The medical and police service costs for the CUA are shown in Table 4.

4.11.4. CBA societal costs

For the CBA, the broad societal costs of casualties of different severity were taken directly from the DfT's *Transport Analysis Guidance (TAG) Unit 3.4.1* document (2009). These costs account for the total value of production lost due to the injury (including lost future earnings and days of work), as well as medical and support costs and the human costs of preventing an injury. These costs account for a lifetime of loss, but in the CBA, as is convention in the DfT, all costs are assumed to occur at the time of the injury. Costs are uprated to 2009 costs and given in Table 4.

4.11.5. Utilities (CUA only)

Age-group specific utilities were obtained from UK Population Norms for the EQ-5D quality of life instrument (Kind et al. 1999). Using data from Nyman et al (2008), a percentage decrement in utility of 4% of the age-specific utilities for serious permanent casualties is assumed for a lifetime. This is based on Nyman et al observing a 0.04 QALY decrement due to permanent injury (compared with full health of one QALY). A loss of 2.38% of the age-specific utilities for serious short-term and 1.46% for slight casualties is assumed in the base case for the year of injury only (again based on Nyman et al's data).

4.12. Sensitivity analyses

Since there is little evidence to inform some of the parameters in this model, it is vitally important that sensitivity analyses are undertaken. One-way deterministic sensitivity analyses (where the value of just one parameter is changed) and probabilistic sensitivity analyses (where parameter values are changed simultaneously) were carried out and their findings are reported by intervention type in Section 5. Deterministic sensitivity analyses allow investigation of the impact of a particular parameter, by changing only one parameter at a time. PSA allows the total uncertainty in the model parameters, characterised in distributions, to be propagated through the model, where results can be interpreted in light of the overall uncertainty in the model's numerical inputs.

4.12.1. Deterministic sensitivity analyses

Simple deterministic sensitivity analysis were undertaken to assess the impact of particular assumptions on the results of the model. These include:

- 5 and 20 year effective lifetimes for each intervention
- 1% and 15% of serious casualties being permanently disabled
- No background reduction in casualties
- 0% discount rates for costs and benefits

- 3.5% discount rate for costs and 1.5% discount rate for benefits
- No QALY loss for slight or serious short-term casualties
- Changing effectiveness of the intervention where evidence is inconsistent
- £500 and £2000 annual maintenance costs for the intervention
- £400 and £2000 annual care costs for permanently disabled serious casualties

4.12.2. Probabilistic sensitivity analyses

Probabilistic sensitivity analyses were undertaken to investigate the joint uncertainty in the model parameter values. Parameter uncertainty was propagated through the base case economic model using Model Carlo simulation (5000 samples). The distributions used and their parameter values are given in Tables in the Appendix. Where there is no evidence available regarding the uncertainty of model parameters, +/- 30% of the mean values are assumed.

5. Results

5.1. Mixed priority routes

5.1.1. Base case and probabilistic sensitivity analysis results

The base case and PSA mean results for an effective lifetime of 10 years for the mixed priority routes scheme are given in Table 7, for the CBA and the CUA. The net present value (NPV) is reported in the CBA, while the incremental cost-effectiveness ratio (ICER), the incremental cost (IC) and the incremental benefit (IB) are presented for the CUA. For the PSA, the mean estimate (and standard deviation) are reported from 5000 simulations. As can be seen from the base case results, both the CUA and CBA suggest that mixed priority routes (indicated by the Norwich mixed priority routes scheme) are not particularly cost-effective with an ICER of £304,823 and a NPV of -£207,073. The first year rate of return is 14%, and the NPV is still negative at 20 years of the intervention. The base case incremental cost of mixed priority routes comprises the total cost of the intervention over 10 years (£2,666,520) minus the medical costs saved (£135,945) minus the police costs saved (£18,925).

Table 7. Mixed priority routes CBA and CUA base case and PSA mean results, £ per km of road

	Cost-Benefit	Cost-Utility		
	NPV	**ICER in £/QALY**	**Incremental Cost**	**Incremental Benefit in QALYs**
Base case	-207,073	304,823	2,511,650	8.24
PSA	-222,345 (1,258,476)	369,996 (186,734)	2,490,681 (795,253)	7.55 (2.48)

Please note that numbers in brackets are standard deviations

The PSA results, which incorporate uncertainty in all of the parameter estimates, suggest that mixed priority routes my be even less cost-effective with an average ICER greater than that from the deterministic base case analysis and an average NPV lower than that from the base case analysis. Moreover, the PSA results in Table 7 show very large standard deviations, indicating a great deal of uncertainty surrounding these estimates, particularly for the NPV.

5.1.2. Deterministic sensitivity analysis results

A number of one-way deterministic sensitivity analyses were undertaken to assess the impact of certain assumptions on the cost-effectiveness of mixed priority routes. A particular assumption was of the effectiveness of the intervention. As mentioned in Section 0, there was some inconsistency between the effectiveness of the three mixed priority route schemes from Norwich, Crewe and Manchester, with an effectiveness of 60% observed in the Norwich study, although 30% was used in the base case analysis.

In Figure 2, the results from the CUA for different levels of effectiveness of the mixed priority routes are shown. As would be expected, as the effectiveness of the intervention increases, the cost per QALY (i.e. ICER) decreases, so that if an effectiveness of 60% from the Norwich study is assumed the cost per QALY is just less than £160,000. A similar analysis with the NPV from the CBA is presented in

Figure 3 showing a linear relationship between effectiveness and NPV. An assumed effectiveness of 60%, leads to a NPV which exceeds £2.5million, indicating a highly cost-effective scheme.

Figure 2. Cost per QALY for different levels of effectiveness of mixed priority routes

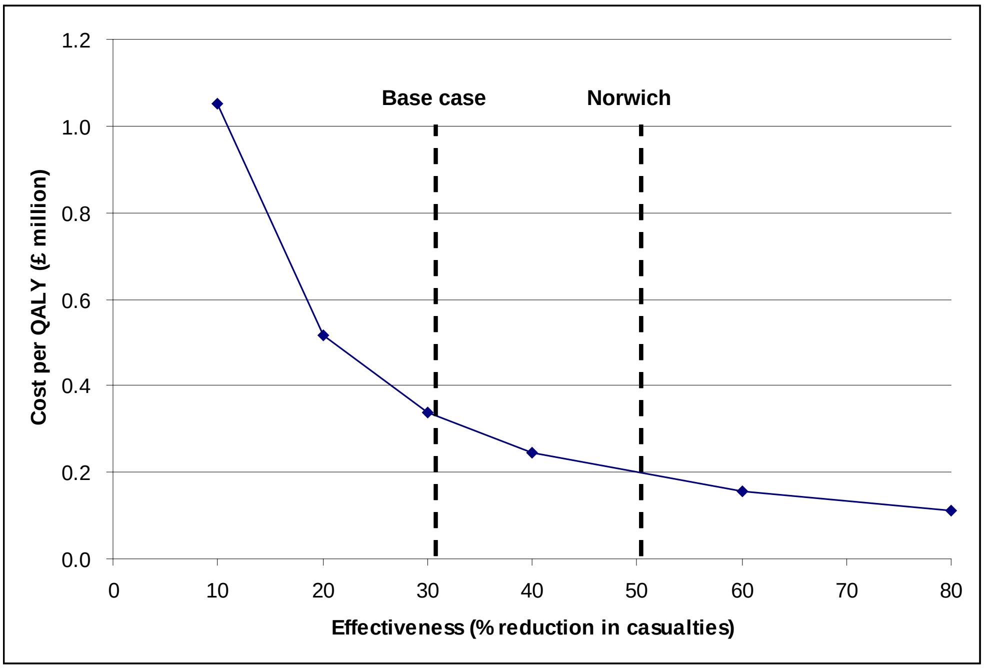
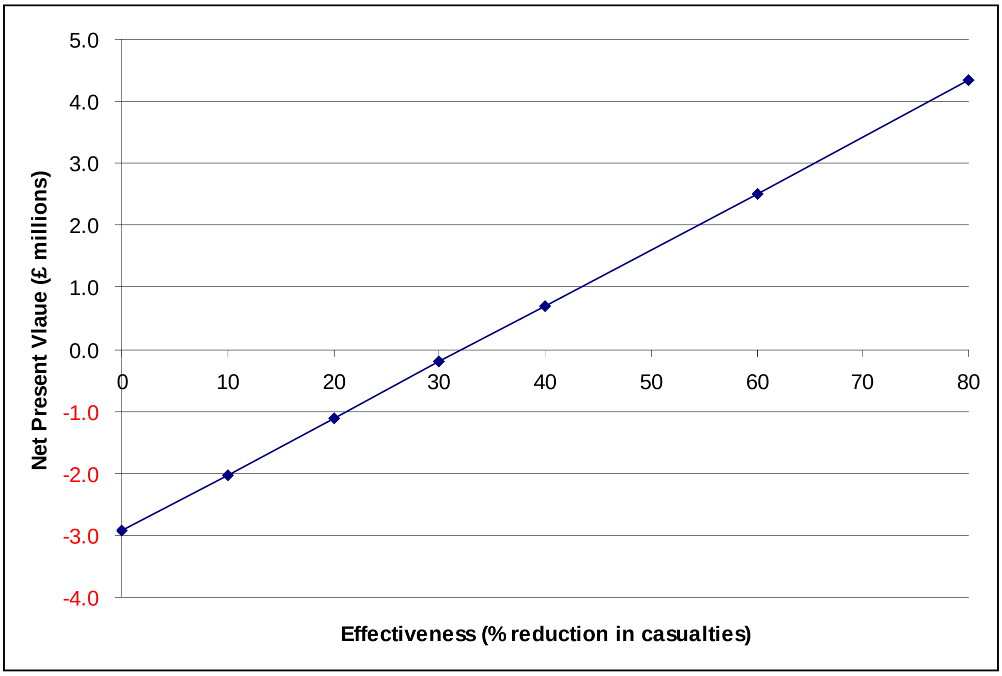


Figure 3. Net Present Value for differing levels of effectiveness of mixed priority routes



The results of further sensitivity analyses in the CUA and CBA are presented in Table 8. As noted in Section 4.1.1, the number of casualties in the comparator area and the cost of the intervention were taken from the Norwich mixed priority routes scheme. If these values are assumed to come from the Crewe scheme, where the annual number of casualties in the ‘before’ study period was relatively low, the mixed priority routes scheme has an ICER of £606,071 (twice that of the base case) and a NPV of -£1,370,373 (a difference of more than a £1 million compared to the base case), suggesting mixed priority route schemes are not cost-effective in low casualty areas. On the other hand, taking data from the Manchester scheme where a larger annual number of casualties were observed in the ‘before’ study period, the results suggest that the mixed priority routes scheme costs much less per QALY gained (£182,640 compared to the base case ICER of £304,823) and the NPV is £1.5 million.

Extending the assumed effective lifetime of the mixed priority routes scheme leads to a greater number of benefits being accrued with only the additional costs of annual maintenance; therefore from the CBA and CUA viewpoint, the mixed priority routes scheme is more cost-effective with an intervention’s effective lifetime of 20 years compared to 5 and 10 years (see Table 8).

Based on data from Hopkin and Simpson (1995), 2% of serious casualties were assumed to be permanently injured. Increasing this to 15% of serious casualties being permanent and disabling injuries leads to a larger number of QALYs saved and lower medical costs (due to higher savings) associated with the mixed priority routes scheme. An ICER of £285,945, which is lower than the base case ICER of £304,823, is obtained. The ICER associated with 1% of serious casualties being permanent is similar to the base case.

The assumption of a background reduction in casualties is based on data from Grundy et al (2008). If no background reduction is assumed, the NPV and ICER change a great deal, so that a large positive NPV (£608,445) and a much lower ICER of £248,817 are obtained compared to the base case.

Table 8. Deterministic sensitivity analyses for mixed priority routes, £ per km road

	Cost-Benefit		Cost-utility	
	NPV	**ICER**	**Incremental Cost**	**Incremental Benefit, QALYs**
BASE CASE ANALYSIS	-207,073	304,823	2,511,650	8.24
Low casualty area and costs (Crewe)	-1,370,373	606,071	2,330,457	3.85
High casualty area and costs (Manchester)	1,500,103	182,640	2,508,164	13.73
5 year effective lifetime	-1,234,601	536,205	2,721,439	5.08
20 year effective lifetime	808,714	192,720	2,193,343	11.38
1% serious permanent	-207,073	307,111	2,518,323	8.20
15% serious permanent	-207,073	285,945	2,503,465	8.76
No background reduction	608,445	248,817	2,460,141	9.89
£400 annual care cost	-207,073	304,990	2,513,026	8.24
£2000 annual care cost	-207,073	304,545	2,509,357	8.24
£500 annual maintenance cost	-203,269	304,318	2,507,483	8.24
£2000 annual maintenance cost	-214,680	305,835	2,519,984	8.24
0% discounting for costs and benefits	175,477	162,096	2,918,984	18.01
3.5% discounting for costs and 1.5% discounting for benefits	-207,073	203,242	2,511,650	12.36
No QALY loss for slight or short-term casualty	-207,073	336,323	2,511,650	7.47

The assumed annual cost of care for serious permanently injured casualties has little impact on the ICER. An assumption of £400 or £2000 leads to a difference in the incremental cost of £1,874. In terms of the ICERs, assuming £400 or £2000 makes very little difference.

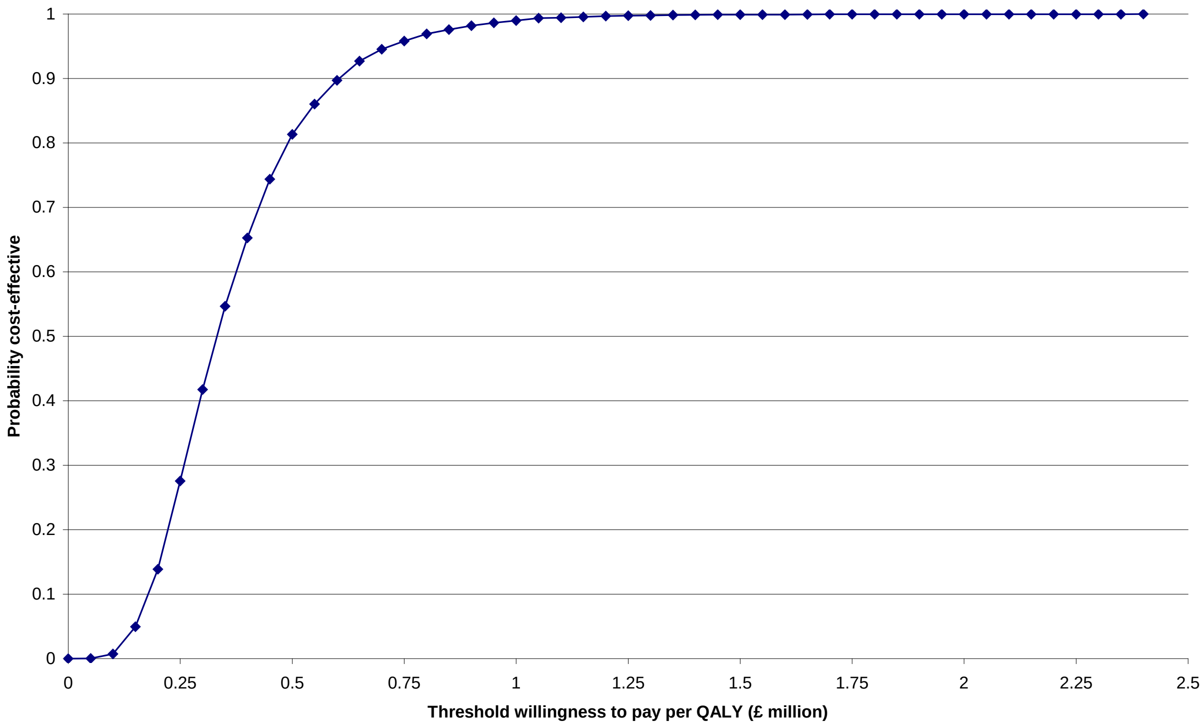
Assuming annual maintenance costs for mixed priority routes of £500 or £2000 leads to a change in the net present value of £11,411 (Table 8) with the lower maintenance cost being more favourable, Interestingly, differences in the maintenance costs assumptions has less impact in the CUA.

Assuming no QALYS are lost from slight or short-term serious casualties leads to an incremental benefit of 7.47 QALYs compared to 8.24 in the base case analysis and so produces a slightly larger ICER (Table 8).

5.1.3. Cost-effectiveness acceptability curve (CEAC)

Figure 4 is a CEAC summarising the 5,000 simulations undertaken in the PSA (the average estimates and standard deviations are presented above in Table 7). From this figure it is possible to ‘read-off’ the probability that mixed priority routes scheme (under the base case assumptions) is cost-effective for a given cost per QALY. For instance, at a willingness-to-pay threshold for a QALY of £200,000 the probability that mixed priority routes would be cost-effective, on the basis of the estimated health gains produced, would be only around 14%

Figure 4. Cost-effectiveness acceptability curve for mixed priority routes



5.2. Mandatory 20 mph zones

5.2.1. Base case and probabilistic sensitivity analysis results

Table 9 shows that the mandatory 20 mph zones are more cost-effective in the high casualty areas (here defined as >1 (=1.658) casualties per km per year) than in the low casualty areas (defined as <1 (=0.625) casualties per km per year), as found with the mixed priority routes interventions.

Table 9. Base case and PSA results of mandatory 20 mph zones, £ per km

	Cost-Benefit	Cost-Utility		
	NPV	**ICER in £/QALY**	**Incremental Cost**	**Incremental Benefit, QALYs**
Low casualty area				
Base case	-25,480	457,762	66,943	0.15
PSA	-25,526 (25,596)	511,299 (182,482)	66,596 (18,292)	0.14 (0.03)
High casualty area				
Base case	90,625	89,700	62,708	0.70
PSA	91,106 (58,288)	93,409 (34,925)	62,595 (18,906)	0.70 (0.14)

Please note that numbers in brackets are standard deviations

The base case CBA suggest that after an effectiveness lifetime of 10 years, the mandatory 20 mph zones are not cost-effective in low casualty areas having a NPV of -£25,480, but are highly cost-effective in high casualty areas (NPV = £90,625). In terms of the CUA, the ICER for the low casualty area is much larger than that for the high casualty area, indicating mandatory 20 mph zones are more likely to be seen as cost-effective in areas of high casualty. Estimated from our CBA, the first year rate of return is 11% for low casualty areas and 36% for high casualty areas, and by the fourth year the NPV >0 for high casualty areas but in low casualty areas the NPV is still negative at 20 years of the scheme. As with the mixed priority routes scheme, the PSA results for mandatory 20 mph zones suggest a great deal of uncertainty in the results.

For the CUA, the base case incremental costs for the mandatory 20 mph zones comprise the total costs of the intervention, minus medical and police costs. These are detailed in Table 10.

Table 10. Incremental costs of mandatory 20 mph zones

	Total incremental costs of intervention (£)	Medical costs saved (£)	Police costs saved (£)	Incremental cost (£)
Low casualty area	69,741	2,502	296	66,943
High casualty area	70,291	6,779	804	62,708

5.2.2. Deterministic sensitivity analysis results

The results of the deterministic sensitivity analyses for mandatory 20 mph zones are shown in Table 11. The different assumptions lead to similar impacts as those seen with the mixed priority routes.

An assumption of 20 years effective lifetime of mandatory 20 mph zones leads to more QALYs being saved by the intervention, and therefore lower ICERs compared to the base case, while a 5 year effective intervention life results in even fewer QALYs and larger ICERs calculated.

Interestingly, the increase in the number of QALYs saved by increasing the percentage of serious casualties to 15% is not very great for either of the prior casualty levels, and the resulting ICER for the high casualty area is £85,454 compared to £89,700 for the base case.

Assuming no background reduction also results to a more cost-effective interpretation of the intervention in both low and high casualty areas (an ICER of £376,258 for low casualty and £72,021 for high casualty). This is as expected since without a background reduction, the intervention prevents more casualties so is more cost-effective.

As seen with mixed priority routes, different assumptions of annual medical costs for serious permanent casualties has little impact on the ICER.

However, the annual maintenance costs do seem to affect the results, with greater maintenance costs leading to a less cost-effective intervention (ICER of £101,621 and a NPV of £83,017 for high casualty areas).

With lower discounting of benefits compared with costs the intervention would be judged as more cost-effective than in the base case, and with zero discounting it would be even more cost-effective.

If no QALYs are assumed to be lost for any slight or serious short-term casualties, the incremental benefit for low and high casualty areas are 0.67 and 0.13, compared to 0.7 and 0.15, respectively. Since the incremental costs remain the same, the ICERs are slightly larger than with the base case: £498,901 compared to a base case of £457,762 for low casualty areas and £94,004 compared to a base case of £89,700 for high casualty areas.

Table 11. Deterministic sensitivity analysis results for mandatory 20 mph zones

	Low casualty area				High casualty area			
	Cost-Benefit	**Cost-Utility**			**Cost-Benefit**	**Cost-Utility**		
	NPV (£)	**ICER (£)**	**IC (£)**	**IB**	**NPV (£)**	**ICER (£)**	**IC (£)**	**IB**
5 year effective lifetime	-40,285	745,177	67,124	0.09	30,944	150,303	64,649	0.43
20 year effective lifetime	-13,153	334,291	67,525	0.20	149,092	63,754	64,684	0.97
1% serious permanent	-25,480	461,311	67,082	0.15	90,625	90,534	63,087	0.70
15% serious permanent	-25,480	425,423	66,773	0.16	90,625	85,454	62,243	0.73
No background reduction	-10,328	376,258	65,993	0.18	137,884	72,021	60,133	0.83
£400 annual care cost	-25,480	457,958	66,972	0.15	90,625	89,812	62,786	0.70
£2000 annual care cost	-25,480	457,436	66,896	0.15	90,625	89,512	62,578	0.70
£500 annual maintenance cost	-21,676	429,269	62,777	0.15	94,428	83,740	58,541	0.70
£2000 annual maintenance cost	-33,088	514,748	75,277	0.15	83,017	101,621	71,042	0.70
0% discounting for costs and benefits	-19,890	242,616	77,999	0.32	112,844	46,659	73,092	1.57
3.5% discounting for costs and 1.5% discounting for benefits	-21,694	304,157	66,943	0.22	103,423	58,926	62,708	1.06
No QALY loss for slight or short-term casualty	-25,480	498,901	66,943	0.13	90,625	94,004	62,708	0.67

IC = Incremental cost; IC = Incremental benefit

5.2.3. Cost-effectiveness acceptability curve (CEAC)

The CEAC for low casualty areas is given in Figure 5 and the CEAC for high casualty areas is in Figure 6. As the base case and sensitivity analyses have revealed, the probability of mandatory 20 mph zones being cost-effective depends on the prior levels of casualties in the area. At a threshold willingness to pay of £200,000, mandatory 20 mph zones have a probability of 0.99 of being cost-effective in areas of high casualty (Figure 6), but a probability of less than 0.1 in areas of low casualty.

Figure 5. Cost-effectiveness acceptability curve for mandatory 20 mph zones in low casualty areas

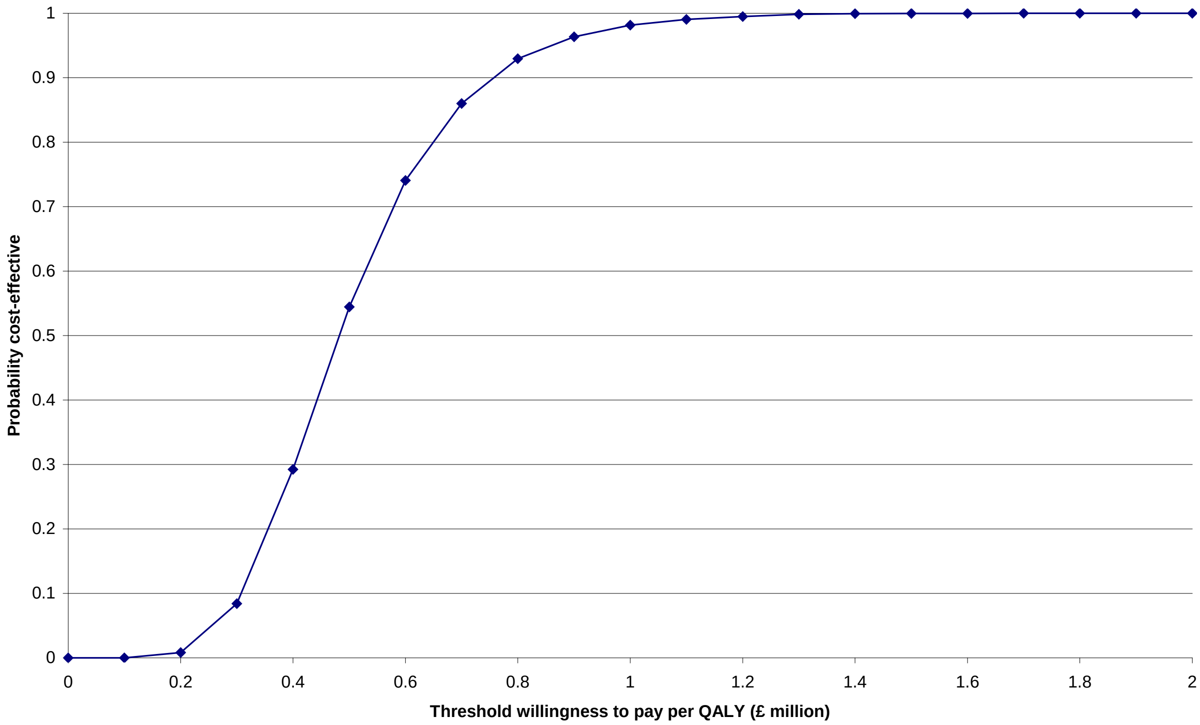
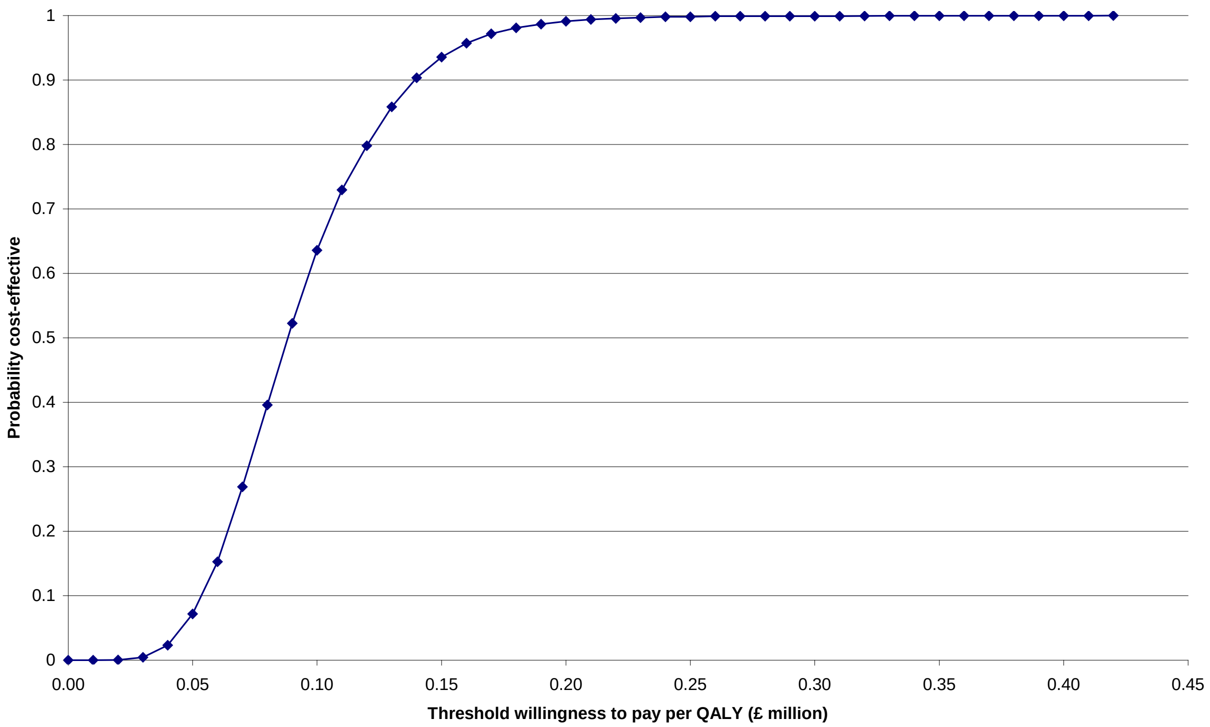


Figure 6. Cost-effectiveness acceptability curve for mandatory 20 mph zones in high casualty areas



5.3. Advisory 20 mph zones vs. no intervention

5.3.1. Base case and probabilistic sensitivity analysis results

The base case results are given in Table 12 for 10 years of the intervention, and suggest that advisory 20 mph zones are highly cost-effective compared to no intervention. Compared to no intervention, 20 years after the installation of the advisory 20 mph zones, the cost per QALY is around £20,000 from the CUA and the NPV is £62,744 from the CBA. The base case incremental cost of advisory 20 mph zones compared to mandatory 20 mph zones comprises the total incremental cost of the intervention over 10 years (£4,686) minus the medical costs saved (£1,852) minus the police costs saved (£258). The estimated first year rate of return is 190%, meaning that the NPV > 0 after the first year.

Table 12. Base case and PSA results of advisory 20 mph zones, £ per km of road

	Cost-Benefit	Cost-Utility		
	NPV	**ICER, in £/QALY**	**Incremental Cost**	**Incremental Benefit, QALYs**
Base case	32,354	22,952	2,577	0.11
PSA	32,073 (11,896)	25,996 (12,445)	2,591 (1,095)	0.10 (0.02)

Please note that numbers in brackets are standard deviations

5.3.2. Deterministic sensitivity analysis results

An important variable in the evaluation of the cost-effectiveness of advisory 20 mph zones is the effectiveness of the intervention. The assumed effectiveness of advisory 20 mph zones for the base case analysis is a 58% reduction in casulaties. In this section lower estimates of effectiveness are assumed and their impact on the cost-effectiveness assessed. The impact on the ICER from the CUA of assuming different levels of effectiveness is shown in

Figure 7 and the changes in the NPV for the CBA are shown in **Figure 8**.

Figure 7. Cost per QALY for differing levels of effectiveness of advisory 20 mph zones

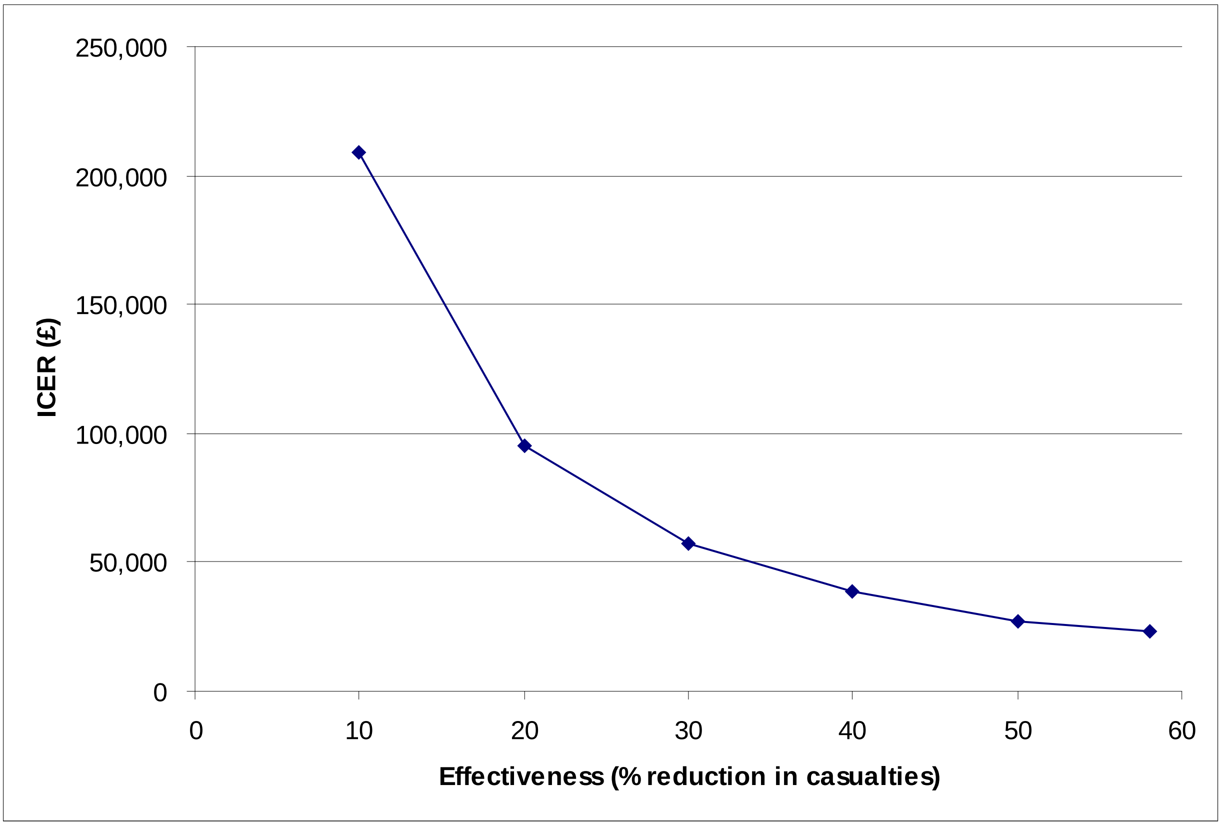
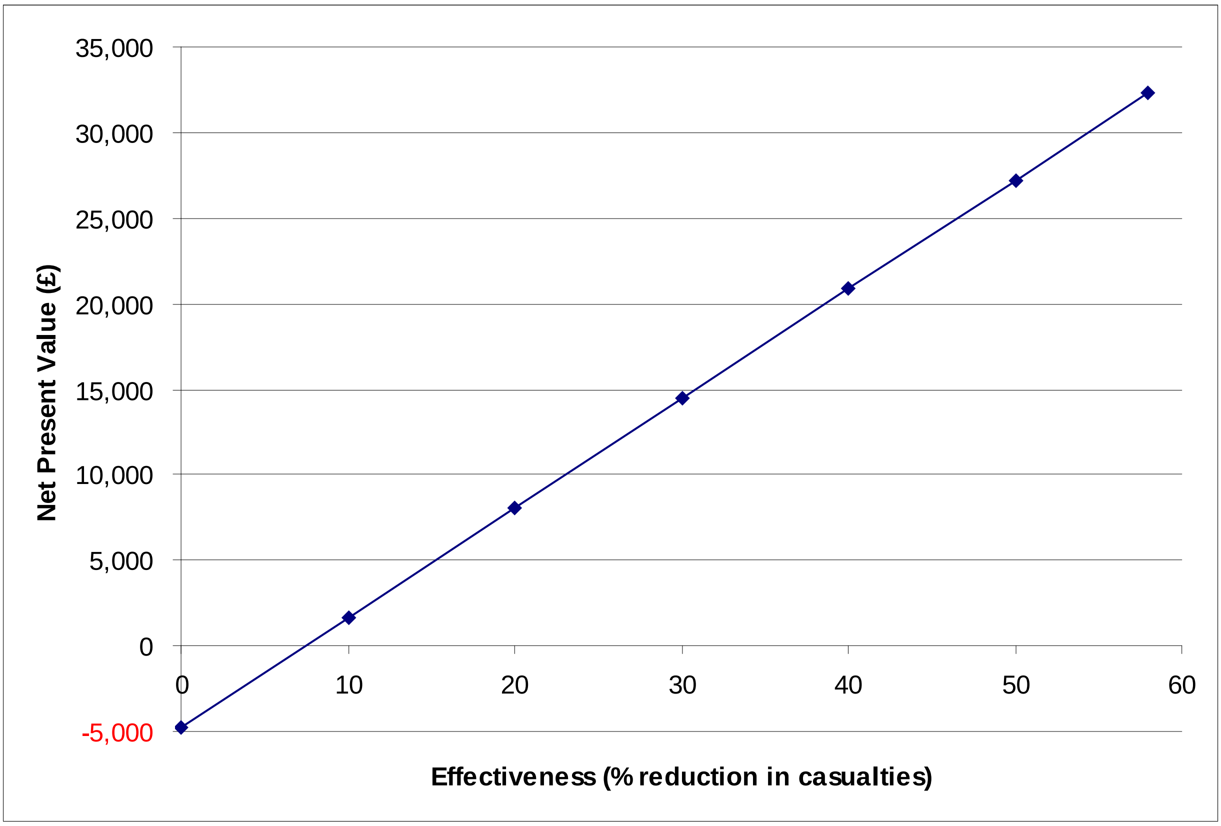


Figure 8. Net Present Value for differing levels of effectiveness of advisory 20 mph zones



As expected the ICER decreases and the NPV increases with increasing effectiveness. Even if only 10% effectiveness is assumed with advisory 20 mph zones, the CBA results suggest they would still have a positive NPV compared with no intervention.

The results of further one-way deterministic sensitivity analyses are presented in Table 13.

Table 13. Deterministic sensitivity analyses for advisory 20 mph zones

	Cost-Benefit		Cost-Utility	
	NPV	**ICER, in £**	**Incremental Cost**	**Incremental Benefit, QALYs**
BASE CASE ANALYSIS	32,354	22,952	2,577	0.11
5 year effective lifetime	19,259	34,864	2,411	0.07
20 year effective lifetime	44,791	22,565	3,499	0.16
1% serious permanent	32,354	23,877	2,667	0.11
15% serious permanent	32,354	20,666	2,465	0.12
No background reduction	43,464	11,944	1,723	0.14
£400 annual care cost	32,354	21,845	2,606	0.12
£2000 annual care cost	32,354	18,702	2,231	0.12
0% discounting for costs and benefits	37,246	10,210	2,670	0.26
3.5% discounting for costs and 1.5% discounting for benefits	35,189	15,304	2,577	0.17
No QALY loss for slight or short-term casualty	32,354	25,324	2,577	0.1

Again, extending the effective lifetime of the intervention or having no background reduction in casualties leads to more favourable cost-effectiveness results.

For the CUA, increasing the number of permanent serious casualties reduces the incremental costs while slightly increasing the incremental benefits, which leads to a lower ICER than in the base case. Changing the annual care costs has a small impact on the incremental cost, leading to a lower ICER where care costs are greater (since more care costs are saved with the intervention than with no intervention).

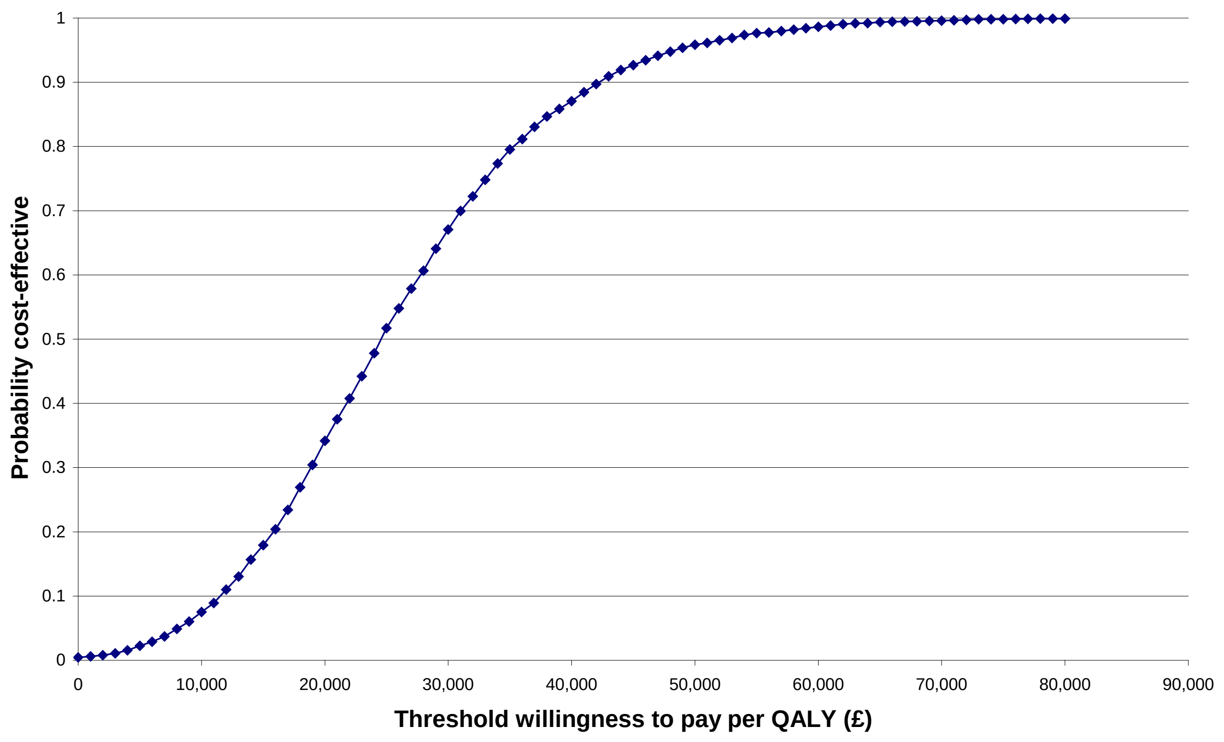
Zero discounting leads to much more cost-effective results, while differential discounting leads to more favourable results than the base case.

For scenarios with an effectiveness of 58% reduction in casulaties, advisory 20 mph zones versus no intervention have an ICER < £25,000 and positive NPV, except when the effective life of the intervention is reduced to 5 years.

5.3.3. Cost-effectiveness acceptability curve

Since this intervention is so highly cost-effective, at a cost per QALY of £5000 there is a 0.99 probability that advisory 20 mph zones are cost-effective (see Figure 9).

Figure 9. Cost-effectiveness acceptability curve for advisory 20 mph zones compared to no intervention



5.4. Advisory 20 mph zones vs. mandatory 20 mph zones

5.4.1. Base case and probabilistic sensitivity analysis results

Compared to mandatory 20 mph zones in areas of high casualty (where the mandatory 20 mph zones are most cost-effective), advisory zones are still highly cost-effective. Summaries from the base case and PSA (mean and standard deviation) CUA and CBA are shown in Table 14. In the CUA, the incremental cost of advisory 20 mph zones over mandatory 20 mph zones is negative (indicating advisory 20 mph zones cost less), and with a positive incremental benefit gained the resulting ICER is negative indicating that advisory 20 mph zones dominate mandatory 20 mph zones. The base case incremental cost of advisory 20 mph zones compared to mandatory 20 mph zones comprises the total incremental cost of the intervention over 10 years (-£65,604) minus the medical costs saved (£9,161) minus the police costs saved (£1,220). The PSA demonstrates a great deal of uncertainty in the incremental benefits of advisory over mandatory 20 mph zones: a mean of 0.07 with a standard deviation of 0.14. This uncertainty is reflected in the standard deviation for the ICER which is £25 million per QALY.

Table 14. Base case and PSA results of advisory vs. mandatory 20 mph zones, £ per km

	Cost-Benefit	Cost-Utility		
	NET PRESENT VALUE (£)	**ICER (£/QALY)**	**Incremental Cost**	**Incremental Benefit (QALY)**
Base case	204,332	-1,025,101	-75,985	0.07
PSA	202,679 (83,785)	-197,629 (25,863,256)	-75,757 (19,252)	0.07 (0.14)

Please note that numbers in brackets are standard deviations

5.4.2. Deterministic sensitivity analysis results

As with the comparison between advisory 20 mph zones and no intervention, changing levels of effectiveness of the advisory 20 mph zones are assessed. The NPV for different levels of effectiveness are seen in Figure 10, where increasing effectiveness leads to increasing NPV.

The impact that different levels of effectiveness of the advisory 20 mph zones have on the ICER can be seen in Figure 11. This figure requires some explanation. For the smaller percentage reductions (10% - 40%), the mandatory 20 mph zones outperform the advisory 20 mph zones, leading to negative incremental benefits, but as the cost of advisory 20 mph zones is less than the mandatory zones, the incremental cost is also negative and so a positive ICER is obtained. At 50% effectiveness, the mandatory zones are only just better than the advisory zones leading to a small negative incremental benefit, which is why the peak is observed at this point. Then, at 58% effectiveness (the base case), the incremental benefit is positive, but the incremental cost is negative leading to the negative ICER observed.

This graph reinforces the cautions that should be made with regard to comparing these two interventions. It is counterintuitive that advisory speed limits (without traffic calming measures) would be more effective than mandatory speed limits with physical traffic calming measures (such as speed humps). Therefore, the ICERs for the casualty reductions in advisory speed limit zones of 10% to 40% might be more reliable than the base case analysis in this instance.

Figure 10. Net present value with changing effectiveness of advisory 20 mph zones compared to mandatory 20 mph zones

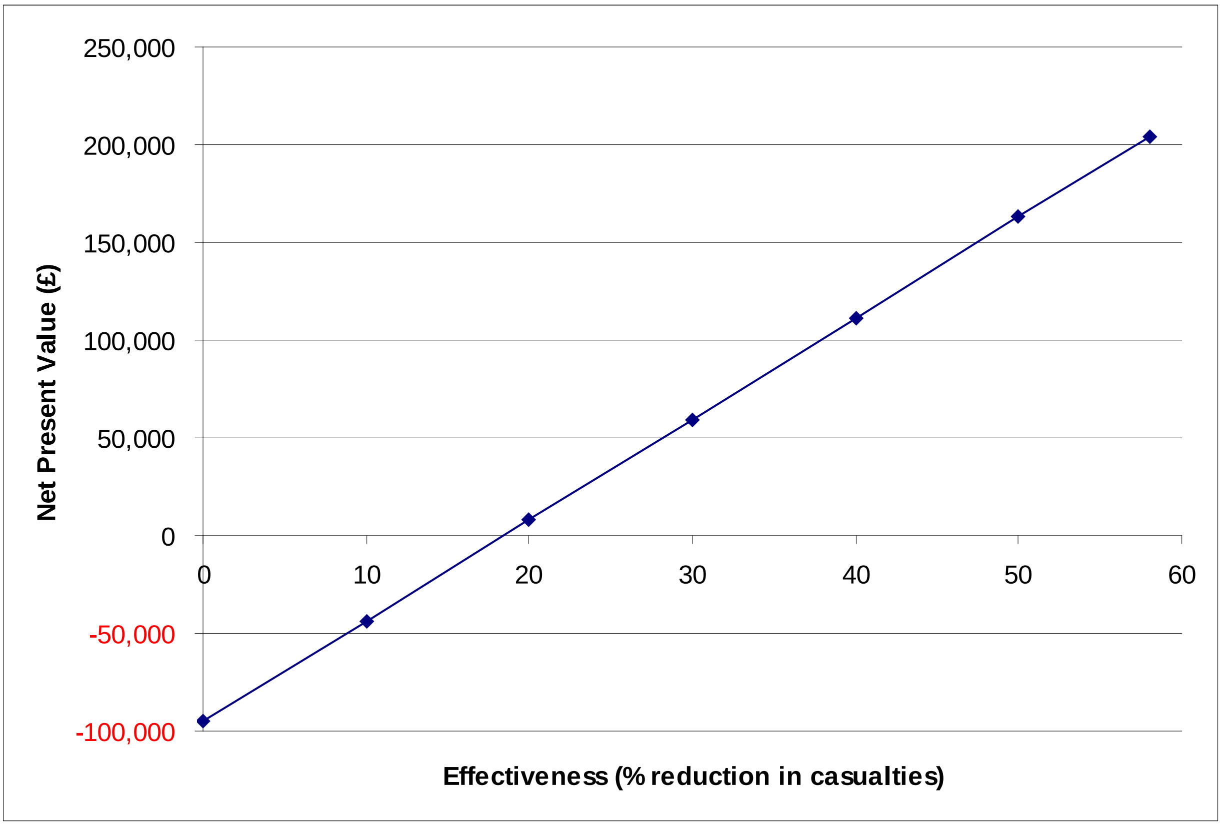
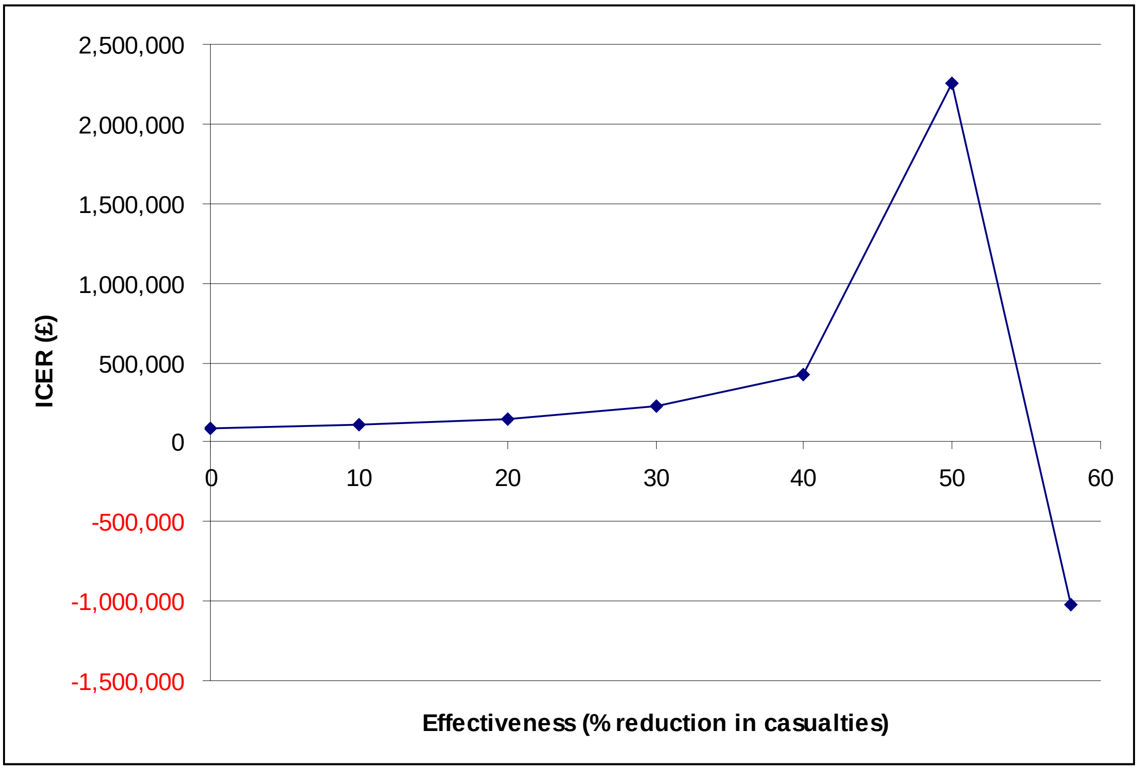


Figure 11. Cost per QALY with changing effectiveness of advisory 20 mph zones compared to mandatory 20 mph zones



The results of sensitivity analyses for advisory versus mandatory 20 mph zones (in high casualty areas) are shown in Table 15. The impact of differing assumptions on the comparison of advisory versus mandatory 20 mph zones is similar to those seen in the previous comparison. Importantly, regardless of the assumptions made, the NPV is positive and the ICER is negative, indicating that the advisory 20 mph zones dominate the mandatory 20 mph zones.

Table 15. Results of sensitivity analyses of advisory vs. mandatory 20 mph zones, £ per km

	Cost-Benefit	Cost-Utility		
	NPV	**ICER, £ per QALY**	**Incremental Cost**	**Incremental Benefit**
BASE CASE ANALYSIS	204,332	-1,025,101	-75,985	0.07
5 year effective life	152,253	-1,558,602	-72,355	0.05
20 year effective life	254,446	-790,897	-79,285	0.10
1% serious permanent	204,332	-1,057,928	-75,526	0.07
15% serious permanent	204,332	-697,962	-76,542	0.11
No background reduction	249,688	-839,358	-79,457	0.09
£400 annual care cost	204,332	-1,023,820	-75,890	0.07
£2000 annual care cost	204,332	-1,027,235	-76,143	0.07
£500 annual maintenance cost	200,528	-968,887	-71,818	0.07
£2000 annual maintenance cost	211,940	-1,137,528	-84,319	0.07
0% discounting for costs and benefits	223,807	-795,277	-88,389	0.11
3.5% discounting for costs and 1.5% discounting for benefits	204,332	-839,253	-75,985	0.09
No QALY loss for slight or short-term casualty	204,332	-3,275,454	-75,985	0.02

5.4.3. Cost-effectiveness acceptability curve

Since the advisory 20 mph zones are so highly cost-effective compared to the mandatory 20 mph zones in areas of high casualty, the probability that the advisory 20 mph zones are cost-effective at a threshold willingness to pay per QALY of £0 is 1. Therefore no CEAC is shown for this comparison as it would consist of a straight line at the probability of one for all threshold costs per QALY.

6. Discussion

6.1. Main findings

The results of this economic evaluation suggest that advisory 20 mph zones are a highly cost-effective use of resources for the prevention of unintentional injuries in the road, whether compared to no intervention or to mandatory 20 mph zones, with base case ICERs <£24,000 and NPV >£30,000. However, caution is required in interpreting these results, particularly those which compare the advisory with the mandatory 20mph zones. This is because of the different legal definitions of these interventions (between Scotland and England), and the related likelihood that they were sited in areas with different prior accident, pedestrian flow and vehicle speed characteristics.

Mandatory 20 mph zones were found to be much more cost-effective in areas with high levels of casualties (~1.6 per year per km), with a base case ICER £89,700 compared to when implemented in low casualty areas (ICER: £457,762). Similarly, mixed priority routes were more cost-effective in areas of high casualty, but were still very expensive and would not be cost-effective according to the decision criteria normally applied by NICE to health technologies (ICER: £182,640).

The PSA results indicated a great deal of uncertainty particularly for mixed priority routes and advisory 20 mph zones, where less evidence-based data were available than for the mandatory 20 mph zones. Deterministic sensitivity analyses identified a number of parameters that were important to all interventions: the number casualties in the comparator area, effectiveness of the intervention, the background reduction in casualties and the effective lifetime of the intervention.

6.2. Limitations of the modelling

Many of the assumptions used in the modelling are based on limited data and so conclusions about the overall cost-effectiveness of interventions must be made with full acknowledgement of these limitations; the analyses should therefore be regarded as exploratory. This also hinders any extrapolation of the results beyond the setting of the main sources of effectiveness and cost information: mandatory 20 mph zones in London, advisory 20 mph zones in Scotland, and mixed priority routes in Norwich, Manchester and Crewe. As discussed in Report 1, this reflects the recurrent issue in transport/road safety evaluations, that interventions are usually inherently multi-component, can be implemented at different scales and levels of intensity, and at sites which have been chosen in a variety of ways (and therefore have different pre-existing levels of vehicle speeds, pedestrian flows and road accidents etc.).

However, the lack of data for informing parameter values has been investigated, to some extent, in the sensitivity analysis results. The following discussion concerns these parameters and their use in light of the lack of data. As noted above, the effectiveness of the intervention is one of the most important parameters in the model. However, for the mixed priority routes scheme, in particular, there was inconsistency in the effectiveness of the schemes even among the three schemes where cost and effectiveness data were available. When effectiveness of 50%, as reported in the Norwich scheme, was used in the model the scheme was found to be highly cost-effective from the CBA, with a much reduced ICER from the CUA than when 30% was assumed (closer to the reduction seen in Manchester). A review of the remaining mixed priority routes schemes on the DfT website indicates a range of effectiveness (casualty reductions) from 24% (in Kingston-upon-Hull) to 60% (Norwich) (Norfolk County Council & JE Jacobs 2008;WSP Development and Transportation 2008). However, there are many differences between these schemes and since cost data were only available for Norwich, Manchester and Crewe it is difficult to generalise the cost-effectiveness of mixed priority route schemes beyond the assumptions made in this economic model from these three studies. Of the analyses conducted here, the mixed priority route schemes were also those where injury reduction was one of a wide range of the schemes' objectives (reduced congestion, more pleasant street environment); so the cost-utility analyses could be regarded as having adopted an inappropriate perspective given the broad aims of these schemes.

The effective life of the intervention is also an important parameter in the model, with a longer scheme life leading to more cost-effective results: as time progresses more casualties are prevented with the only extra expenditure being the maintenance costs. There are complications with this parameter as different interventions are likely to have different effective lifetimes, but there is currently little data on which to inform this parameter.

An assumption which had a great deal of influence on the cost-effectiveness results is the assumption of a background reduction in casualties. The data used in the base case were from Grundy et al (ref) which formed the basis for the economic evaluation of the mandatory 20 mph zones. Grundy et al calculated this trend from areas of London where 20 mph zones were not installed, and so these data are entirely relevant for the evaluation of mandatory 20 mph zones. However, their relevance to the mixed priority routes and advisory 20 mph zone interventions is less certain. Although up to three years of 'before' data were available from the mixed priority routes, the resulting estimates for a background trend were so variable as to be uninformative. Obtaining national data on the reduction in casualties over the years from RCGB was also considered, but was not used since these data may well include reductions in casualties due to interventions, rather than just the background reduction. For these reason, the Grundy data were used for all interventions more to give an indication of the likely impact of such an assumption. Since, this assumption appears to have a large impact on the cost-effectiveness of interventions, further research would be needed to properly inform this parameter for mixed priority routes and advisory 20 mph zones.

Another area where data were limited concerned the proportion of serious casualties that were likely to be permanently injured. Although, changing this value in sensitivity analyses had little impact on the findings, the data used to inform this parameter were collected over 15 years ago from a number of hospitals in Greater Manchester. It is not known how relevant these values are to casualties in 2009 in the UK.

Limited data were also used to inform the QALY decrement associated with different severities of casualties in the CUA, and these data were based on casualties in the US. The assumption of no QALY decrement for slight or short-term serious casualties, not surprisingly, lead to fewer QALYs being saved and a slightly lower ICER observed.

Areas where the lack of data inhibited the use of evidence-based parameters are the annual medical care costs for permanently injured casualties and the excess maintenance costs for mixed priority routes and mandatory 20 mph zones. With respect to the annual medical care costs, sensitivity analyses suggested that the results were not particularly sensitivity to this parameter. This is no doubt due in part to the small percentage of casualties to which these costs applied. However, maintenance costs did appear to have some impact on the results, with lower maintenance costs leading to more favourable cost-effectiveness findings. Further research into these costs would be required to inform this parameter.

It is also important to point out that although the cost values used for the prevention of injuries for the CBA and the medical and police costs saved in the CUA came from DfT data, there are limitations with these data. As noted above, there are based on data collected over 15 years ago and although they are uprated each year, it does not appear that these data have on which the calculations are based, have been updated since.

There are concerns that the STATS19 data, on which all the effectiveness studies are based and from which the split of casualty severities is derived, may under-report the levels or severities of casualties (where studies have compared them to hospital and other follow-up data).

A more general limitation of this modelling exercise is that it does not consider health benefits other than those due to casualties saved. For instance, health benefits from increased physical activity due to changing use of roads as a direct result of the road intervention are not considered, and neither is improved health from reductions in air pollution etc.. For a wider (and more fully resourced) evaluation of the effectiveness of road interventions, it would however be appropriate to also consider these potential benefits.

6.3. Strengths of the modelling

As far as the authors are aware, this is the first cost-utility analysis of road design-based interventions of this kind. All other economic evaluations have followed the recommendations from the DfT for cost-benefit analysis of road interventions. In all comparisons, the CBA was more likely to indicate that the intervention was cost-effective than the CUA. For example, in high casualty areas mandatory 20 mph zones were found to be very cost-effective from the CBA with a NPV of £90,625 in the base case. This is compared to an ICER of £89,700 from the CUA. The main differences between the CUA and CBA in this economic model are:

1. How benefits are characterised (health-related only vs societal valuation and savings from casualties avoided)

The CUA measures health benefits in terms of QALYs based on age and utility at the time of the casualty, the severity of the casualty and the length of time the effects from the injury impact on the individual's health. In the CBA, the health benefits are characterised in terms of the cost of casualties saved. These include the costs of medical and support services, lost output (including earnings lost) and willingness to pay calculations for the human costs associated with the prevention of an injury.

2. Time at which benefits are incurred

   In the CUA the benefits of a prevented casualty are accounted for in the year when they are assumed to occur. For instance, for the prevention of a serious permanent casualty, the health benefits (i.e. quality of life losses avoided) occur from the year of the presumed injury and continue until death or until the individual is 95 years of age. On the other hand, as is usual in DfT economic evaluations, the benefits of preventing a casualty in the CBA are all accounted for at the time of the prevention of the casualty, even though those benefits may include lifetime estimations.

3. Time at which intervention (i.e. mainly capital) costs are incurred

   In the CUA, intervention costs are annuitized for the assumed effective life of the intervention (10 years in the base case), and all costs saved due to the prevention of a casualty are accounted for over the individual's lifetime. For the CBA, the total intervention costs are assumed to occur at the first year of the intervention, hence the typical focus on the First Year Rate of Return in DfT literature.

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Appendices

Appendix Table B and C detail the parameter values and distributions used in the probabilistic sensitivity analyses for each intervention. The parameters of the distributions are given by α and β, and differ depending on the distributions used. For each of the distributions used (normal, beta and gamma) α and β are defined in Appendix Table A, where $\bar{x}$ is the mean and υ is the variance.

Appendix Table A. Definitions of α and β for the Normal, Beta and Gamma distributions

Distribution	α	β
Normal(α , β)	$\bar{x}$	υ
Beta(α , β)	$\bar{x}\left(\frac{\bar{x}(1-\bar{x})}{\upsilon}-1\right)$	$(1-\bar{x})\left(\frac{\bar{x}(1-\bar{x})}{\upsilon}-1\right)$
Gamma(α , β)	$\frac{\bar{x}^2}{\upsilon}$	$\frac{\upsilon}{\bar{x}}$

Appendix Table B. Parameter values and distributions used in all probabilistic sensitivity analyses

Model parameter	Distribution used	Severity of casualty/ Age of casualty	α	β	Justification
Background reduction in casualties	Normal – truncated at zero	Fatal	0.043	0.014	Means and standard errors from Grundy et al (2008)
		Serious permanent	0.079	0.035	
		Serious short-term	0.079	0.035	
		Slight	0.062	0.030	
Full age-specific health utility	Beta	Under 25 yrs	1118.29	71.38	Means and standard errors from Kind et al (1999)
		25-34	2025.24	152.44	
		35-44	1632.32	161.44	
		45-54	845.34	149.18	
		55-64	915.65	228.91	
		65-74	956.46	272.31	
		Over 74 yrs	619.01	228.95	
Utility loss	Beta	Serious permanent	10.63	255.04	Mean from Nyman et al (2008), standard error assumed to be 30% of mean
		Serious short-term	10.82	443.92	
		Slight	10.93	737.99	

Model parameter	Distribution used	Severity of casualty/ Age of casualty	α	β	Justification
Costs attributed to lives saved (CBA only)	Gamma	Fatal	11.11	153943.12	Means from DfT (Department for Transport 2009), standard error assumed to be 30% of mean
		Serious	11.11	17403.27	
		Slight	11.11	1341.75	
Medical costs (CUA only)	Gamma	Fatal	11.11	91.14	Means calculated from DfT (Department for Transport 2009), standard error assumed to be 30% of mean
		Serious permanent	11.11	10235.06	
		Serious short-term	11.11	1038.35	
		Slight	11.11	92.08	
Police costs (CUA only)	Gamma	Fatal	11.11	87.64	Means calculated from DfT (Department for Transport 2009), standard error assumed to be 30% of mean
		Serious permanent	11.11	32.90	
		Serious short-term	11.11	32.90	
		Slight	11.11	23.29	

Appendix Table C. Parameter values and distributions for effectiveness and costs for the probabilistic sensitivity analysis

	Distribution used	Severity of casualty/ Age of casualty	α	β	Justification
Mixed priority routes					
Number of casualties in comparator area	Normal – truncated at zero	Fatal	0.21	0.06	Based on data from (Cheshire County Council & JE Jacobs 2008), standard error assumed to be 30% of mean
		Serious permanent	0.06	0.02	
		Serious short-term	3.09	0.93	
		Slight	26.64	7.99	
Percentage reduction in casualties due to intervention	beta	All severities	7.48	17.45	Based on data from (Cheshire County Council & JE Jacobs 2008) and (Manchester City Council & JE Jacobs 2008), standard error assumed to be 30% of mean
Annuitized intervention costs	Gamma		11.11	27793.39	Based on data from (Cheshire County Council & JE Jacobs 2008), standard error assumed to be 30% of mean
Maintenance costs	Gamma		11.11	90	Based on mean assumption of £1000,

	Distribution used	Severity of casualty/ Age of casualty	α	β	Justification
					standard error assumed to be 30% of mean
Mandatory 20 mph zones (low casualty area)					
Number of casualties in comparator area	Normal – truncated at zero	Fatal	0.002	0.001	From Grundy et al (2008)
		Serious permanent	0.002	0.001	
		Serious short-term	0.074	0.022	
		Slight	0.547	0.164	
Percentage reduction in casualties due to intervention	beta	Fatal	0.565	0.200	From Grundy et al (2008)
		Serious permanent	0.262	0.060	
		Serious short-term	0.262	0.060	
		Slight	0.217	0.040	
Annuitized intervention costs	Gamma		11.11	642.061	From Grundy et al (2008)
Maintenance costs	Gamma		11.11	90	Based on mean assumption of £1000, standard error assumed to be 30% of mean

	Distribution used	Severity of casualty/ Age of casualty	α	β	Justification
Mandatory 20 mph zones (high casualty area)					
Number of casualties in comparator area	Normal – truncated at zero	Fatal	0.01	0.003	From Grundy et al (2008)
		Serious permanent	0.004	0.001	
		Serious short-term	0.201	0.060	
		Slight	1.443	0.433	
Percentage reduction in casualties due to intervention	beta	Fatal	0.565	0.200	From Grundy et al (2008)
		Serious permanent	0.262	0.060	
		Serious short-term	0.262	0.060	
		Slight	0.217	0.040	
Annuitized intervention costs	Gamma		11.11	647.811	From Grundy et al (2008)
Maintenance costs			11.11	90	Based on mean assumption of £1000, standard error assumed to be 30% of mean

	Distribution used	Severity of casualty/ Age of casualty	α	β	Justification
Advisory 20 mph zones					
Number of casualties in comparator area	Normal – truncated at zero	Fatal	0.001	0.001	From Burns et al (2001), standard error assumed to be 30% of mean
		Serious permanent	0.001	0.001	
		Serious short-term	0.022	0.006	
		Slight	0.188	0.056	
Percentage reduction in casualties due to intervention	beta	All severities	0.580	0.174	From Burns et al (2001), standard error assumed to be 30% of mean
Annuitized intervention costs	Gamma		11.11	27.80	From Burns et al (2001), standard error assumed to be 30% of mean
Maintenance costs			11.11	21.90	From Burns et al (2001), standard error assumed to be 30% of mean