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The development of road and rail transport safety valuation in the United Kingdom

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A B S T R A C T

An extensive body of theoretical and empirical work has been undertaken in the UK since the middle of the last century on the estimation of values of safety for use in the appraisal of proposed transport projects, particularly road and rail. This research has focused largely on 'willingness-to-pay' based values in order to measure the strength of the travelling public's preference for marginal improvements in transport safety, relative to consumption of other goods and services. In terms of practical policy making, the research has resulted in a set of values for the prevention of statistical fatalities and non-fatal injuries that are applied not only in transport safety decision making, but also in other public sector contexts. This paper summarises the main findings of this research.

1. Introduction

Research aimed at estimating monetary values of safety for use in UK transport project appraisal was first undertaken in the 1940s and 1950s – see Jones (1946) and Reynolds (1956). While Jones based his estimates principally on court awards and therefore included at least a notional allowance for pain and suffering, Reynolds focused exclusively on the direct cost of road accidents in the form of lost output, physical damage and medical and administrative costs. In particular, Reynolds made no attempt to place a value on the avoidance of pain, grief and suffering on the grounds that '... it is beyond the competence of economists to assign objective values to [such] losses ...' Output losses in the case of fatalities were assessed on a *net* basis (as they are today), that is as the loss of the discounted present value of the potential victim's future output net of the present value of his/her future consumption. Reynolds estimated the average cost per casualty as follows in 1952 prices (with figures in brackets at 2011 prices[1]):

Fatal injury £2000 (£40,930)
Serious injury £520 (£10,640)
Slight injury £40 (£820)

In the process of updating his estimates for the UK Road Research Laboratory in the late 1960s and early 1970s, Dawson introduced two amendments to the definition of the cost of road casualties and hence the valuation of their prevention. First, in Dawson (1967) it was argued that since society sustains those who are past retirement age it clearly values their continued survival. So, in order to ensure that a positive value was accorded to the continued survival of all age and gender groups under the net output approach, a minimum level of £5000 was treated as the best available approximation to the subjective cost of pain, grief and suffering associated with a fatal injury. Second, in Dawson (1971) it was argued that since continued consumption constitutes one of the benefits of survival, future consumption should *not* be deducted from future output and that the value of preventing a fatality should therefore include the loss of *gross* output, not just net output. With the subjective cost of pain, grief and suffering updated to £5270 for a fatality, Dawson's estimates of the average cost per road injury and fatality were as follows in 1970 prices (with figures in brackets at 2011 prices):

Fatal injury £16,750 (£187,100)
Serious injury £1130 (£12,620)
Slight injury £203 (£2270)

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[1] Updating to 2011 prices has been carried out on the basis of the UK GDP deflator and therefore reflects only the impact of inflation. By contrast, as noted in the main text, the UK Department of Transport uprates its values of safety on an annual basis to reflect both inflation and the growth of real GDP per capita.

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Throughout the 1970s and early 1980s Dawson's estimates were regularly updated in line with growth in real output per capita and inflation, though two significant real terms increases in these gross output-based costs were also implemented in the late 1970s. The first of these involved a 50% increase in the pain, grief and suffering allowance, in 1978. This followed the recommendation of the Advisory Committee on Trunk Road Assessment chaired by Sir George Leitch (see Leitch, 1977). The second substantial increase occurred in 1979 as a result of revisions, described later below, to the procedure used to calculate the gross output component of the road casualty costs.

However, during the 1960s a number of authors had expressed concern that the gross output approach failed to accommodate the fundamental ethical precept of social cost–benefit analysis which requires that values used in public sector project appraisal should reflect the preferences – and more particularly, the *strength* of preference – of those members of society who will be affected by the allocative decision concerned – see, for example, Drèze (1962), Schelling (1968), Jones-Lee (1969) and Mishan (1971). More specifically, given that most people value safety principally because of their aversion to the prospect of death and injury *per se*, rather than a desire to preserve current and future output, there is a clear case to be made in favour of defining and estimating values of safety in such a way as to reflect the rate at which people are prepared to trade off safety against other desirable goods and services. Clearly, an individual's maximum willingness to pay for safety provides a clear indication of the rate at which he or she is prepared to make this trade-off. Under what has naturally come to be referred to as the 'willingness-to-pay' (WTP) approach, the value of a safety improvement is therefore defined as the aggregate (possibly with distributional weights applied) of the amounts that affected individuals would be willing to pay for the safety improvement concerned.

This led to the concept of the prevention of a 'statistical' fatality (or non-fatal injury). Thus, consider a safety improvement that will reduce the risk of death in a road accident during the coming year by 1 in 100,000 for each member of a group of 100,000 people. While the actual number of deaths prevented could be 0, 1, 2, or more, the *mathematical expectation* of deaths prevented (i.e. mean value of the probability distribution) would be a 'statistical fatality' of precisely 1. Now suppose that individuals within the affected group would, on average, be prepared to pay £20 for the safety improvement. The value of preventing a statistical fatality – now more succinctly referred to as the 'value of preventing a fatality' (VPF)[2] – would then be set at £20 $\times$ 100,000 = £2 million.

Notice that an individual's willingness to pay for a small reduction in the risk of death is effectively equal to his/her *marginal rate of substitution (MRS)* of wealth for risk of death (i.e. the rate at which the individual is willing to trade off wealth against reduction in the risk of death at the margin) multiplied by the risk reduction. Now consider a large group of n individuals each enjoying a $1/n$ reduction in the risk of death during the forthcoming period, thereby preventing one statistical fatality. Each individual's willingness to pay would then be given by his/her MRS multiplied by the risk reduction $1/n$. Aggregate willingness to pay would therefore be equal to the individual amounts, MRS $\times$ $1/n$, summed across the n members of the group, which is, by definition, equal to the *arithmetic mean* of MRS for the affected group. It therefore follows that the VPF – defined as aggregate willingness to pay – can equivalently be expressed as the mean MRS for the affected group of individuals – see, for example, Jones-Lee (1989). In the example just developed, this mean MRS would be estimated as £20/10^{-5}, which is of course again equal to £2 million.

By the early 1970s it was clear that within the Department of Transport (DoT)[3] and the Department of the Environment there was fairly widespread agreement that, at least in principle, the gross output approach to the valuation of safety should be replaced by the WTP approach – see, for example, Harrison (1974) and Mooney (1977). This view was no doubt reinforced by further exploratory theoretical and empirical work carried out in the UK on the conceptual and quantitative foundations of the WTP approach – see, for example Jones-Lee (1974, 1976) and Melinek (1974). It was therefore not surprising that in 1977 the Leitch Committee concluded that:

> *'...the general principles of cost-benefit analysis...would suggest that the Department [of Transport] should aim to find the amount that an average individual would be willing to pay (or would require in compensation) for a reduction (increase) of (correctly perceived) risk of sustaining an accident.'* (Leitch, 1977).

However, given the very limited nature of the empirical evidence concerning the level at which WTP-based values of safety should be set, as noted above, the DoT continued to employ gross output-based values throughout the 1970s.

2. Willingness-to-pay based values of road safety[4]

Following publication of the Leitch Committee Report and extensive discussion and correspondence with one of the authors, in 1980 the UK Department of Transport decided to explore the possibility of obtaining empirical estimates of WTP-based values of safety for use in road project appraisal in the UK. However, some members of the DoT Steering Group were rather sceptical about the ability of members of the public to comprehend adequately the basic wealth-risk tradeoffs that underpin WTP-based values of safety. It was therefore decided that it would be necessary to use a 'contingent valuation', stated-preference approach carried out on a face-to-face basis rather than a revealed-preference approach which, given the relative paucity of observable data concerning wealth-risk tradeoffs in other contexts, would almost inevitably have involved focussing on labour market wage/risk tradeoffs. In particular, a stated-preference study carried out on a face-to-face basis would allow interviewers to form a judgement concerning the quality of respondents' understanding of the questions being asked and the care with which their answers were thought-out. In addition, interviewers would be in a position to clarify any difficulties that respondents might have with the wording of the questions.

Other factors that it was felt weighed in favour of the stated-preference as opposed to the revealed-preference approach were that a) it could, in principle, provide information concerning individual willingness to trade off wealth against risk of death or injury for a nationally-representative sample, whereas a labour market wage/risk study could at best provide only information concerning market equilibrium trade off rates; b) the labour market approach is based on the somewhat questionable assumption that workers are well-informed about job risks and that market forces rather than union pressure are the main determinants of wage rates; c)

[2] In the US this is typically referred to as the 'Value of Statistical Life'(VSL), but the two terms are synonymous.

[3] While this was the name and acronym of the Department until 1997, from 1997 to 2001 it was absorbed into the Department for the Environment, Transport and the Regions (DETR) and then, in 2001, into the Department for Transport, Local Government and the Regions (DTLR). Since 2002 it has been the Department for Transport (DfT).

[4] The material in this section draws extensively on work undertaken by the authors, among others, for the UK Department for Transport, recorded in Spackman et al. (2011).

the revealed-preference approach inevitably requires that researchers confront the difficult task of disentangling wage/risk trade off rates from the many other factors that are likely to influence wage rates and d) since the revealed-preference approach is typically based on labour market data it is inherently incapable of providing any information concerning the rates at which those employed in 'safe' occupations or those not in paid employment (such as housewives/husbands) are willing to trade off wealth or income against the risk of death or injury. Finally, there would not appear to be any persuasive *a priori* grounds for assuming that preference-based values of safety derived from labour market data are necessarily transferrable to the transport context.

The DoT decided that before any attempt was made to carry out a nationally representative sample survey, it would be essential to conduct an extensive pilot study. This pilot would a) test the quality of the public's understanding of risk-related concepts and b) develop the questions to be included in the main study. In fact the findings of the pilot study (carried out in Newcastle during 1980 on a sample of 120 respondents) were rather encouraging – see Hammerton, Jones-Lee, and Abbott (1982). They indicated that respondents were, on the whole, comfortable with the general idea of placing a monetary value on safety, were capable of dealing with probability concepts and were broadly consistent in their responses to questions involving probabilities. In addition – with the possible exception of a question concerning willingness to pay for a local road safety improvement which would affect all of the residents of the area concerned and was therefore essentially a public good – respondents appeared to provide answers that were a genuine reflection of their true preferences. In general terms, therefore, the various different types of validity criteria (i.e. content and context validity etc) appeared to have been adequately met.

2.1. The 1982 study[5]

Given the generally encouraging nature of the 1980 pilot study's findings, the DoT decided to proceed to the main study which involved a nationally representative sample survey carried out in June and July 1982 by NOP Market Research Ltd. with face-to-face interviews, using a questionnaire designed by Jones-Lee and Hammerton with advisory input from the DoT Project Steering Group. In the event, the study produced a useable sample of 1103 completed questionnaires.

While the survey presented respondents with a variety of questions, two were directly aimed at providing the basis for estimating a WTP-based VPF for road safety. The first of these concerned the additional amount that the respondent would be willing to pay in excess of the standard fare (already funded by, say, his/her employer) in order to travel by a safer coach service on a foreign journey a) in order to enjoy a reduction of 4 in 100,000 of being killed in a fatal coach accident and b) for a 7 in 100,000 reduction, the 'baseline' risk on the standard coach facility being 8 in 100,000. The second question concerned the amount that the respondent would be willing to pay for a car safety feature that would reduce his/her annual risk of being killed in a road accident from the (then) UK average baseline risk of 10 in 100,000 a) by 2 in 100,000 per annum and b) by 5 in 100,000 per annum.

With seven outliers from the first question and two from the second question trimmed out (all of these outliers having been judged to be most probably the result of interviewer coding errors), the mean and median marginal rates of substitution of wealth for risk of death implied by the responses were as shown in Table 1.

[5] For a detailed account of this study, see Jones-Lee, Hammerton, and Philips (1985).

Table 1
Marginal rates of substitution of wealth for risk of death (1982 prices).

	Mean	Median
Coach fare question		
4 in 100,000 risk reduction	£1,600,00	£1,240,000
7 in 100,000 risk reduction	£1,390,000	£720,000
Car safety feature question		
2 in 100,000 risk reduction	£2,210,000	£770,000
5 in 100,000 risk reduction	£1,210,000	£500,000

These figures, augmented by about £30,000 (in 1982 prices) for avoided loss of net output and other direct costs – which a majority of respondents had indicated they had not taken account of in their responses to the WTP questions – these results therefore pointed clearly in the direction of a substantial upward revision to the DoT's gross output-based VPF which, in 1982 prices, was about £140,000 (DoT, 1983). However, while the DoT had clearly been persuaded that it should, in principle, replace its gross output approach to the valuation of safety with WTP-based values, it was unable to reach agreement concerning the precise figures to adopt. This appears to have been at least partly because some members of the Project Steering Group remained rather sceptical about the reliability of the 1982 study's findings. Following extensive discussion, correspondence and debate over a protracted period, in 1987 the DoT finally decided to commission one of its economists, M. Q. Dalvi, to review the work that had been undertaken to date (principally in the UK and USA) on the empirical estimation of WTP-based values of safety and suggest how the results of this work should be interpreted. The review was published as the Dalvi Report (Dalvi, 1988).

Arguably, one of the most disturbing features of the findings of the 1982 study was that, setting aside zero responses, over one third of the sample had indicated the *same* willingness to pay for the two different sizes of risk reduction (i.e. had demonstrated zero scope-sensitivity) in both of the safety valuation questions. This clearly added to the concern that had been expressed from the outset by some members of the Project Steering Group about the reliability and general validity of the stated-preference approach and it no doubt reinforced the recommendation in the Dalvi Report that, while the DoT should replace its gross output figure with a WTP-based VPF, the value should be set at the very bottom end of the range of estimates obtained in the 1982 study. In particular, Dalvi argued that "… the available evidence suggests that Jones-Lee et al's median value may be taken as a working basis for valuing fatality costs …". However the main reason given in the Dalvi Report for taking the low end of the range was concern about the substantial change that would in any case be imposed on the balance between the valuation of time savings and safety improvement in the DoT's (and local authorities') cost–benefit analysis. There was therefore a case for moderating the rate of introduction of such a change.

Thus, while Dalvi acknowledged that the median results from the 1982 study (augmented to include an allowance of about £30,000 for avoided loss of net output and other direct economic costs) pointed towards a VPF in the region of £800,000, which Dalvi uprated to £890,000 in 1985 prices,[6] he nonetheless recommended that the roads VPF should be set at £500,000 in 1987 prices. Essentially, Dalvi's reason for recommending the more conservative

[6] Although his report was published in 1988, Dalvi explicitly states that the VPF figure of £890,000 is in 1985 prices – see Dalvi (1988), p34. If he had in fact updated the 1982 figure of £800,000 to 1987 prices, then this would have given a VPF closer to £1 million, which makes Dalvi's recommendation of a VPF of £500,000 in 1987 prices seem even more conservative.

figure of £500,000 was that adoption of a value as high as £890,000 "… would probably change the present relationship between time savings and accident benefits … and would relatively downgrade the priority given to faster traffic movement and congestion benefits as opposed to safety of life and limb." (Dalvi, 1988, p34).

In the event, the DoT adopted the more conservative figure recommended by Dalvi and in 1988 set the VPF at £500,000 in 1987 prices – see DoT (1988) – though it should be noted that this still constituted an increase of more than 175% (in nominal terms, but not much less in real terms) in the DoT's most recent gross output-based VPF of £180,330 in 1985 prices.[7]

The figure of £500,000 was equivalent to £1,015,000 in 2011 prices.

As in the case of its earlier gross output-based figures, the DoT then uprated its values of safety on an annual basis in line with growth in real output per capita and inflation, and continues to do so, using an assumed income elasticity for the VPF of unity.

2.2. The 1991 non-fatal injuries study[8]

Having decided to abandon the Gross Output approach as the basis for defining and estimating the roads VPF and replace it with the Willingness to Pay (WTP) approach, the DoT recognised the importance of applying a similar revision to the valuation of non-fatal road injuries, and in 1989 the Department commissioned a programme of research to estimate WTP-based values for the prevention of statistical non-fatal road injuries.

Non-fatal road injuries classified as 'Serious' by the DoT ranged from those involving no overnight stay in hospital and full recovery within 3–4 months, through to paraplegia/quadriplegia and serious, permanent brain damage. It was therefore necessary to establish a breakdown of these injuries into different classes of severity, together with their associated probabilities of occurrence. It was decided that, from a practical point of view, it would be most feasible to work with only a relatively limited number of descriptions of different severities of injury and their implications (e.g. in terms of pain, hospitalisation and long term prognosis), about which respondents in a stated-preference study might be expected to be able to express meaningful preferences. As a result, with the advice and assistance of Professor Charles Galasko and his research team in the Department of Orthopaedic Surgery at the University of Manchester, the DoT's Serious Non-Fatal injury category was broken down into eight different classes of severity. Showcards providing a brief description of each category were then prepared for presentation to respondents in the stated-preference study. These showcards, together with their randomly allocated injury codes, were as shown in Fig. 1.

In addition, the average annual probabilities of suffering the injuries were estimated to be as shown in Table 2.

After extensive piloting, it was decided to conduct the main study on the basis of two subsamples. Both would be presented with a common set of questions that required the respondents to rank and 'score' the injuries (together with 'normal health' and 'death') on a scale from 0 to 100 in terms of 'badness', together with two 'risk-test' questions designed to test the respondent's understanding of basic risk concepts. The first subsample would then be presented with contingent valuation (CV) questions concerning their willingness to pay for reductions in the risk of the non-fatal injuries. However the second subsample would be asked 'standard gamble' (SG) questions aimed at establishing the 'indifference probability' at which the respondent would be indifferent between a) suffering the prognosis of the injury concerned and b) undergoing an alternative treatment which, if successful, would result in an immediate cure, but if it failed would result in death. If the respondent's marginal rate of substitution of wealth for risk of the injury is denoted by m_I and the corresponding MRS of wealth for risk of death by m_D, then under standard economic assumptions the ratio m_I/m_D is given by the indifference probability of treatment failure – see Jones-Lee, Loomes, O'Reilly, and Philips (1993).

To constrain the CV and SG interviews to manageable length, it was decided to focus on injuries R, S, X and W and to interpolate values/indifference probabilities for the remaining injuries L, N, V and F from responses to the ranking and scaling questions. Respondents who answered the CV version of the questionnaire were asked about willingness to pay for a risk reduction of 4 in 100,000 during the coming year for each of injuries K (immediate death) and R, as well as a risk reduction of 12 in 100,000 during the coming year for each of injuries X and W. In order to test for scope sensitivity, respondents were also asked about willingness to pay for each of the two different risk reductions (4 in 100,000 and 12 in 100,000) for injury S.

The nationally representative sample was drawn from England, Scotland and Wales by the Office of Population Censuses and Surveys (OPCS) and interviews were conducted on a face-to-face basis by a team of 42 professional Transport Research Laboratory (TRL) interviewers, each of whom had participated in a one-day briefing session and – following four practice interviews – a half-day debriefing session, in order to familiarise themselves with the nature of the questions to be asked and the underlying risk concepts. In the event, the CV and SG versions of the questionnaires were administered by each interviewer on an alternating basis, yielding 414 completed CV questionnaires and 409 completed SG versions.

The ranking, scaling and 'risk-test' question responses were very similar across both sub-samples. The risk-test question responses, in particular, indicated that a substantial majority of the respondents had a satisfactory understanding of the basic risk concepts.

In both the CV and SG questionnaires respondents were presented with a list of possible answers. For the CV questions this was '£0, £1, £2………………£300, £400, £500, more than £500' and for the SG questions the list of possible 'chances of success' ranged from 99 in 100 down to 10 in 100 with corresponding 'chances of failure' ranging from 1 in 100 up to 90 in 100; also included was a possible 'less than 1 in 100' response for chances of failure. CV respondents were then asked to put a tick against sums they definitely would pay, a cross against amounts that they definitely would *not* pay and, finally, an asterisk against the amount at which they would find it most difficult to decide. SG respondents were similarly asked to put a tick against chances of success at which they definitely would undertake medical treatment, a cross against the chances of success at which they would definitely *not* undertake the treatment and an asterisk against the chance of success at which they would find it most difficult to decide. This allowed an upper and lower bound, as well as a 'best estimate', to be associated with each response.

Mean and median marginal rates of substitution of wealth for risk of the injury concerned, computed from the CV responses (in 1991 prices), and mean and median m_I/m_D ratios implied by the SG responses, all based on the asterisked 'best estimate' figures, were as shown in Table 3.

On close inspection, the most notable feature of these results is the relatively limited sensitivity to injury severity in the CV results. For example, the mean estimates of m_I imply that aggregate willingness to pay for the prevention of six statistical injuries of

[7] However the DoT had already increased the VPF to £252,500 in 1985 prices in order to maintain the relativity between its value of safety and its value of leisure time, following an increase in the latter in March 1987.

[8] For a detailed account of this study, see Jones-Lee, Loomes, and Philips (1995).

J Your normal state of health	**S** **In Hospital** ▪ 1-4 weeks ▪ Moderate to severe pain **After Hospital** ▪ Some pain gradually reducing, but may recur when you take part in some activities ▪ Some restrictions to leisure and possibly some work activities for the rest of your life
F ▪ No overnight stay in hospital – seen as an outpatient **After Effects** ▪ Slight to moderate pain for 2-7 days followed by some pain/discomfort for several weeks ▪ Some restrictions to work and/or leisure activities for several weeks/months ▪ After 3-4 months, return to normal health with no permanent disability	**R** **In Hospital** ▪ Several weeks, possibly several months ▪ Moderate to severe pain **After Hospital** ▪ Continuing pain/discomfort for the rest of your life, possibly requiring frequent medication ▪ Substantial and permanent restrictions to your work and leisure activities – possibly some prominent scarring.
W **In Hospital** ▪ 2-7 days ▪ Slight to moderate pain **After Hospital** ▪ Some pain/discomfort for several weeks ▪ Some restrictions to work and/or leisure activities for several weeks/months ▪ After 3-4 months, return to normal health with no permanent disability	**N** **In Hospital** ▪ Several weeks, possibly several months ▪ Loss of use of legs and possibly other limbs due to paralysis and/or amputation **After Hospital** ▪ Confined to a wheelchair for the rest of your life ▪ Dependent on others for many physical needs, including dressing and toileting.
X **In Hospital** ▪ 1-4 weeks ▪ Slight to moderate pain **After Hospital** ▪ Some pain/discomfort, gradually reducing ▪ Some restrictions to work and leisure activities, steadily improving ▪ After 1-3 years, return to normal health with no permanent disability	**L** **In Hospital** ▪ Several weeks possibly several months ▪ Head injuries resulting in severe permanent brain damage **After Hospital** ▪ Mental and physical abilities greatly reduced for the rest of your life ▪ Dependent on others for many physical needs, including feeding and toileting.
V ▪ No overnight stay in hospital – seen as an outpatient **After Effects** ▪ Moderate to severe pain for 1-4 weeks. Thereafter, some pain gradually reducing, but may recur when you take part in some activities ▪ Some restrictions to leisure and possibly some work activities for the rest of your life.	**K** **Immediate unconsciousness, followed shortly by death.**

Fig. 1. "Galasko" injury/health state showcards.

type W (slight to moderate pain but full recovery after a few months) would be more than the corresponding figure for the prevention of one statistical fatality (Injury K) which is simply not credible: it is evidence of serious scope-insensitivity in responses to the CV questions. This is reinforced by three other findings of the study that are not reported in Table 3, namely: a) the mean WTP for a 12 in 100,000 p.a. reduction in the risk of injury S (moderate to severe pain followed by some permanent disability) was only about 20% larger than the mean response for a 4 in 100,000 reduction; b) of those respondents who viewed death as

Table 2
Injury probabilities.

Injury	Average annual probability
F	8 in 100,000
W	16 in 100,000
X	30 in 100,000
V	4 in 100,000
S	24 in 100,000
R	16 in 100,000
N or L	2 in 100,000

Table 3
"Best estimate" CV and SG responses to the 1991 non-fatal injuries study.

Injury	m_I (£ millions, 1991 prices)		m_I/m_D	
	Mean	Median	Mean	Median
W	0.76	0.33	0.020	0.000
X	0.84	0.42	0.055	0.000
S2[a]	1.03	0.63	0.151	0.050
S1[b]	2.56	1.25	/	/
R	3.51	1.88	0.233	0.150
K	4.25	2.50	/	/

[a] Risk reduction 12 in 100,000 p.a.
[b] Risk reduction 4 in 100,000 p.a.

strictly worse than injury S in the ranking exercise, 26% indicated *precisely the same* WTP for a 4 in 100,000 p.a. reduction in the risk of death as for the same reduction in the risk of injury S; and c) of those who ranked S as strictly worse than X (similar to W but with slower recovery), 37% gave the same WTP responses for the same risk reduction for both, with 40% of those who ranked X as strictly worse than W giving the same WTP responses for the same risk reduction for X as for W.

In marked contrast, the SG responses displayed no obvious scope-insensitivity problems. But the one slightly disturbing feature of the SG results was that, in the case of the less severe non-fatal injuries in particular, the proportion of respondents indicating that they would not undertake the treatment if there were *any* associated incremental risk of death was very substantial, i.e. 75% in the case of injury X; 41% for S and 25% for R. It was essentially for this reason that a 'modified' SG approach (rather than the 'standard' SG approach) was adopted six years later in the 1997 CV/SG 'Chained' Approach Study discussed below in Section 2.4.

Given the clear evidence of serious scope-insensitivity exhibited in the CV study responses, the DoT decided to base its revised estimates of the non-fatal injury values exclusively on the SG study results. Weights were based on the relative probabilities of occurrence of the different severities of non-fatal injury. In light of the findings of the ranking and scaling results injuries L and N were treated as equivalent to death and injury F as equivalent to W. The weighted average WTP component of the value of preventing a statistical serious non-fatal road injury was estimated to be 9.5% of the corresponding component of the roads VPF, giving a figure of about £59,000 in 1990 prices. Given that in order to simplify matters, in both the CV and SG questionnaires respondents had been asked to ignore the direct economic effects of injuries, it was clearly necessary to add a further allowance for avoided output losses as well as medical and ambulance costs. Together with an allowance of approximately £8,500 in 1990 prices for avoided output losses (computed on a gross basis, rather than net of consumption, since the victim of a non-fatal accident continues to consume),as well as some £2500 for avoided medical and ambulance costs (see O'Reilly, 1993), this resulted in an overall WTP-based value for the prevention of a serious non-fatal road injury of roughly £70,000 which was more than three times the DoT's gross output-based figure of £20,160 in 1990 prices – see DoT (1991). In light of these findings, in 1993 the DoT increased the value of preventing a serious non-fatal injury to £74,480 in 1992 prices. Following further more minor adjustments, this figure was then uprated to £84,260 in 1993 prices – see DoT (1993, 1994). Updated to 2011 prices, this figure is equivalent to £125,200.

Turning to injuries classified as 'Slight' by the DoT, these consist principally of minor cuts and bruises from which recovery will typically be complete within a matter of days. However, somewhat paradoxically, whiplash neck injuries are not included in the DoT's 'Serious' category and are therefore classified as being only 'Slight'. Whiplash neck injuries, which in the early 1990s constituted up to 20% of the Slight category, often involve protracted periods of pain and incapacity and were regarded by most respondents in the non-fatal injuries pilot study as being effectively equivalent to serious injuries falling in the category X, as defined above in Fig. 1. Thus, while the preference-based value accorded to the avoidance of minor cuts and bruises (based on answers to a question asking respondents to specify the amount that would 'just make up for' suffering such an injury) amounted to little more than £100, the overall value for the prevention of a slight non-fatal road injury (including whiplash neck injuries) was set at £6080 in 1992 prices and then uprated to £6540 in 1993 prices, which is equivalent to £9720 in 2011 prices.

Overall therefore, given that in 1993 the DoT willingness-to-pay-based roads VPF stood at £744,057, the corresponding WTP-based values for the prevention of serious and slight non-fatal road injuries stood at, respectively, slightly more than 10% and slightly less than 1% of the VPF and continue to do so given that, as with the VPF, these values have been increased annually in line with inflation and the growth of per capita output.

To date, no further work has been commissioned by the DoT on re-estimating the WTP-based values for the prevention of non-fatal road injuries. However, as part of a larger study on the valuation of rail safety carried out in 2007, the Rail Safety and Standards Board (RSSB) commissioned a stated-preference survey to be carried out on the internet, aimed at estimating preference-based values for the prevention of non-fatal rail injuries, including those involving protracted periods of shock and trauma which are apparently a fairly common consequence of being involved in or witnessing rail accidents. But unfortunately the findings of this study raised serious doubts concerning the reliability of responses to an internet-based stated-preference survey, particularly when the questions concerned are of a more complex nature. This is discussed in Section 3.4 below.

2.3. The 1995/96 feasibility study[9]

To ensure consistency in the treatment of safety in public sector decision making, the HSE, DoT, the Home Office and HM Treasury jointly commissioned a programme of research in 1995 to a) update the roads VPF and b) estimate preference-based values of safety in three other contexts – specifically, rail, domestic fires and fires in public places – relative to the roads value. In view of the scope-insensitivity problem encountered in the direct CV component of the 1991 Non-Fatal Injuries Study and the (then) growing evidence of other problems with the stated-preference approach, such as 'embedding' and 'sequencing' effects, it was felt appropriate to carry out extensive piloting to test for such effects and, if possible, assist in the design of question formats that would mitigate their adverse impact on responses.

'Embedding' refers to the tendency for a respondent to report the same willingness to pay for one component of a bundle of goods as for the whole bundle (and, as such, is clearly closely related to scope insensitivity). 'Sequencing' occurs when a respondent's reported willingness to pay for each of a set of different benefits differs when the order in which the valuation question concerning the benefits is altered.

To ensure that respondents had adequate opportunity to comprehend and give careful thought to issues involved in the questions that would be put to them, before the one-to-one main interviews were conducted, respondents participated in preliminary focus-group sessions. These involved 5 or 6 participants. Various safety issues were discussed and participants were introduced to the basic stimuli and concepts that would underpin the individual interviews. Subsequently the one-to-one interviews were followed by feedback meetings (again involving 5 or 6 participants), in which those involved were given the opportunity to comment on the response patterns that had emerged in the individual interviews and to offer further reflections on the thought processes that had underpinned their responses.

However, although respondents had been given ample opportunity to grasp key concepts and give careful thought to their answers, responses to the WTP questions (which concerned two different reductions in the respondent's own personal risk of sustaining a fatal road injury, and reductions in the risk of various

[9] For a detailed account of this study see Beattie et al. (1998).

severities of non-fatal road injury) displayed marked embedding, scope and sequencing effects. It was therefore decided to conduct a second-phase pilot study having the same three-stage form as the first phase study, but with the self-focused personal risk reduction questions replaced by questions concerning the respondent's willingness to pay out of his/her household's budget for a local safety improvement expected to prevent a specified number of fatal and non-fatal road accidents. It was hoped that by framing questions in terms of the prevention of a given number of fatalities and injuries, rather than in terms of personal risk reductions expressed probabilistically, the problems of scope insensitivity, embedding and sequencing effects encountered in the first-phase pilot study would be significantly mitigated. This turned out not to be the case; in fact, the scope insensitivity problem was somewhat exacerbated.

2.4. *The 1997 CV/SG 'chained approach' study*[10]

Following the findings of the 1995/96 Feasibility study it was still agreed by members of the research team and the Project Steering Group that the stated-preference approach was, in principle, markedly preferable to any approach that relied on revealed preferences. However it seemed clear that, if the stated-preference approach was to be maintained, it would be necessary to effect rather radical revisions to the nature of the questions put to respondents.

It was therefore decided that rather than presenting respondents with questions involving a direct trade-off between wealth and risk of death, it would instead be preferable to employ a two-stage 'chained' approach that involved asking:

- First, a pair of 'contingent valuation' (CV) questions about 1) willingness to pay (WTP) for the certainty of a complete cure of a given non-fatal road injury of limited severity, and 2) willingness to accept compensation (WTA) for the *certainty* of suffering that same non-fatal injury.
- Second, a 'modified standard gamble' (MSG) question that effectively requires the respondent to trade off the risk of suffering the same non-fatal injury against risk of death resulting from failure of a treatment to cure the injury.

Assuming that a) the respondent's preferences are coherent and b) his/her utility of wealth functions conditional on normal health and suffering the non-fatal injury are generally well-behaved (i.e. continuous and differentiable), it is possible to infer from the WTP and WTA responses for the certainty of the injury (at least to a reasonable approximation) his/her marginal rate of substitution, m_I, of wealth for risk of suffering the injury.

It is then also possible to infer (again assuming that the respondent's preferences are coherent), from the response to the modified standard gamble question, the ratio, m_D/m_I, where m_D is the individual's marginal rate of substitution of wealth for risk of death as a result of treatment failure.

The estimates of m_I and m_D/m_I for a given individual can then be combined to obtain an estimate of m_D for the person concerned, where the estimation procedure has at no stage required the individual to confront a direct trade-off between wealth and a fractional change in the probability of injury or death. It has instead entailed the arguably rather more comprehensible 'risk–risk' trade-off involved in the decision as to whether or not to undergo a medical treatment.

However, as already noted, the estimation of m_I at the first stage of the chained procedure and the inference of the ratio m_D/m_I at the second stage are both based on the assumption that the individual concerned has essentially well-behaved preferences. To assess the plausibility of this assumption and, more significantly, to gain some feel for the extent to which departure from the assumed properties of underlying preferences might bias the derived estimate of m_D, it is important to be clear about what exactly is being assumed in the CV/SG chained approach.

The three key assumptions underpinning the chained approach are as follows:

1. The individual's utility of wealth function conditional on normal health, U (w), is increasing, strictly concave, continuous and differentiable (i.e. 'smooth' and generally well-behaved).
2. The non-fatal injury under consideration is of sufficiently limited severity to ensure that the marginal utility of wealth is unaffected by the injury. The individual's utility of wealth function conditional on suffering the injury, I (w), can therefore be expressed simply as $I(w) = U(w) - a$, $a > o$, where the constant, a is the anticipated utility loss from suffering the injury. In addition, given the limited severity of the injury, it is assumed that there exists a finite sum that the individual will regard as adequate compensation for suffering the injury.
3. Given that the standard gamble used to estimate the ratio m_D/m_I takes the 'modified' form, involving the choice between two risky situations (rather than between a riskless and a risky situation as in the more common format), and since experimental evidence indicates that Expected Utility Theory (EUT) performs just as well as alternative theories (such as Prospect Theory) in such choices – see, for example, Bleichrodt, Abellan-Perpinan, Pinto-Prades, and Mendez-Marinez (2007) – EUT is the most appropriate tool to use in analysing the responses to the MSG question.

Given these assumptions it follows that the individual's compensating variation, v, for a change, δp, in the risk of suffering the non-fatal injury during the forthcoming period from $\overline{p}$ to $p = \overline{p} + \delta p$ will be such that:

$$U(\overline{w} - v) = U(\overline{w}) + a\delta p \quad (1)$$

where $\overline{w}$ denotes the individual's initial level of wealth and the constant, a, is as defined above.

If v in equation (1) is positive it defines the individual's WTP for a risk reduction δp (< 0). If v is negative it defines his/her WTA for a risk increase δp (> 0). In addition, the value of v for $\delta p = 1$ (i.e. for an increase in risk from $\overline{p} = 0$ to $p = 1$) can be viewed as the individual's WTA as compensation for the certainty of suffering the injury, while the level of v for $\delta p = -1$ (i.e. for a risk reduction from $\overline{p} = 1$ to $p = 0$) is the individual's WTP to eliminate the certainty of suffering the injury.

In equation (1) the relationship between v and δp is uniquely determined by the properties of U (w) and the levels of $\overline{w}$ and a. In particular, given the assumed properties of U (w), the relationship is completely *independent* of $\overline{p}$, the initial level of risk. It then follows from the assumed properties of U (w) that the general form of the relationship between v and δp will be as shown in Fig. 2. Clearly, the domain of the function relating v and δp in any particular case will be restricted to the closed interval $[-\overline{p},\ 1 - \overline{p}]$, $(\overline{p} \leq 1)$.

From Fig. 2 it can be seen that the individual's marginal rate of substitution, m_I, of wealth for risk of suffering the non-fatal injury is equal to the modulus of the gradient of the graph of v versus δp at the origin. This will be strictly *greater* than the modulus of the gradient of the ray OA and strictly *less* than the modulus of the gradient of the ray OD. But the modulus of the gradient of OA is

[10] For a detailed account of this study, see Carthy et al. (1999).

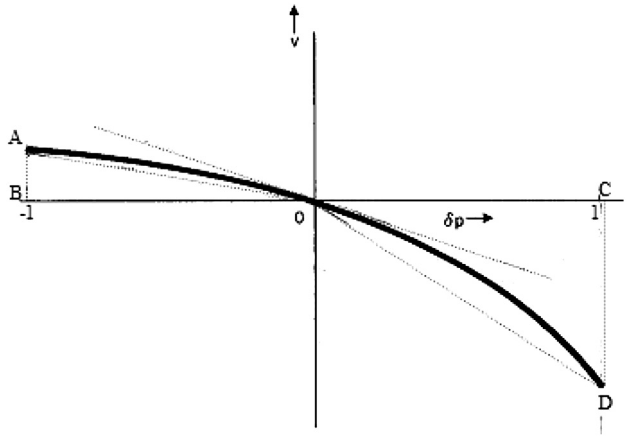

Fig. 2. Compensating variation, v, for a change in risk of ∂p.

equal to AB, which is simply the individual's WTP to avoid the certainty of suffering the injury, while the modulus of the gradient of OD is equal to CD which is his/her WTA as compensation for the certainty of suffering the injury.

Not surprisingly, it transpires that for any given class of underlying utility of wealth functions (e.g. logarithmic, homogeneous, negative exponential), m_I will be uniquely determined by – and expressible as a weighted average of – these WTP and WTA amounts for the certainty of suffering the injury.

The precise weights to be applied to the WTP and WTA responses in order to arrive at an estimate of m_I will depend upon the particular class of underlying utility of wealth functions that is assumed to apply. However it turns out that, at least for those classes normally considered, the effect of the choice of utility function is not substantial. For example, with WTA = 2 WTP, in the case of the logarithmic utility of wealth function, $m_I = 1.39$ WTP, whereas the homogeneous function gives $m_I = 1.33$ WTP, while with WTA = 4 WTP the implied values are, respectively, $m_I = 1.85$ WTP and $m_I = 1.60$ WTP.

Following extensive piloting and development, a full 'chained' approach study was eventually carried out in late 1997. Face-to-face interviews were administered by members of the research team in Newcastle, York, Brighton and Bangor on a sample of members of the public selected by a professional market research organisation, resulting in 167 completed interviews. The decision to use face-to-face interviews conducted by members of the research team reflected the desire to ensure that interviewers were in a position to provide direct and well-informed answers to questions raised by respondents, which piloting had indicated to be of considerable importance, given the nature of the questions to be asked. In addition to the project's budget constraint, this was the principal reason for the relatively small sample size.

In specifying the nature of the non-fatal injury it was clearly important to strike a balance. On the one hand, the injury needed to be of limited severity to ensure that for most people a) there would exist a finite sum that would compensate for the certainty of suffering the injury and b) the marginal utility of wealth would be unaffected by the injury. On the other hand the injury needed to be severe enough to ensure that most respondents to the Modified Standard Gamble question would regard it as realistic to consider the possibility of undertaking a treatment involving some risk of treatment failure resulting in death in order to cure the injury. In the event it was decided to use a slightly simplified version of the injury that had been coded 'X' in the 1991 Study (as in Fig. 1 above). The description of the injury, presented to respondents on a showcard, was as follows:

In hospital
- 2 weeks
- Slight to moderate pain

After hospital
- Some pain/discomfort, gradually reducing
- Some restriction to work and leisure activities, steadily improving
- After 18 months, return to normal health with no permanent disability.

In the Modified Standard Gamble (MSG) respondents were asked to suppose that they had been injured in a road accident and that, if untreated, the injury would result in death, but that two alternative treatments were available, namely:

TREATMENT A:
If successful, this treatment will result in the hospitalisation and prognosis associated with the non-fatal injury X, but if unsuccessful, will result in immediate unconsciousness, followed shortly by death with probability 1 in 1000.
TREATMENT B:
If successful, this treatment will result in a return to normal health within 3–4 days, but if unsuccessful, will result in immediate unconsciousness, followed shortly by death with probability π (> 1 in 1000)

The aim was then to find the level of π at which the respondent was indifferent between the two treatments. This was done using a 'card sorting' exercise which involved a shuffled pack of cards – each showing a risk of treatment failure ranging from 1 in 1000 up to 500 in 1000 and providing a display showing 1000 squares with the appropriate number 'blacked-out' to represent the specified risk of treatment failure. Respondents were asked to sort the cards into three piles on a template marked 'Would Definitely Choose B (rather than A)', 'Unsure' and 'Would Definitely Not Choose B (choose A instead)' and then to focus on the cards in the 'Unsure' pile in order to determine their indifference probability. In fact the WTP, WTA and MSG responses were, as is typically the case in this type of study, highly right-skewed, with means and medians as shown in Table 4.

Consider first the hypothetical case of an individual whose WTP, WTA and π responses are equal to the sample means. Given that mean WTA is approximately equal to 6 times the mean WTP, the value of m_I (which we denote in this case as m_X) implied by the logarithmic and homogeneous classes of underlying utility of wealth functions would be approximately equal to 2 WTP, so that for this individual we would have $m_X = £10{,}516$. In addition, it follows from Expected Utility Theory that with the probability of death under Treatment A set at 1 in 1000, then at the level of the individual, the ratio m_D/m_X will be equal to $1 - 0.001/\pi - 0.001$. (Notice that with π substantially larger than 0.001, this is approximately equal to $1/\pi$). The ratio m_D/m_X for an individual with π equal to the sample mean response of 0.041 will therefore be given by $1 - 0.001/0.0041 - 0.001 = 24.975$. One might therefore suppose that the implied sample mean value of m_D will simply be equal to £10,516 × 24.975 = £262,637. However, this will almost certainly constitute a serious underestimate of the true sample mean value of m_D.

Table 4
"Best estimate" CV and SG responses to the 1997 chained approach study (1997 prices).

	Mean	Median
WTP	£5258	£3000
WTA	£33,746	£10,000
π	0.041	0.012

To see why, notice first that by the definition of covariance, the mean of a ratio a/b will be equal to $\overline{a}/\widehat{b} + Cov(a, 1/b)$ where $\overline{a}$ is the mean of a, $\widehat{b}$ is the *harmonic* mean[11] of b, and $Cov\ (a, 1/b)$ is the covariance of a and $1/b$. It therefore follows that even if a and $1/b$ are uncorrelated, the mean of a/b will exceed $\overline{a}/\overline{b}$, where $\overline{b}$ is the arithmetic mean of b, because for any sample of non-negative observations the arithmetic mean necessarily exceeds the harmonic mean. In addition, if – as seems likely to be the case – an individual with a large value of m_x would also be highly risk-averse as far as a medical treatment involving the possibility of a fatal outcome was concerned, then one might reasonably expect that m_x and $1/\pi$ would be positively correlated. Taken together, these two effects will therefore entail that the mean of $m_x\ (1 - 0.001)/(\pi - 0.001)$ will substantially exceed the mean of m_x multiplied by $1 - 0.001/\pi - 0.001$ with π set at its mean value. Given that the ultimate aim is to estimate the VPF on the basis of the appropriate central tendency measure of individual values of m_D, then as far as the arithmetic mean of m_D is concerned it is therefore clearly essential that this should be computed as the sample mean of $m_x\ (1 - 0.001)/(\pi - 0.001)$. For the logarithmic specification of the underlying utility of wealth function this was £2.98 million and for the homogeneous specification £2.74 million, with corresponding median values of only £460,000 and £370,000 respectively (all in 1997 prices). Even with two extreme top-end outliers (one with $m_D > £235 \times 10^6$ and the other with $m_D > £15 \times 10^6$) trimmed out, the sample mean was still £1.26 million for the logarithmic case and £1.03 for the homogeneous specification. It should be noted that in computing both the trimmed and untrimmed means – but not the medians – it was necessary to omit sixteen cases in which the respondent would not accept any increment in the risk of death in order to take the medical treatment which, taken literally, would imply an infinite m_D/m_x ratio.

As an addition to the main CV/SG chained study a two-stage chaining process was also included as a consistency check. This involved asking respondents two additional sets of questions related to a lesser severity of non-fatal injury, W, which involved only 2–3 days' hospitalisation and full recovery within 3–4 months. As with injury X, the first question concerned WTP and WTA for the certainty of suffering the injury. In the counterpart to the Standard Gamble question, however, the respondent was asked to suppose that he/she had suffered injury W and that the consequence of treatment failure was not death but, instead, the symptoms and prognosis associated with injury X. The individual's marginal rate of substitution, m_W of wealth for risk of suffering injury W was then inferred from the WTP and WTA responses. In turn, the ratio m_D/m_W was derived by chaining together the indifference probability, θ of treatment failure from the SG question concerning injury W with the indifference probability π, from the SG question concerning X.

Full internal consistency would have resulted in estimates of m_D from the two-stage chaining process that were much the same as those obtained from the direct chaining approach. Somewhat disappointingly this did not turn out to be the case, with the untrimmed sample means of m_D being in the region of eight times as large as the untrimmed sample means obtained from the direct chaining approach. However, with fifteen upper-tail outliers trimmed out, the sample means of m_D given by the two-stage chained approach moved very much closer to the trimmed mean figures given by direct chaining, being in the region of 60–70 per cent larger, with the medians being about double their direct chaining counterparts. While these results are far from ideal, at least in the case of the trimmed means, they do not seem to be grossly unreasonable. However, since the two-stage chaining process seems likely to have resulted in some 'compounding of errors', there can be little doubt that the results obtained via direct chaining are the more reliable for policy purposes.

It was therefore recommended to the DETR that if any revision was to be made to the VPF then this should be based on the trimmed means obtained via direct chaining, but that account should also be taken of the medians, given the highly right-skewed nature of the distribution of individual marginal rates of substitution. To the extent that the trimmed means obtained from the two other specifications of the underlying utility of wealth function considered in the study – i.e. negative exponential and *n*th root – were, respectively, £0.92 million and £1.55 million, and since the logarithmic and homogeneous specifications produced figures of £1.26 million and £1.03 million, it was argued that, together with an allowance of some £65,000 for avoided net output losses and medical/ambulance costs, the VPF implied by the trimmed means could legitimately be taken to lie in the interval £1.0 million to £1.6 million. On the other hand, the medians – again augmented by £65,000 for avoided net output losses and medical/ambulance costs – pointed to a very much lower figure of the order of £0.5 million. In light of this, it was argued that in 1997 prices a figure anywhere in the range £0.75 million to £1.25 million would be entirely consonant with the findings of the study.

In the event, the DETR elected to set the roads VPF at the midpoint of this range, which constituted an increase of about 10% in 1997 prices on its then-existing figure and updated to 1998 prices gave a VPF of £1,047,240 (DETR, 1999). Expressed in 2011 prices, this figure is equivalent to £1,394,000.

2.5. Avoided output losses and medical and ambulance costs

This paper is concerned mainly with the monetary valuation of people's preferences about small changes in transport fatality or injury risks, but references are also made to avoided output losses and medical and ambulance costs, which are additional, smaller components of transport 'casualty costs'. This section describes and comments on how these two components are currently derived by the UK Department for Transport.[12]

In policy analysis and public presentation, casualty costs themselves are normally one component of 'accident costs', which include yet other components, especially property damage. The relative contributions of all the components of accident costs, for Great Britain in 2010, are as shown in Table 5. (The total cost of accidents reported in that year was approximately £15bn.)

Table 5 indicates that some 90% of accident costs were accounted for by the WTP component and property damage. Of these the WTP figure in Table 5 is much larger than property damage, although the Department believes that property damage is currently very substantially under-reported and may be the largest component. However the focus of this paper is casualty costs. The magnitudes of the casualty costs for 2010 as published by the DfT are as shown in Table 6, where the 'lost output' heading refers to gross output, including what would have been the consumption of fatalities.

We discuss in turn below lost output and medical and ambulance costs, each of these separately for fatalities and for non-fatal injuries.

[11] Where the harmonic mean of a random variable, x, is defined as the inverse of the arithmetic mean of x^{-1}.

[12] This section is largely a summary of work done for the Department in 2011, based mainly on research by Professor Andrew Evans of Imperial College: for more detail on that work see Spackman et al. (2011, section 2).

Table 5
Cost elements in the valuation of prevention of road accidents as a percentage of total accident costs, Great Britain 2010.

	Percentage of total accident costs
Casualty costs	
WTP	55.7[a]
Lost output	7.5[a]
Medical and ambulance	8.1
Other accident costs	
Property damage	31.9
Insurance administration	0.9
Police	0.2
	100.0

[a] These two figures are adjusted as explained below, so as to reflect correctly the empirical data on which the costs of fatalities are based. Source: Department for Transport (2011)

2.5.1. Lost output

The principal paper on the DfT's estimation of lost output in the context of UK road casualties, both fatal and non-fatal, is still O'Reilly (1993). The calculations are detailed. Potential casualties were divided into groups based on age and gender, and calculations were then based on estimates of average earnings, activity rates and life expectancy for each group. An allowance was also made for the output of unpaid workers (house-persons and volunteers). Real future output per head was assumed to grow at 2 per cent per year. Future earnings were discounted at HM Treasury's discount rate at that time of 6 per cent. Net output (i.e. excluding the individual's own consumption) was estimated from the 1992 national accounts as 20.25 per cent of gross output. Since 1993 the numbers have simply been increased pro rata to the increase in nominal GDP per capita.

2.5.1.1. Lost output and fatalities. As explained in Section 1 above, the very first lost output-based approach to monetising fatalities, in the early 1950s, included a figure for the *net* output which the individual would have provided for the rest of society. However by the late 1960s an allowance had been added for "pain, grief and suffering" and by the early 1970s the consumption that the individual would have consumed was also added.

With the development of WTP methodology the monetary value of an individual's expected future consumption, to the extent that it influences his or her WTP to reduce fatality risks, can be assumed to be incorporated in the direct measurement of this WTP. The original case for including the value of potential fatalities' own consumption as an extra item therefore disappeared. However, although as explained in section 2.1 above, the WTP methodology was adopted by DfT in 1988, public presentation of it's value of a prevented fatality still includes *gross* output as one component. This convention appears now to be retained because it is simpler to present figures for fatal injuries and non-fatal injuries (for which, as explained below, gross output losses are correctly added as an extra item) under a common set of column headings, as in Table 6 below.

Table 6
Average casualty costs for fatal, serious and slight injuries as published by the Department of Transport, Great Britain 2010.

Injury severity	Lost output	Human costs	Medical & ambulance	Total £(2009 prices)
Fatal	568,477	1,084,230	980	1,653,687
Serious	21,903	150,661	13,267	185,831
Slight	2315	11,025	980	14,320

Source: DfT, at http://www.dft.gov.uk/webtag/documents/expert/unit3.4.1.php#021 (accessed 24.8.12).

In algebraic terms, the VPF is equal to WTP + NQ + MA, where WTP is the willingness to pay component, NQ is the present value of the avoided loss of *net* output and MA is the avoided medical/ambulance costs. Net output, NQ, is by definition equal to (GQ − C), where GQ is the reduction in *gross* output and C is the consumption that a fatality would on average have otherwise consumed. By substituting (GQ − C) for NQ the VPF can thus be presented as (WTP − C) + GQ + MA. The DfT describe the quantity (WTP − C), the two components of which are not set out separately, as the 'human costs' of a statistical fatality. This convention might convey to many readers the false impression that the VPF is still derived on the basis of the gross output approach.

Another aspect of the VPF that might merit further attention is the magnitude of the figure for net output, NQ.

First, as noted above, NQ was estimated in 1993 to be 20.25 per cent of gross output (for the population as a whole) and this estimate has been used in presenting the VPF. But, 20 per cent of gross output seems implausibly high as an average net output over the population as a whole.

As for road fatalities, the relationship between an individual's output and his or her consumption clearly changes greatly over most people's life cycles. Until they enter the workforce people consume more than they produce: their output is low and their consumption is high (living costs plus education). People of working age generally produce more than they consume. Retired people typically again consume more than they produce, especially because of health care.

There is a growing literature on this, sometimes described as national transfer accounting, which typically portrays two superimposed graphs in units of money against time. One is an inverted U of people's gross output. The other is a much flatter, upright but shallow U of their own consumption of resources. Casual inspection of such graphs suggests that for road fatalities, where the average age is 42 and the median 37, while the net output from their remaining normal lifespan (that is their gross output minus their consumption of living costs and health service and other care costs) is probably positive, it is unlikely to be as much as 20% of the gross output that they would have produced had they survived.

However the impact of net lost output on the VPF, even at its *current* level, is much less than 2 per cent of accident costs, or probably little more than 0.5 per cent when under reporting is taken into account. A more plausible calculation would seem likely to yield a (positive or negative) figure near zero. There is therefore a case for assuming that the lost net output for road fatalities is on average negligible.

2.5.1.2. Lost output and non-fatal injuries. As with fatalities, the DfT's estimation of lost output in the context of UK road casualties follows from O'Reilly (1993). The calculations are similarly detailed, similarly structured in terms of age and gender, are based on estimates of average earnings and activity rates, and follow similar conventions concerning, for example, discounting. The estimates are of gross output losses, which is more clearly justifiable for non-fatal injuries than for fatalities. Following an accident, the victim's loss of income is a real loss, reducing the victim's welfare. This is of course not the case following death. Moreover, respondents to UK surveys seeking their WTP to reduce risks of non-fatal injuries have been explicitly asked to exclude financial effects, not least to avoid the unmanageable complications of having to make assumptions about the allocations after an injury accident of insurance-based compensation.

For 'serious' casualties a weighted average of gross lost output was calculated for those who recover within a year, those who recover within one to three years, and those who never return to work. For 'slight' casualties a weighted average was calculated for those who recover within a year and those who recover within one to three years: the calculation methodology used is the same as for serious casualties, but with different data for average days lost.

Lost output currently represents about 12 per cent of the serious non-fatal casualty cost and about 16 per cent for slight casualties.

2.5.2. Medical and ambulance costs

2.5.2.1. Medical and ambulance costs for fatalities. Medical and ambulance costs for fatalities cover the costs of ambulance services, Accident and Emergency departments, in-patient services and blood transfusions. Costs are based on 1984–1985 Department of Health data, indexed over time to GDP per head. (It has been suggested that these costs should be disregarded because we all die and incur such costs in the end. But the medical costs that would have been incurred later, in the absence of the premature fatality, should be included as a negative item in lost "net output".)

2.5.2.2. Medical and ambulance costs for non-fatal casualties. Medical and ambulance costs for non-fatal injuries are a field of overlap between the derivation of non-WTP costs and WTP valuations. Both use precise definitions of injury consequences, as for example in Fig. 1 above, to provide a basis for WTP survey work to value people's aversion to these injuries and to provide a basis for costing the associated ambulance and medical costs.

Medical and 'support costs' for non-fatal casualties were revalued in the early 1990s. These revisions more than doubled the medical and ambulance costs for serious injuries and quadrupled them for minor injuries. Since then these costs have been updated indexed over time, as for fatalities, to GDP per capita.

The calculation methodology is described in Hopkin and Simpson (1995, Appendix B). The calculations were based on evidence from two studies undertaken in the Manchester area on road accident patients. The results of the first study are described in Murray, Pitcher, and Galasko (1993) and cover whiplash and fracture injuries. The second study is documented in Murray, Pitcher, and Galasko (1994) and covers other serious and slight injuries (not fractures or whiplash).

Central to the calculation of non-fatal medical and ambulance costs are the 'Galasko' injury or health states presented in Fig. 1 above.

A mapping of the average use of health services associated with each Galasko injury state was combined with the unit cost of health services to give an average cost of health services, for each injury state. A further mapping of serious and slight casualties onto the Galasko injury states has been combined with these costs, to calculate the average cost of health services for serious and slight casualties. This entailed statistical studies of police and hospital data, work on linking police and hospital data for road accidents, and expert clinical judgements on recovery rates. Serious casualties were split between all the states. Slight casualties were distributed only across the states coded F and V. These data are set out in Hopkin and Simpson (1995), page 7. It is unclear whether these averages took into account slight casualties that did not require hospital treatment.

The data sources used for these calculations may now be outdated. The use of health services by casualties may have changed as a result of changes in treatment methods or technologies and/or changes in the type of injuries brought about by road accidents. The latter might arise in part from changes in car technologies: e.g. vehicle strength; braking capacities; headrests; air bags; use of seatbelts.

Most (or arguably, all) all of the Galasko injury/health states themselves could be retained indefinitely. However for future work they need to be extended, to fill gaps between some states and probably (at least for public transport injuries) to cover post

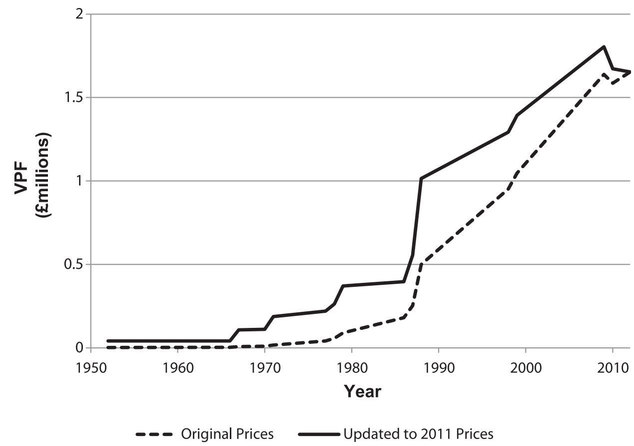

Fig. 3. Development of the roads VPF over time.

traumatic stress disorder. They could then be adapted if needs be to the suggestion in Ward et al. (2010) that the injury classification itself should include three types of serious casualty.

However the Galasko states, while central to the WTP valuations of non-fatal casualties, could be by-passed for the purposes of estimating medical and ambulance casualty costs. It would be possible to reformulate the calculations by more directly mapping health service use onto serious and slight injuries.

Somewhat anomalously, Social Security Benefits were included in what were originally described as 'medical and support costs', and they appear still to remain in 'medical and ambulance costs'.[13] It is inconsistent to aggregate social security costs, which are transfers,[14] with medical and ambulance costs, which are measures of consumed resources.[15] There would be a case for retaining the estimation of social security costs if it were decided to include in the national accident statistics an estimate of how the costs are distributed between the public and private sectors. But if this were done they would properly be included as a public sector cost offset by a numerically equal private sector benefit.

2.6. Summary of development of UK roads VPF

In order to summarise the development of the UK roads VPF since its adoption in the transport allocative decision-making process, a graph tracking key changes over time is shown in Fig. 3. As noted earlier, in the periods between these changes the DoT increased the VPF annually in line with inflation and the increase in per capita output. It should also be noted that the values are shown in the year in which they were published and are, as a result, expressed at the price level of the preceding year. The values are shown in nominal terms (i.e. at their original prices) and in real terms, updated to 2011 prices on the basis of the UK GDP deflator.

[13] These costs were estimated in June 1994 prices as £687 per serious casualty and £228 per slight casualty. As a percentage of medical and support/ambulance costs as a whole, these amount to 10 per cent for serious casualties and 44 per cent for slight casualties.

[14] Fatalities are an exception. Reductions in expenditures such as pensions in later years are a national saving. And these should be covered in the 'net output' element of the VPF.

[15] It would be consistent to include the social security costs if the benefit to the recipients were reflected in the WTP valuation by potential victims, who would in principle be willing to pay less, by an amount equal to the value of these benefits, to reduce the risk of such injuries. But respondents in willingness to pay studies of *non*-fatal injury have been explicitly asked ***not*** to take account of the financial consequences.

As far as the values for the prevention of non-fatal injuries are concerned, following the change from gross-output to willingness to pay-based values in 1993 – which resulted in substantial increases for both the 'Serious' and 'Slight' figures – the non-fatal values have followed much the same time-path as the VPF, with the 'Serious' figure set at roughly 10% and the 'Slight' figure at about 1% of the latter.

3. Willingness-to-pay based values of rail safety

Safety on the UK rail system is subject to the Health and Safety at Work Act 1974 (HSWA). These regulations require that the rail industry should reduce risks to the public and employees 'so far as is reasonably practicable' (SFAIRP), or equivalently, to a level that is 'as low as reasonably practicable' (ALARP). From 1988 until 2006, enforcement of these regulations was undertaken by the Health and Safety Executive (HSE), but this is now a responsibility of the Office of Rail Regulation (ORR), while the industry-based Rail Safety and Standards Board (RSSB) provides expert advice on safety to the industry.

In routine situations the process of ensuring that risk levels are ALARP is usually undertaken by complying with engineering 'good practice' and well-established procedures. But in cases involving new technology or as yet untried procedures it is now accepted that some form of cost–benefit analysis is required, though this is by no means treated as the sole input to the decision-making process. The application of cost–benefit analysis to rail safety raises two questions: a) what does the ALARP condition entail as far as the required benefit/cost ratio is concerned and b) how should the benefits of safety improvement be defined and measured?

On the first of these two questions the ORR accepts the precedent set by Her Majesty's Railway Inspectorate (HMRI) stemming from an Appeal Court ruling in 1949, following a coal mine fatality, that ALARP is to be interpreted as requiring that a safety improvement should be carried out provided that the costs of doing so are not in 'gross disproportion' to the resultant risk reduction – see *Edwards vs National Coal Board*, 1949, IKB 704 and RSSB (2007). In fact the 'gross disproportion' interpretation of ALARP persists even though, in marked contrast to the situation that prevailed in 1949, the values of safety used in cost–benefit analysis are now explicitly aimed at capturing the public's strength of preference for safety relative to other goods and services. In real terms these values are also about 40 times higher than the corresponding values applied in the 1950s. In addition, a subsequent legal judgement in the House of Lords in 1954 said that the test of ALARP was 'whether the time, trouble and expense of the precautions suggested are or are not disproportionate to the risk involved' with the term 'gross' clearly omitted – see *Marshall vs Gotham Co Ltd*, 1954, AC 360. And much more recently the House of Lords Economic Affairs Committee has criticised the continued use of the term 'grossly disproportionate' as being 'decidedly ambiguous' – see *House of Lords* , 2006, Volume 1, para 63. However, it seems unlikely that any regulator or regulated body will formally challenge such a long-established convention in the near future and indeed the ORR continues to rely on the 'gross disproportion' interpretation in its definition of SFAIRP – see ORR (2009). More specifically, it appears that the ORR does not disagree with the HMRI's earlier 'rule of thumb' guidance which suggested that a benefit/cost ratio of 1–2 is required in cases involving low levels of baseline individual risk and no 'societal' risk (i.e. no risk of wider adverse social consequences); a ratio of 3 for low individual risk and some societal risk and a ratio of 3–10 for cases involving a high level of baseline individual risk – see RSSB (2007). Nonetheless, it is clear that a substantial element of informed judgement is still required on the part of the rail industry decision makers.

The second question is how the benefits of a rail safety improvement should be defined and measured. Following adoption of the WTP approach by the Department of Transport in 1988 and considerable pressure from advocates of the approach, the rail industry was persuaded in the early 1990s to apply WTP-based values of safety in its cost–benefit appraisal of proposed rail projects. This made it necessary for the rail industry to address the question of the level at which to set the VPF and WTP-based values of preventing non-fatal injuries and, in particular, whether or not it would be appropriate to employ the values that had been adopted for road project appraisal by the Department of Transport. More specifically, both British Rail (BR) – now Network Rail – and London Underground Limited commissioned research on whether psychological factors related to dread, control and responsibility, as well as the possibility of accidents involving large-scale loss of life and injury, warranted higher values of safety than those adopted by the DoT, as had been suggested by a number of authors – see for example, Wilson (1975); Ferriera and Slesin (1976); Slovic, Fischoff, and Lichtenstein (1981) and Sunstein (1997).

In the event, in 1994, following a study directed by Dr David Ball of the University of East Anglia, British Rail decided to apply two distinct VPFs in its appraisal of proposed rail safety projects. The first – which was set equal to the Department of Transport roads figure of £715,330 in 1992 prices – was applied in cases in which passengers or rail workers could be taken to have a substantial degree of control, as in cases such as single-fatality accidents on platforms. By contrast, the second VPF, which was employed in cases in which risk affected large numbers of people and those affected had little or no control, or where baseline risk levels were high, was set at £2 million, that is 2.8 times the roads-based figure. British Rail arrived at its higher figure by applying multipliers estimated on the basis of judgement and expert opinion elicited in the study directed by Dr. Ball, based on a sample of individuals with extensive experience of decision making in this area. Essentially, these multipliers were designed to reflect six 'risk-aversion' factors, including lack of control, catastrophic potential, benefits to other than those directly exposed to the risk concerned, unknown nature of the risk, dread concerning the cause of death and blame applied to the rail industry.

3.1. The 1991/92 and 1994 London underground studies[16]

Following a fire in 1987 at Kings Cross Underground Station, in which 31 people died, London Underground Limited (LUL), which is the state-owned operator of London's underground rail system, set up an extensive programme of research to develop and refine its risk-assessment and safety project appraisal procedures. Given that the Department of Transport had adopted a WTP approach in 1988, part of that programme focused on the estimation of monetary values of safety and was undertaken by one of the authors in conjunction with Professor Graham Loomes.

The Underground safety valuation project took part in three phases. In the first of these (referred to as the 'Phase 0 Study'), which was carried out during 1991 and early 1992, the basic conceptual issues were explored and the case in favour of the willingness to pay approach was developed. Amongst other things, it was argued that WTP-based values of Underground safety might differ from the roads values in two key respects. First, over time roughly 50% of Underground fatalities can be expected to occur in large-scale accidents involving ten or more fatalities and the possibility that people might display a higher degree of aversion to the prospect of involvement in such accidents could result in

[16] For a detailed account of these studies, see Jones-Lee and Loomes (1994, 1995).

a significant premium for WTP-based values of Underground safety. Second, values of Underground safety might differ substantially from their roads counterparts as a result of people's psychological response to factors such as the attribution of responsibility, control, and dread associated with the prospect of death or injury in a remote underground location.

Amongst other things, the Phase 0 study led to the conclusion that, given the very low level of the baseline risk of an Underground accident, questions that asked directly about willingness to pay for risk reduction would not be feasible, given that they would require annual risk reductions to be expressed to a base of 10^6. It was therefore decided that it would be more effective to present respondents with 'matching' (or 'person-trade off') questions aimed at estimating a) the relativity between the preference-based VPF for a multiple-fatality Underground accident and the VPF for a single-fatality Underground accident and b) the relativity between the VPF for a single-fatality Underground accident and the single-fatality roads figure.

In light of the conclusions of the Phase 0 study it was decided to carry out a pilot study (referred to as the 'Phase 1 Study') to assess the feasibility of conducting a stated-preference survey aimed at estimating valuation ratios using matching questions. This was carried out in late 1992 on a focus-group basis involving 12 groups, each group comprising 6 or 7 members of the public drawn from the area served by London Underground. Respondents tended to find the questions posed far from straightforward. However, following discussion and careful reflection most respondents were able to answer the questions and provide broadly plausible responses. Given the apparent feasibility of the matching question format it was decided to proceed to a main study (referred to as the 'Phase 2 Study'). This was carried out in early 1994 and involved 30 focus groups, each comprising between 6 and 8 members of the public, all of whom were required to be both Underground users and car drivers or passengers. Respondents were also selected so as to represent a reasonable spread of age, gender and social class.

As well as several questions aimed at eliciting respondents' views concerning control, responsibility, blame etc., the focus group sessions presented respondents with four questions (which were answered on an individual rather than group basis) designed to shed light on their relative valuation of the prevention of a fatality in large and small-scale Underground accidents, and the relative magnitudes of their Underground and road VPFs. In particular, respondents were asked whether or not they agreed with the statement '25–30 deaths in a single Underground accident is worse than 25–30 deaths in separate Underground accidents.' The responses were as follows:

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
24%	43%	13%	17%	3%

$n = 222$.

Clearly, therefore, a substantial majority of respondents (67%) disagreed or strongly disagreed with the proposition and hence, by implication, did not believe that it would be appropriate to accord a higher VPF to the prevention of a fatality in a multiple-fatality accident than in the single-fatality case. Responses to various other questions, as well as open-ended discussion, indicated that the absence of a 'scale' premium for the multiple-fatality VPF was due in part to respondents' doubts concerning the effectiveness of expenditure aimed at reducing the risk of large-scale Underground accidents, given the unique and unpredictable nature of the cause of such accidents.

In the second of the relative valuation questions respondents were asked to consider a situation in which London Underground had to choose between spending a given sum which it had been allocated for safety improvement on *either* a scheme, L, which could be expected to prevent 25–30 fatalities in large-scale Underground accidents over the next 25 years *or* a scheme, S, which would be expected to prevent the same number of fatalities over the same period in small-scale Underground accidents. Respondents were then asked to express their preferences concerning the two options and the responses were as follows:

L preferred to S	L and S equally good	S preferred to L
23%	31%	46%

$n = 222$.

These responses therefore reinforce the conclusion drawn from the previous question. However, in order to gain further insights into the strength of respondents' preferences, those who had indicated a preference for L over S were then asked how many small-scale accidents would have to be prevented in order for them to regard L and S as being equally good. By contrast, those who had indicated a preference for S over L were asked how *few* small accidents would have to be prevented in order for them to regard L and S as being equally good. The ratio of the individual's value for the prevention of a fatality in a large-scale accident relative to his/her value for the prevention of a fatality in a small-scale accident was then inferred as the *inverse* of the ratio of the number of fatalities prevented when the two schemes were judged to be equally good.

Given that the frequency distribution of responses was somewhat right-skewed, it transpired that the VPF for large-scale accidents implied by the sample arithmetic mean of the responses to the matching questions was 0.98 times the VPF for small-scale Underground accidents, which was effectively an equal valuation of the two cases.

However, since the study was completed and the results published, those who carried out the study have substantially revised their views concerning the appropriate way in which to aggregate the results of a relative valuation study in order to arrive at an unbiased central-tendency measure- see, in particular, Chilton et al., 2002, Appendix B. Essentially, the preferred method involves assigning an individual's more highly-valued alternative a 'context index' of unity and his/her less highly-valued alternative a context index equal to the fraction of unity implied by his/her response to the relative valuation question. For example, in the case of an individual with an L:S valuation ratio of 4:1, context L would be assigned an index of 1 and context S an index of 0.25. The overall valuation ratio is then computed as the ratio of the sample means of the context indices for the two alternatives.[17] Proceeding on this basis the Phase 2 Underground study data then implies a VPF for

[17] The argument in favour of proceeding in this way is as follows. For simplicity, consider a group of individuals who are in all respects identical except for the fact that half of the group values safety in context A relative to context B at a ratio of 2:1, whereas the other half has an A:B valuation ratio of 1:2. In the absence of any other information concerning the preferences of members of the group (such as absolute individual valuations of safety in each of the two contexts), it would seem completely unreasonable to set the safety valuation ratio for the group as a whole at other than 1:1. However, if one takes the arithmetic mean of the A:B valuation ratio, this gives a ratio of 1.25:1, with the mean of the B:A ratio also being 1.25:1, neither of which appears to be in any way defensible. By contrast, the indexing procedure does produce an overall valuation ratio of 1:1. Notice that while the geometric mean of the valuation ratios is also 1:1 in this example, in more general cases the geometric mean is potentially vulnerable to the impact of "bottom-end" outliers, particularly if these include any x:0 or 0:x responses.

large-scale Underground accidents that is only 0.79 times the VPF for small-scale accidents, which seems to sit rather more comfortably with the percentage breakdown of the 'L preferred to S', 'L and S equally good' and 'S preferred to L' responses shown above.

Following the large-scale/small-scale matching questions, respondents were then presented with the third relative valuation question which asked whether or not they agreed with the statement 'The thought of being killed in an Underground accident is worse than the thought of being killed in a road accident'. The responses were as follows:

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
11%	29%	30%	21%	9%

$n = 223$.

In this case it is therefore clear that opinion appeared to be more or less evenly split.

The fourth relative valuation question then began by asking respondents to give their preferences concerning two options which would cost the same but would prevent either 25–30 fatalities in small-scale Underground accidents over the next 25 years (scheme S) or 25–30 fatalities in small-scale road accidents (scheme R) over the same period. The responses were as follows:

S preferred to R	S and R equally good	R preferred to S
41%	44%	15%

$n = 218$.

As in the scale question, respondents who had expressed a preference for S over R were then asked how many road fatalities would need to be prevented in order for R to be judged equally as good as S and those who had expressed a preference for R over S were asked how few road accidents would need to be prevented in order for S and R to be judged equally good. On the basis of the sample arithmetic mean of the responses to these matching questions the VPF for small-scale Underground accidents was 1.51 times the roads VPF. However, under the now-preferred context index-based aggregation procedure, the implied small-scale Underground/roads VPF ratio falls to 1.16, which implies that the two VPFs are effectively equal.

In light of the findings of the Phase 2 study and, in particular, the valuation ratios computed on the basis of the arithmetic mean of responses to the matching questions, it was recommended that LUL should maintain the VPF that it (and British Rail) had adopted as an interim measure pending the outcome of the valuation research. Although this figure was, at £2 million, well in excess of the roads figure which at that time was about £750,000, it was argued that this was justified because the roads figure was based on the rather conservative recommendations of the 1988 *Dalvi Report* (see Section 2.1 above).

Not surprisingly, given the responses to the questions concerning large-scale Underground accidents, it was also recommended that if values of Underground safety were to reflect the views and attitudes of members of the travelling public, then there were no grounds for setting the VPF for large-scale Underground accidents at a premium relative to the small-scale accident figure.

Clearly, the case against setting the VPF for large-scale Underground accidents at a premium relative to the small-scale figure is, if anything, reinforced if valuation ratios are computed on the basis of the now-preferred context index-based aggregation procedure. By contrast, with the Underground/roads valuation ratio re-estimated on this basis, the argument in favour of an Underground VPF that substantially exceeds the roads value is effectively negated. As noted below in Section 3.3, this – together with the findings of subsequent research – has led to the application of the same VPF in the road and rail contexts since 2003.[18]

3.2. The 1998 and 2000 rail studies[19]

As part of the programme of research jointly commissioned by the UK Health and Safety Executive; the Department of the Environment, Transport and the Regions; the Home Office and HM Treasury, which led to the re-estimation of the roads VPF (see Sections 2.3 and 2.4 above), a relative valuation study was carried out using matching questions aimed at estimating the values of safety for rail, domestic fires and fires in public places relative to the roads value. Following extensive piloting, the main study was carried out in late 1998 and involved a representative sample of 130 drawn from four areas in England and Wales. The study was carried out on a focus group basis with groups of 4–5 participants overseen by members of the research team. In addition to questions intended to shed light on respondents' views concerning factors such as voluntariness, control, dread and so on, respondents were required to answer (on an individual rather than group basis) a number of questions aimed at estimating values of safety for rail, domestic fires and fires in public places, relative to their value of road safety.

From the qualitative questions one of the most significant results was that, as in the 1994 Underground study, a majority of respondents did not regard the possibility of large-scale accidents as a valid reason for prioritising rail over road safety improvement, with only 20% indicating that they did regard it as being a valid reason. From the quantitative matching questions, which were framed in broadly the same way as those used in the 1994 Underground study, using the now-preferred 'context index' approach to data aggregation it transpired that in all three cases (i.e. rail, domestic fires and fires in public places) the VPF relativity with respect to the roads figure was *strictly less than one*, with the rail/roads relativity in particular being 0.83. Focus group discussion and subsequent research – see, in particular, Chilton, Jones-Lee, Kiraly, Metcalf, and Pang (2006) – strongly suggest that the relatively low baseline risk of being killed in a rail accident more than offsets the effect of factors such as dread, control and so on that might be expected to drive up the rail VPF.

Tragically, shortly after completion of the 1998 study a major rail accident occurred at Ladbroke Grove near London's Paddington Station in which 29 passengers and two train drivers died. This accident appeared to break the downward trend in fatalities on Britain's main-line railways – see Evans (2000) and, not surprisingly, generated considerable press and media attention. As a result the UK Health and Safety Executive commissioned a 'follow-up' to the 1998 study to examine a) the impact of the Ladbroke Grove accident and the attendant press and media attention on the rail/roads safety valuation relativity and b) the effect of focussing more directly on the views and attitudes of regular rail users. The follow-up study used the same general format as the 1998 study, but also included a concluding discussion of the impact of the Ladbroke Grove accident. In addition, the sample of 150 respondents (again in focus-groups of 4–5 participants) was drawn from three locations in the London commuter area and a rail-use quota was also specified requiring that at least 40% of the sample should be regular rail users.

[18] Although this does not mean of course that investment decisions necessarily apply the same cost/safety trade off to road and rail. There are factors outside the cost–benefit analysis that in practice give a higher priority to rail safety.

[19] For a detailed account of these studies, see Chilton et al. (2002).

In spite of the fact that it was carried out in the aftermath of the Ladbroke Grove accident, the percentage of respondents indicating that they did *not* regard scale as constituting a valid reason for prioritising rail over road safety expenditure fell by only a small amount and those expressing a clear preference for prioritising rail because of the greater likelihood of large-scale accidents rose from 20% to only 23%. However, as far as responses to the matching questions were concerned, the implied rail/roads safety valuation relativity rose to 1.003 for the sample as a whole and 1.157 for the sub-sample of those who travelled 1000 miles or more per annum by rail. This is very similar to the Underground/roads relativity implied by the 'context index' approach to data aggregation – see Section 3.1 above.

3.3. The 2006 rail safety studies[20]

In light of the findings of the 1998 and 2000 studies, as well as vigorous argument from those who favoured uniform treatment of safety on different transport modes – see, for example Lords Hansard, 5 June 2003, Columns GC 271,272) – in 2003 the RSSB decided to abandon its policy of applying different VPFs to the prevention of small and large-scale rail accidents and instead elected to use the Department for Transport's roads figure in all cases. However, this still left open the question of how to deal with cases in which potential victims were behaving irresponsibly or illegally, which on average constituted more than 75% of all rail fatalities – see, for example, Evans (2006). As a result, RSSB commissioned two studies to explore the public's attitudes to rail safety improvement with a clear distinction being drawn between potential victims who were behaving responsibly, and those who were behaving irresponsibly or illegally. The RSSB also wished to obtain further confirmation of the earlier findings which pointed towards the equal valuation of the prevention of a fatality in large and small-scale rail accidents.

The first of these two studies (reported in Horlick-Jones, 2008) employed a qualitative research approach involving discussion groups of lay citizens. It indicated that, so far as members of the UK public were concerned, more should be spent on protecting the safety of rail passengers and workers than trespassers, vandals and suicides and that there was not a case in favour of prioritising expenditure aimed at preventing major rail accidents at the expense of more everyday small-scale accidents.

The second study, directed by one of the authors and colleagues, was more quantitatively focused and was based on two effectively parallel sample surveys, one involving face-to-face interviews and the other carried out over the internet. Thus, while the principal aim of the study was to estimate relative values of safety, a secondary objective was to provide a direct comparison between two of the more common procedures that had been used to conduct sample surveys of this type. So far as possible, the questions used in the two surveys were effectively identical. As in the earlier rail and Underground studies, the questions took the form of matching tradeoffs aimed at establishing valuations relative to a 'baseline context', which in this case was taken to be a single fatality rail accident involving an adult rail passenger behaving responsibly (for which it had already been decided that a VPF equal to the roads figure would be applicable).

The first survey, carried out in June 2006, used a Computer Assisted Personal Interview (CAPI) format administered to respondents in their own homes by trained professional interviewers employed by GfK NOP and involved a nationally representative sample of 1033 respondents. The second, internet-based survey was administered by YouGov and involved a nationally representative sample of 1957 respondents. Both surveys were based on matching questions, which began by asking the respondent to choose between two safety programmes which would cost the same and would be effective over the same period (i.e. the next ten years), but differed to the extent that they would each prevent 10 fatalities by different causes. If the respondent expressed a preference for one of the two programmes then the number of fatalities prevented by the preferred programme was reduced until the respondent regarded the two programmes as being equally beneficial. However, in the case of a comparison between multiple and single-fatality accidents, if the prevention of the multiple-fatality accident was preferred then the number of single-fatality accidents prevented was increased.

In the event – and somewhat to the surprise of the research team – the CAPI and internet surveys produced very similar results. Pooling the results of the two studies and using the mean context index aggregation procedure, examples of the implied valuation ratios relative to the single-fatality accident involving a responsibly-behaved adult rail passenger are shown in Table 7.

In light of these findings, and given the difficulty of predicting the specific nature of the types of fatality that are likely to be prevented by a particular rail safety project, it was recommended by the research team that the rail industry should work with just two distinct VPFs in its safety project planning, namely: a) a figure equal to the roads value for cases in which the victim is not to blame or is a child trespasser not involved in an act of vandalism and b) a figure equal to about 40% of the roads value for cases in which the victim is behaving irresponsibly or illegally. However, it appears to be the case that because of doubts concerning the legal defensibility of applying such explicit discounts, the RSSB has, in the event, decided to maintain a common VPF for all cases.

3.4. The 2007 rail non-fatal injuries study

Given that the 2006 rail safety internet survey had produced results that were very similar to those obtained from the face-to-face CAPI survey, and since an internet survey is, for a given sample size, considerably less costly and more straightforward to administer, it was decided to carry out a subsequent study aimed at estimating the value of preventing various severities of non-fatal rail injury (relative to the VPF for a single-fatality, responsible adult passenger) using only an internet survey. The survey instrument was designed by the same team as had been involved in the 2006 rail studies and was again administered by YouGov during June and July 2007.

While the injuries considered were, broadly speaking, similar to those that had featured in the 1991 non-fatal road injuries study (see Section 2.2), two scenarios involving different severities of

Table 7
VPF ratios relative to VPF for single, train accident fatality of a responsible adult passenger.

Adult passenger; large-scale collision accident caused by signal failure	1.18
Adult passenger; large-scale accident involving fire in a tunnel	1.11
Adult passenger; tripped and fell from platform; behaving responsibly	0.86
Child trespasser; taking shortcut	0.70
Child trespasser; involved in act of vandalism	0.51
Adult trespasser; taking shortcut	0.41
Adult passenger: leaning out of window	0.40
Adult suicide; jumps from platform	0.34
Adult passenger; drunk; fell from platform	0.33

[20] For a detailed account of the quantitative study, see Covey, Robinson, Jones-Lee, and Loomes (2010).

shock and trauma were also included, given that such cases are, apparently fairly common consequences for those involved in or having witnessed a rail accident.

Unfortunately – and greatly to the research team's disappointment and surprise following the apparent success of the 2006 internet-based fatalities study – the findings of the 2007 study were, to put it bluntly, littered with responses that implied relative valuations which were simply implausible and in some cases inconsistent. Thus, for example, 240 out of 1098 (i.e. over 20%) of those respondents who were asked to compare an injury involving no hospital visit and full recovery in 4–7 days and another injury involving an overnight stay in hospital and full recovery in 10–14 days provided answers which implied that they regarded the former as being *worse* than the latter. What was perhaps even more disturbing was that dubious responses of this type were not restricted to a particular subset of respondents but were, instead, spread throughout the sample.

But in spite of these problems with the empirical estimation of the value of preventing non-fatal rail injuries, in 2008 the RSSB in fact implemented fairly substantial revisions to the non-fatal values that it had employed since the early 1990s. The latter had been based on a breakdown of rail non-fatal injuries into 'major' and 'minor' categories which broadly paralleled the DoT's 'serious' and 'slight' classification and were accorded, respectively, values equal to 0.1 and 0.005 times the rail VPF for single-fatality accidents – see RSSB (2008a). However, exploratory research commissioned by the RSSB prior to the 2007 empirical study had examined the implications of using data concerning the proportionate breakdown of the different severities of non-fatal rail injury, together with the valuation relativities derived in the 1991 roads non-fatals study, to re-estimate the values of preventing major and minor non-fatal rail injuries – see RSSB (2008b). This research produced three key conclusions, namely:

a) That there was no persuasive reason for altering the relative value for the prevention of a major non-fatal rail injury (i.e. 0.1 times the single-fatality rail VPF).
b) That since rail accidents typically result in a far smaller proportion of whiplash neck injuries than in road accidents, there was a strong case in favour of reducing the value placed on the prevention of minor non-fatal rail injuries.
c) That in contrast to road accidents, the (often protracted) shock and trauma experienced by those witnessing a rail accident constituted a significant consideration that ought to be explicitly recognised.

As a result, in 2008 the RSSB decided to adopt the following revised breakdown of relative valuations for the prevention of non-fatal rail injuries, excluding any allowance for avoided material damage costs (see RSSB, 2009):

	Valuation relative to fatality
Major injury	10%
Reportable minor injury	0.5%
Non-reportable minor injury	0.1%
Class 1 shock and trauma	0.5%
Class 2 shock and trauma	0.1%

The essential difference between Class 1 and Class 2 shock and trauma is the severity of the accident witnessed by the victim. For example, witnessing a fatal accident or train collision is taken to result in Class 1 shock/trauma, whereas witnessing a non-fatal accident or near-miss is taken to result in Class 2.

4. Summary and concluding comments

It is a basic fact of life that in most situations safety can be improved, but only at a cost. Amongst other things, this means that if scarce resources are to be allocated efficiently and to society's greatest advantage, then it is essential to confront the question of the appropriate monetary value to place on safety improvement so that benefits can be compared directly with costs in the allocative decision making process. Work on safety valuation in the UK began in the context of road safety. Following early work in the 1940s and 1950s based largely on the 'gross-output' approach, in the late 1970s and early 1980s the UK Department of Transport was persuaded to fund research aimed at estimating so-called 'willingness-to-pay' based values, which are designed to reflect the preferences of those members of the public who are likely to be affected by safety expenditure decisions. This then led to the adoption of willingness-to-pay based values by the Department of Transport in 1988 and subsequently by the rail industry, as well as several other UK government departments and related public sector bodies.

Substantial points arising from UK transport safety valuation research include the following.

4.1. Road safety versus rail safety

It is sometimes suggested that preference-based values of rail safety might be expected to differ significantly from their roads counterparts, given the higher level of dread – and lower level of factors such as perceived control – that the travelling public appears to associate with the prospect of rail relative to road accidents. But in the event this turned out not to be the case. In fact, focus group discussion as well as the findings of a study aimed directly at assessing the impact of dread *per se*[21] indicated that, while the prospect of being involved in a rail accident is typically viewed with a considerably greater degree of dread, this has little effect on WTP for greater rail safety. As suggested in Chilton et al. (2002), it is possible that the considerably lower baseline risk of being involved in a rail accident offsets any effect of dread.

4.2. Multiple-fatality versus single-fatality accidents

Another key finding of the UK transport safety research that ran counter to widely-held assumptions and the safety policy initially adopted by the UK rail industry was that, as far as members of the public are concerned, the prevailing view appears to be that the prevention of a statistical fatality in a large-scale multiple fatality accident does not warrant a higher value than is applied in the small-scale single fatality case. In light of this evidence the UK rail industry recently decided to apply a common VPF to all cases.

4.3. Transport versus other fatality risks

The application of the same VPF for small and large-scale rail accidents, together with the rail industry's decision to set this VPF equal to the DfT roads figure, reflects a more general tendency towards uniformity in the valuation of safety in UK public sector and related cost–benefit analysis. Thus, an underlying predisposition in favour of egalitarianism, together with evidence of the type just described indicating that dread tends to be offset by baseline risk, has led the UK Health and Safety Executive (HSE) to recommend that a common VPF should be applied in all contexts, regardless of considerations such as the age or income of those affected, the only exception being cancer for which the HSE argues

[21] See Chilton et al. (2006).

in favour of a value equal to double the standard figure – see Health and Safety Executive (1999). However the HSE has recently commissioned research aimed at investigating the extent to which latency (i.e. the delay between exposure to cancer-inducing conditions and the actual onset of the disease) may offset any arguments for a higher than normal rate for cancer. In addition, cancer typically entails an extended period of ill-health before death and this may not always be clearly distinguished from people's aversion to the prospect of death itself.

4.4. Values of safety independent of income and age

Considerations of egalitarianism have also led the Department for Transport, the Rail Industry and other UK public sector bodies to apply the same values of safety to all groups, regardless of the level of income, age or other personal characteristics of those affected by a safety improvement, in spite of the fact that empirical evidence clearly indicates that individual willingness-to-pay for safety is an increasing function of income and, at least beyond middle years, a decreasing function of age – see, for example, Jones-Lee (1989).

4.5. Stated-preference versus revealed-preference

Given the lack of data on actual (rather than hypothetical) individual wealth-risk tradeoffs in the transport context, virtually all of the empirical work on transport safety valuation in the UK has been based on the stated-preference contingent valuation approach. Not surprisingly, this work has almost invariably produced highly right-skewed distributions of individual valuations, with means that substantially exceed medians. Given doubts concerning the reliability of extreme upper-tail outliers, there has therefore been a tendency to base policy recommendations on a combination of trimmed means (computed with upper tail outliers removed) and medians, the most recent roads VPF being effectively set at the mid-point between the trimmed mean and median. This may go some way towards explaining why the UK roads VPF is only about half the US figure. However the US values are basically derived from revealed-preference data on labour market risk-related wage premia (see, for example, Viscusi & Aldy, 2003) and are therefore arguably more appropriately viewed as being willingness-to-accept (WTA), rather than willingness-to-pay (WTP)-based values. Given the extensive evidence indicating that WTA values typically exceed their WTP counterparts to a significant degree, this is almost certainly a major contributory factor to the differential between the UK and US roads VPFs.

4.6. The role of cost–benefit analysis in decision making and 'gross disproportion'

In safety expenditure decisions, particularly in the case of rail safety, which is subject to the ALARP and 'gross disproportion' criteria embodied in the Health and Safety at Work Act 1974, a considerable element of informed judgement is typically applied in assessing the implications of the results of a cost–benefit analysis for the acceptability (or otherwise) of a proposed safety project. This means that (quite appropriately, in the authors' opinion) the results of a CBA do not constitute the 'final word' on the acceptability of a road or rail transport project, but are nonetheless an important input to the decision-making process. On the other hand, there are those (again including the authors) who take the view that the high degree of imprecision and potential ambiguity associated with the term 'gross disproportion' *per se* could be fruitfully replaced with a more clearly specified set of requirements and criteria. As noted in Section 3, the term 'gross disproportion' originated in a 1949 Appeal Court ruling. A more recent legal judgement in 1954 omitted the term 'gross' and referred rather less ambiguously to 'disproportion'. Given that the values accorded to the prevention of rail fatalities and injuries have been increased in real terms about forty-fold since the original Appeal Court ruling, it would seem more appropriate to rely on the more recent legal judgement and require that a rail safety improvement should be undertaken only if the costs of doing so are not *disproportionate* to the expected benefits, that is if the project generates a positive net benefit, as under the standard CBA criterion.

4.7. Presentation of the UK transport department VPF

The UK Department for Transport presents its VPF in a potentially confusing way. The VPF is correctly defined and estimated as $VPF = WTP + NQ + MA$ where WTP denotes the willingness to pay component, NQ is the present value of the avoided loss of net output and MA is the avoided medical/ambulance costs per statistical fatality. But for presentational purposes the consumption, C, that would have been consumed by fatalities is subtracted from the measured WTP component and added to the loss of net output. Given that the sum of net output and consumption is, by definition, equal to gross output, GQ, the DfT then presents the VPF as $VPF = (WTP - C) + GQ + MA$.

The rather meaningless quantity $(WTP - C)$ is described as the "human cost" of a statistical fatality. This presentation conceals the true derivation of the VPF.

4.8. The need for face-to-face work for WTP valuation of safety

In our experience, developed with colleagues over a period of some forty tears, it is most important to ensure that any stated-preference study to shed light on the public's attitude to and valuation of safety should be carried out on a face-to-face basis (either individually or in small focus groups) by interviewers who have a clear understanding of the nature and purpose of the questions being posed. Only in this way will it be possible to ensure a) that respondents have ready access to an explanation and clarification of any points that they find confusing and b) that the research team is able to get some idea of the extent to which respondents have understood and given carefully-considered answers to the questions being asked. Face-to-face interviews or small focus group sessions also facilitate the provision of a clear explanation of *why* the study is being carried out (i.e. to ensure that full account can be taken of the public's preferences in decisions affecting public safety), which in our experience has appeared to greatly incentivise the provision of honest and carefully-considered answers by a substantial majority of respondents.

Given these arguments in favour of face-to-face interviews, as noted above we have serious doubts, despite one early apparent success, about the reliability of responses to safety-related surveys conducted over the internet. We would have similar reservations concerning any other safety survey procedure that does not involve direct face-to-face contact with respondents, such as postal or telephone-based surveys.

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