Judgements required in the defence domain when developing the value of an accident event when deciding on ALARP status.

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Abstract:

Frequently in projects, particularly when considering safety, there comes a time when costs have to be considered and decided upon. One area, which may be difficult to deal with, is the ethically sensitive area of the value of preventing a catastrophic event, typically a multi-fatality, system loss and/or environmental loss. This value can be used in cost-benefit analysis to determine between product options, or if a project should go ahead at all. It is also used as a major consideration when judging if some further mitigation should be applied to a risk position which is approaching as low as reasonably practicable (ALARP).

Very often the method of establishing this value utilises the UK Government Department for Transport (DfT) determined benefit value for the prevention of a fatality in a road traffic accident. Studies and reports discussing costs and values associated with accidents have been produced (Maguire, 2005; Maguire, 2007) and appear to indicate that the almost blind use of the DfT valuation across diverse industry systems may not be fully appropriate. The DfT valuation includes components limited to the property damage associated with road transport only; it contains values calculated from a wide societal group that includes persons below employable age; it includes data values from non-accident events; and it does not consider the impact of the cost of replacement resources.

This paper discusses the use of the DfT value of a prevented fatality as a value for cost-benefit analysis in wider industry in general and takes specific example from the military domain; it discusses the cost components of accidents, and extends existing guidance in determining appropriate values for analysis of proposed mitigation efforts.

Introduction

The DfT value of a prevented (single) fatality can be, and frequently is seen as the starting (and ending) point for judging the value of preventing a variety of accident severities. Although the DfT fatality is most usually considered under the typical definition of a ‘Critical’ (single fatality) event, the accepted practice of applying a logarithmic axis to the severity component of risk, allows for events of greater and lesser severity to be constructed from this starting position. The DfT value is made up of the following component parts (DfT, 2007);

Lost Output

This is calculated as the present value of the expected loss of earnings plus any non-wage payments that would have been paid by the victim’s employer (inclusive of salary, National Insurance and pension contributions etc.). This is averaged across

all recorded fatalities and is dependent on several factors, but mainly age and whether the victim was employed or not.

Medical Costs

This is calculated as the direct ambulance costs and the costs of the hospital treatment.

Human Costs

This is calculated based on a willingness-to-pay value. This itself is based on values which represent pain, grief and suffering to the casualties, their relatives and friends. Further, for fatalities it represents a value for the intrinsic loss of enjoyment of life over and above the consumption of goods and services.

Police Costs

This is calculated as the direct police costs for their attendance and investigation time following the accident.

Insurance and Admin Costs

This is calculated as the direct costs of paperwork administration within the local authority and the insurance firms – it does not represent the cost of insurance or any insurance pay out amounts.

Property Damage Costs

This is calculated as the direct cost of the damage to vehicles, road surface and property involved in the accident.

The most recent published information on these costs, for the year 2005, is presented in Table 1 below (ibid.);

Table 1: Average value of prevention per accident by severity and element of cost

Cost Element							
	Casualty related costs (£)			Accident related costs (£)			
Accident severity	Lost output	Medical & Ambulance	Human costs	Police costs	Insurance & Admin	Property damage	**TOTAL**
Fatal	547,290	5,450	1,080,290	1,660	260	9,830	1,644,790
Serious	21,920	13,130	149,030	230	160	4,460	188,920
Slight	2,660	1,130	12,660	50	100	2,650	19,250
All injury	13,070	2,700	45,490	100	110	2,980	64,440
Damage only				3	50	1,660	1,710

Judgements on the appropriateness and quantified magnitude of these component parts need to be made before they can be used in a dissimilar industry sector. A judgement on the additional inclusion of any components not applicable to the DfT values also needs to be made. The rest of this paper firstly reviews the need for making a judgement on the value of preventing accident events and then progresses

through an assessment of the main components where judgement is felt necessary.

The need for a value of preventing catastrophic events

Morally and legally, industry has to work to prevent accident events so far as is reasonably practicable. The test for what is reasonably practicable was set out in the Edwards vs. National Coal Board case in 1949 (Court of Appeal, 1949). The full legal definition is as follows;

"Reasonably practicable is a narrower term than physically possible … a computation must be made by the owner in which the quantum of risk is placed on one scale and the sacrifice involved in measures necessary for averting the risk (whether in money, time or trouble) is placed on the other, and that, if it be shown that there is a gross disproportion between them – the risk being insignificant in relation to the sacrifice – the defendants discharge the onus on them."

This case gives the requirement for carrying out a measure of risk in terms of money, time or trouble, AND comparing this to a measure of the sacrifice necessary to avert or mitigate the risk. In order to discharge this onus, a duty holder in charge of system risk first needs to establish a judgement of the value measure for the outcome of an accident event. The subsequent part concerns the cost of the sacrifice component, but this second judgement is beyond the scope of this paper and will not be considered further as it is very likely to be specific to individual projects.

The DfT value of a prevented accident is the transport industry's record of their judgement on the costs in monetary terms that represent the benefits which would be obtained by prevention of road traffic accidents (DfT, 2007). When carrying out appraisals of road schemes, these values are used to judge whether particular schemes can be approved or declined on financial grounds.

Each industry sector should carry out and record similar judgements that are appropriate to that industry sector, rather than copy across the judgements made in a completely different one. This paper will now consider the judgements required in the armed service industry. The methodology is suitable for any industry; however the defence industry is used as the example as it is the area where the author has the most experience.

Appropriateness and quantification of 'Loss of Output costs'

The loss of output component is based on the future contribution that would be made to society through the future employment of the victim(s). As all persons in the armed services are employed by the defence industry, so the component of loss of future output is appropriate for inclusion. The magnitude of this cost in the DfT judgement is primarily based on the age of the victim – the younger that person is, the higher the cost would be. The DfT does average out all the details from all the fatalities to arrive at a mean value. As all the persons in the armed services are employed, they are of employable age. This means that there are no children in the demographic of the armed services. This group form the largest proportion of victims from road traffic accidents, so the DfT figure for loss of output will have a significant proportion of its contribution from very young persons; those with the most output to be lost. The magnitude of this cost in the defence industry has been argued to be lower that the

DfT figure (Maguire, 2005). For a specific sub-demographic of the whole population that are already above employable age, the loss of output value should be lower, perhaps by as much as 50%. This factor quantifies the defence industry version of this component at £273,645.

Appropriateness and quantification of 'Medical and Ambulance costs'

This component is calculated in the DfT judgement from the direct costs of the ambulance, medical persons and hospital treatment given to the victims of the road traffic accident event. These are the costs of *civilian* medical provisions. A judgement has to be made as to whether these costs are transferable to the armed services industry. Certainly there are medical attendants, medical vehicles and hospital buildings/tents used to treat accident victims in the defence industry, so it is appropriate that this cost is included.

The judgement on the level of the figure attributed in the defence industry is more difficult to argue either way – higher or lower. Military hospitals do not have to support all the medical conditions of the general public – pregnancy, dementia, cancer, so would have lower overhead costs. However, many military accident victims still require medical evacuation from theatre in much the same way as an air-ambulance is used in civilian life. Also, many injured service personnel are treated in civilian medical establishments (whether that is a good thing or not is not part of this paper). With the range of opposing argument, it is recommended that the DfT cost can probably be applied on a like-for-like basis at £5450 per accident event.

Appropriateness and quantification of 'Human costs'

This component is arrived at from research into how much real cash the public would be willing to pay to avoid types of injury and distress. It includes a monetary amount that represents the grief, shock and emotional suffering of friends and relatives as a result of the injury event. It also contains an amount based on a monetary value for the enjoyment of life itself – obviously this is only included in the fatality class of injury (DfT, 2007). The first judgement here is whether a member of the armed services would be willing to pay at all to avoid (accidental) injury or a fatality. There is no specific research in this area, but common sense suggests to this author that no matter what sub-set of the population is considered, the highest majority would all be willing to pay something to avoid an accident event. It is therefore appropriate that this factor is included for the defence industry.

The next judgement is on what quantification should be allowed for this factor. It can not be argued that the amount that people would be willing to pay would be any different for this sub-set of the population than any other. The area that is not so clear is the amount that represents the grief and emotional suffering of the victim's friends and relations. The defence industry and armed forces are dangerous places to be – most of the equipment under use is designed specifically to be lethal. Accidents with lethal equipment may be considered to be of higher severity that accidents without lethal equipment in the mix. This is borne out by the order of magnitude difference in the statistics of accidental fatalities in several industries as recorded by the Health and Safety Commission (HSC, 2007) and the Defence Analytical Statistics Agency (DASA, 2008A), and summarised in Table 2 below.

Table 2: Rate of Fatal Injuries by Industry

Standard Industry Classification	2007 Rate of fatal injuries to workers by industry as reported to authorities (per 100,000 employees)
Agriculture, hunting, forestry and fishing (HSC, 2007)	6.1
Extractive and utility supply industries (HSC, 2007)	6.4
Manufacturing industries (HSC, 2007)	1.2
Construction (HSC, 2007)	4.0
Service industries (HSC, 2007)	0.4
Military service personnel – deaths due to accidents (DASA, 2008A)	42

Tragic and shocking as these numbers are, there is an argument that the level of risk is known by the armed forces personnel and also by their friends and relations. It may also be argued that the service personnel are compensated for being exposed to this risk. Whether that level of compensation is sufficient or not is not an objective of this paper.

With these two arguments in place concerning the acceptance and compensation of the risk of being in this particular employment sector (it will be different in other industries), it may be argued that the public grief and emotional suffering will be less for a service person than for a young child knocked off their bicycle and run over by a lorry. The judgement is: how much less? There is probably a whole paper on this point alone, so for the sake of brevity, the author proposes an arbitrary 20% reduction taking the DfT figure of £1.08m down to £864,232. However, I remain open to argument on this point.

Appropriateness and quantification of 'Police costs'

This factor is made up of the direct costs of the attendance and service of the police following an accident event. There are similar investigations following military accidents, so it seems appropriate that this cost factor is included. However, the judgement into the quantification needs some careful consideration. In the military, many accidental fatalities do result in public enquiry investigations. There is some evidence (Hadley Society, 2003) that public enquiries for planning issues cost in the order of £125,000. In the absence of any direct evidence of public enquiries into military fatalities, it is judged that this figure can be used as indicative. It should be noted however that public enquiries into high profile military accidents are likely to be significant, so it is suggested that specific military areas might want to re-judge this average figure for themselves.

Appropriateness and quantification of 'Insurance and Admin costs'

In the DfT example this factor is built from the direct costs of paperwork administration within the local authority and the insurance firms – it does not represent the cost of insurance or any insurance pay-out amounts. In a military-based injury or accident there may equally be the likelihood of insurance considerations. Agreed it may not be car insurance and claim assessing, but there are well known cases of injury payouts and these must be administered by someone. It appears appropriate that this factor is appropriate for use. The judgement on the magnitude of this factor can only recognise that this type of service is reasonably likely to be similar in nature whatever industry is involved. As such this factor should be applied at the DfT determined value of £260. This is actually pretty insignificant compared to the hundreds of thousands discussed above, but for completeness, it is included.

Appropriateness and quantification of 'Damage to property'

The DfT calculation for this component contains the direct cost of the physical equipment that is damaged, broken or lost as a result of the road traffic event. In any industry there is likely to be some material damage as a result of most accidents and especially those involving fatalities. So it is entirely appropriate for this component to be included in any industry's calculation of the value impact from an accident event. The real judgement for this factor is the quantification of the factor for the specific case of the military domain.

In the case of road traffic accidents the property and material that gets damaged is always related to private vehicles, some private property and some public owned property – e.g. the road surface, crash barriers, lamp-posts and that sort of thing. In the military domain and in other industries as well, the property involved during an accident is equipment rich. In 2007 ten aircraft assets were lost or badly damaged in air accidents (two fixed wing, eight rotary wing), nine people were killed and eight suffered major injuries (DASA, 2008Ab). There is no record of Land or Sea-based equipment that has been lost due to accidents – although common sense would indicate that there must have been some.

ASIDE: The definition of major injury in the military statistics is one which results in absence of more than 28 days, plus major bone fractures and second or third degree burns. This is not consistent with the RIDDOR definition, and a RIDDOR-based set may contain a higher number of major injury victims. The RIDDOR definition of major reportable injuries may be found in full via the HSE website (HSE, 2008), but in summary it includes additional injuries beyond fractures and burns including, dislocations, causes of unconsciousness, hypothermia, illnesses and any injury requiring admittance to a hospital for more than 24 hours.

To judge the quantified value of what this factor should be a review of the known equipment losses has to be carried out. The DASA statistics on fatalities in the UK regular armed forces (DASA, 2008A) indicate that there were 61 non-operational fatal incidents accounting for 67 deaths. Five of these incidents also resulted in the loss of seven of the aircraft noted above; the other three aircraft losses were as a result of three other non-injury incidents (DASA, 2008Ab).

An estimate for the contemporary value of the ten aircraft destroyed (2 Squirrels, 4

Pumas, and 1 each of Lynx, Hawk, Bell, Tornado and Hercules) is judged to be around £100M. Averaged over all the fatal and platform loss incidents, in the same way as the DfT averages the property damage over all road traffic incidents would give £1.56M each. This is some three-orders of magnitude higher than the DfT value.

In addition to these costs there were another 60 non-operational fatalities from 56 incidents. For completeness a value for the property and equipment loss from these incidents must also be judged. As noted above, there are no records of how much equipment was lost as a result of these incidents, but we must assume that equipment rich platforms are significantly more valuable than civilian road traffic vehicles, perhaps by as much as five times. This puts the value at £50,000 per incident, which multiplies up to a further £2.8M to the total to be averaged.

Averaging over the whole data set of 61 incidents and then added to the value from the air platform calculation. This gives a total property damage value of £1,685,246

Total value from the carried over DfT components

So far we have looked at the individual components and now is the time to present the summation.

Table 3: Summation of Components

Component	DfT component calculation for a fatality incident (£)	Component calculation for the defence industry fatality incident (£)
Loss of output	547,290	273,645
Medical and Ambulance	5,450	5,450
Human costs	1,080,290	864,232
Police costs	1,660	125,000
Insurance and admin costs	260	260
Damage to property	9,830	1,685,246
TOTAL	**1,644,790**	**2,953,833**

Discussion on additional considerations

The Highways Economics Note produced by the DfT does not contain an explicit definition of a road traffic accident. There is an assumption that everyone knows what a road accident actually is. Legal judgements on the causes of road accidents and the verdicts on fatalities are of more concern. Consider the following recent report of a road traffic accident:

"Mrs B was travelling on the A360 just south of Tilshead when Mr S's car crashed into hers. The inquest heard that Mr S was travelling in the opposite direction to Mrs B, in excess of 60mph limit and had overtaken on double white lines on the blind brow of a hill when the accident happened. A police investigation put the accident down to driver error on Mr S's part. The coroner said "The only lesson in this is for drivers not to overtake against a double white line system on any circumstances –

you cause not only your own death but someone else's as well." (Wiltshire Times, 2007)

The coroner's verdict on Mr S's fatality was death by misadventure, and the verdict on Mrs B's was unlawful killing (ibid.). Neither of the fatalities was judged to be an accident event. It is understood that the emergency servcies now refer to these events as "road traffic collisions" rather than "road traffic accidents" as the latter infers that there is no blame.

In this collision case, the full value of the DfT components would apply to the DfT accident data set. However, this was not an accidental event. From this example it is seen that the DfT data set contains all fatalities however caused and not just those that safety engineers would call the accidents.

It is likely that many of the components would simply keep the values as has already been defined above and be averaged out in the same way. There is no rich information on the property damage or medical cost values for the DASA fatality classes of killed-in-action and died-of wounds. In the absence of this, there is no justification for changing the average totals. However, if this information is known within specialist areas then it would be prudent to include them. Alternatively, it may be that the DfT data set should be stripped of the non-accident items. However, unless the new resulting set is particularly biased in the absence of fatalities, then there is unlikely to be a significant change in the average DfT values.

Another area that the author feels needs additional consideration is the potential inclusion of an additional component based on the cost of replacing the assets lost due to the incident. This is explicitly not included in the DfT values, as it is noted in the definition of the insurance component that it does not include a value of the insurance payout (DfT, 2007). This is probably because this cost is not borne by society, which is the whole rationale behind the DfT figures. However, in the industry specific case, the industry must provide some replacement of the lost assets if it wishes to continue providing that capability performed by that asset. So, it is certainly appropriate for industry specific values to have some component based on providing replacement assets.

The key judgements to make are what levels of value should be placed on this component, and as a forerunner to this, what assets should be included in the calculation. The main assets to be considered for inclusion are military equipment and military personnel. In some instances it can be that the personnel (e.g. specialist officers and pilots) are considered more valuable than equipment, in other instances, the relationship will be the other way around. However, the consideration should only be based on what assets would necessarily be specifically replaced as a result of the incident. The loss of specialist personnel is likely to require additional specialist personnel to be recruited and trained; this will have an additional cost. Prince William's military pilot training was recently reported as costing £162,000 (Daily Telegraph, 2008) and the cost of the 26 week training course for and Army Guardsman is quoted as £26,000 (British Army, 2008). These may be taken as indicative of the average costs of training new replacement personnel. The DASA statistics indicate that of the 160 deaths due to external causes, 18 were in the Navy, 127 were in the Army and 15 were in the RAF (DASA, 2008A). Using the pilot training figures for both RAF and Navy (as they both use expensive assets for training) and the Guardsman figures for Army personnel, the average cost of

replacement for a military person works out as £54,000 per replacement.

An amount to reflect the replacement of the equipment and property lost should also be considered. It is not clear that the DfT property damage in their figures were considered as the costs of the damage as full replacement costs, contemporary value of the asset at the time of the accident, or the costs when the property was new. The industry specific consideration of the property damage value already shown in this paper considered the contemporary value of the assets lost. The judgement has to be made whether an additional cost for the replacement of the asset should also be included. From the author's experience in the wider and the defence industry, two options are usually offered when considering replacement items. Either there were a number of spares bought or 'optioned' at the time of the original purchase, so a new item is commissioned from stores. Alternatively, the loss is mitigated in the short term and an additional item is procured at the next purchase opportunity in the future. In the first case, there is little additional cost to the programme – the equipment has already been purchased. In the second case, the incremental costs of one additional item at some time in the future may remain undetermined for a considerable length of time. In light of this discussion the author proposes not to include an equipment replacement cost, although, each area of the military or wider industry should make and record this argument for themselves.

Summary

This paper has shown that the use of the DfT determined value for the benefits of avoiding a fatality are not wholly transferable to other industry domains. Whilst it is appropriate that all the cost components do transfer, the magnitude of the costs as determined by the DfT does not. This is due to a number of reasons, as follows;

1. The demographic differences between the data set used for the DfT analysis and the specific demographic in specific industry types, in this case the military domain.

2. Due to the equipment-rich nature of the (military) specific domain, the cost component based on property damage is several orders higher in the specific industry calculation.

3. The costs of investigations and enquiries into accidental fatalities in industry may also significantly higher than in the public domain.

An additional factor of replacement costs is also likely to be a cost associated with an accident in industry. In the DfT calculation the insurance payout or costs of insurance are deliberately left out. Some allowance should be made in the industry-specific case. An additional £54,000 has been allowed for this factor.

Conclusion

The total for the defence industry value of preventing a (single) fatality accident for consideration in cost-benefit analyses typically associated with ALARP justifications is £3,007,883. This of course may be rounded to £3M. This value is approximately double the DfT value, which indicates that the direct carry-over of use in the defence industry should be treated with caution.

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Biography

Richard has over ten years of experience specialising in Safety Case Development, Human Factors Assessment and the Verification and Validation of Models and Simulations. He has gained his in-depth knowledge in three employment fields – his first role was designing, modelling and testing prototype safety systems for the auto industry. He then moved on to stress analysis and computational fluid dynamics modelling in oil and gas pipework systems. And finally, he is now a senior safety consultant in military and civilian domains, constructing and advising on safety cases, hazard assessments and system assurance arguments.

He has presented several papers in the UK, Europe and the USA, and has also been guest lecturer at Universities in London and Munich. Richard has been a chartered engineer since 1996 and is now a Director of an engineering consultancy working in

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