Written evidence from Professor Philip Thomas, Risk Management team at City University London (SLC 009)

**Personal statement**
My Risk Management team at City University London has developed a new method, the J-value framework, that is able to estimate objectively for the first time the maximum sum it is rational to spend on measures and systems to protect people and the environment. An up-to-date list of J-value papers and publications is given on the website, [www.jvalue.co.uk](http://www.jvalue.co.uk).

I have carried out risk development and appraisal work for several nuclear industry organisations (BNFL, MoD and EDF) and am currently Principal Investigator for a research contract under the UK-India Civil Nuclear Power Collaboration, with the UK component being funded by the Engineering and Physical Sciences Research Council. We are tasked with applying objective techniques such as the J-value to assess the post-accident mitigation measures desirable following a large nuclear accident such as Chernobyl or Fukushima. City is being supported by Manchester, Warwick and The Open Universities in the UK, and by the Atomic Energy Commission (AEC) in India.

I carried out a recent, preliminary appraisal of level crossing safety in connection with discussions and a small contract laid on City University London by First Group.

**Summary**
My evidence reviews the problem of level-crossing safety, and considers how to assess the amount that should be spent on uprating safety against the background of UK and international safety law. The principles of cost-benefit analysis (CBA) are considered, including the difficult question of how to value human life. The current rail industry practice is reviewed, and deficiencies in the approach are pointed out. It is shown that a CBA using the DfT value of a prevented fatality (VPF) will understate the safety benefit of a measure to reduce level-crossing risk. The J-value method is recommended as a fully objective and better technique for assessing level-crossing safety upgrades.

**Evidence: Assessing methods of improving level crossing safety**

**The risks associated with level crossings**
1. Level crossings allow pedestrians and road vehicles to cross the track along which passenger and goods trains may run at high speed. Permitting trains and road users to use the same piece of ground creates a hazard for:
   - pedestrians
   - road vehicle drivers
   - road vehicle passengers
   - train drivers
   - train passengers, as well as, potentially
   - those living nearby.

This was illustrated well by the collision at the Ufton Automatic Half Barrier Level Crossing near Reading, early in the evening of 6 November 2004. A London to Plymouth train travelling at just less than 100 mph struck a Mazda 323 car that was stationary on the crossing. The car was destroyed and the train suffered a massive derailment. 7 people were killed (car driver, train driver, 5 train passengers), 18 train passengers were badly injured and 53 train passengers suffered more minor injuries. (Rail Safety and Standards Board, 2005). Moreover, although only on-site damage and human harm were caused at Ufton, train crashes can have the potential to cause off-site damage and injury, as demonstrated by Canada's Lac-Megantic recent rail tragedy (BBC, 2013).
2. However, the existence of a hazard does not of itself mean that the hazardous activity should be discontinued. Key additional factors are the expected frequency of occurrence and the cost of the countermeasures that would be needed to reduce that frequency to a lower level. In the case of level crossings, the frequency might be reduced by replacing half barriers by full barriers and might be eliminated more or less entirely by the provision of a bridge and fences. The question is then to balance the cost of the provision by the reduction in the frequency of the adverse consequences: are the gain in safety and reduced financial loss worth it? Or is the installation safe enough already?

Legal requirements
3. The Health and Safety At Work Act 1974 sets down, for most work situations, how to determine when the current level of safety is satisfactory. This Act puts duties on employers to safeguard the health, safety and welfare of their workers and to control risks to the health and safety of those not their employ so far as is reasonably practicable (SFAIRP). The precedent for this requirement was set in the Court of Appeal by Lord Justice Asquith in the case of Edwards v. National Coal Board (All England Reports, 1949). The judge mandated that risks should always be reduced unless the employer could demonstrate that there was "gross disproportion" between the sacrifice (money, time, trouble) of implementation and the benefits, in terms of greater safety or reduced risks, the sacrifice being greater.

4. The requirement of "gross disproportion" creates an imbalance in favour of safety that is not unique to the UK. In the USA, despite the landmark judgment of Judge Learned Hand in United States v Carroll Towing Co. (Second Series of the Federal Reports, USA, Court of the Second Circuit, 1947), in which he deemed strict proportionality to be acceptable for protection schemes, the concept of disproportion appears to be reflected in other verdicts in US courts. For example, the jury in the civil case Grimshaw v Ford Motor Company rejected the company's contention that the disproportion factor needed to sanction the safety expenditure would be too great at 2.8, and found against the Ford Motor Company (Third Series of Court of Appeal Reports, USA, 1981). In the UK, inspectors of the Health and Safety Executive (HSE) may insist on a sacrifice, in regard to a safety measures against a high risk, that is between twice and ten times the benefit in terms of risk averted. [These figures have never been tested in a court but were accepted at the Public Inquiries held in the 1980s and early 1990s into the PWRs that were built at Sizewell B and contemplated for Hinkley C (Office of Nuclear Regulation, 2009)].
Cost-benefit analysis

5. While in many cases there is sufficient good practice to determine the necessary safety measures, it is sometimes necessary to carry out a direct comparison of the sacrifice with the risk averted. Such a comparison requires a common measure and in general this is money, with the comparison being a form of cost-benefit analysis (CBA). Here one of the significant difficulties is putting a value on the direct effects on people, viz. injury, ill-health and death. These aspects are rarely thought of in a financial form in general public discourse. Moreover, although courts may offer compensatory amounts to the injured and to the relatives of the dead, this has not been found to provide a good guide to how much such be spent a priori (Thomas and Vaughan, 2013). But finding a sound, well-established figure for the values people put on their life is essential for CBA.

What is life worth?

6. Placing a value on a good is a simple matter when there is a market in that good — it is simply the price on which the buyer and the seller agree. But placing a price on a non-market good such as clean air or the continued survival of a rare plant species is more difficult. Human life falls into this second category, for which two approaches are possible: revealed preferences and stated preferences. Revealed preference methods deduce the worth of the good from people's actions, and are thus fully in sympathy with the precept of the philosopher, John Locke:

"I have always thought the actions of men the best interpreters of their thoughts".

Stated preferences, which rely on what people say rather than what they are observed to do, run the risk of the person shading his response to fit what he thinks he should say or what it is advantageous for him to say. Thus Levitt and Dubner (2005) suggest that

"The gulf between the information we publicly proclaim and the information we know to be true is often vast. (Or, put a more familiar way: we say one thing and do another.) This can be seen in personal relationships, in commercial transactions, and of course in politics."

7. The UK rail industry relies for its valuation of life on the "value of a prevented fatality (VPF)" published by the Department for Transport. There are concerns about the concept of a single-valued VPF, since what we can expect to lose if we are killed is our expected life to come, and this differs between young and old, between the genders and between workers and the general public (Thomas and Vaughan, 2013). However, the gap between the VPF and what should be measured can be bridged in some cases (although not all, e.g. school bus safety, breast cancer treatments) by assuming the VPF to represent an average value across the UK population.

8. The DfT's VPF is based on a stated preference study published in 1999 (Carthy et al., 1999), following that team's decision not to recommend the results of their first stated preference study, published a year earlier (Beattie et al., 1998), where the authors stated that the form of the question had a great influence on the answers given:

"it would appear that the VOSL [value of a statistical life, a synonym for VPF] can be more or less arbitrarily inflated or deflated simply by manipulating the magnitude of the risk reduction in the CV [contingent valuation, a synonym for opinion survey] question concerned."
Problems of opinion censoring in the DfT VPF

9. Problems remain, however, with the DfT VPF based on the 1999 paper. In contrast to the 1998 paper, the later paper censored many people's opinions on the way to finding its VPF, choosing to ignore altogether the opinions of about 10% of the 167 people in the sample. But, as a general point, the analyst is entitled to downgrade or discard opinions only if those offering the opinions are unqualified to do so. Those legitimately disqualified may include the insane, those without the necessary knowledge or experience and those trying deliberately to subvert the aims of the study. The rest of the people in the survey need to be treated on an equal rights basis – the opinion of each person should be accorded the same worth as everyone else's in the survey, no more, no less. For who is to decide which views should be given higher weightings? Not the analyst, because he does not know what the correct valuation is – he will not know until after he has analysed the results of the survey in order to find out. Not the other participants, who presumably would each give the highest weightings to their own and similar views, and the lowest weightings to views with which they personally disagreed most.

10. The chosen mean should not impose any structural bias whereby the size of the views results in some of those views being favoured over others. It is proved in Thomas (2013) that the only way of protecting the analyst from the charge of bias is for him to use the well known and conventional sample mean: add up the views of all the people in the sample, without exception, and divide the sum by their number.

11. "Trimming" of means is a procedure intended to reduce the influence of outliers in measurements by rejecting data points in pairs. It is not a valid procedure for applying to human opinions because of its violation of the concept of structural view independence – the equal rights philosophy outlined above (Thomas, 2013). Trimming is, however, sometimes used as a rule of thumb in applications involving repeated but unreliable physical measurements, where the idea is that some degree of compensation for the censoring of an outlier is achieved by rejecting a data point at the other end of the spectrum. Thus the term, "trimmed mean", denotes the arithmetic average of a sample subjected to a double-sided reduction in size: the same number of measurements is taken from the bottom end of the range as from the top end (Rice, 2007). While the authors of the 1999 paper describe their final VPF as a "trimmed mean", in fact they use single-sided censoring, rejecting the top 10% of the sample without attempting to make a compensating rejection of the bottom 10%. On this basis, and on its own terms, the DfT VPF can be expected to have an inherent bias towards putting too low a value on human life.

12. In the past the UK rail industry used to apply a factor of 2.8 to the VPF used in CBA analyses that could involve multiple fatalities such as a level-crossing accident, thus including an allowance for gross disproportion. However the rail industry dropped that multiplier a few years ago, and now uses the DfT VPF without uprating. But any CBA applied to level crossings using the unmodified DfT VPF can be expected to underestimate the value of a safety measure as opposed to its cost.

Applying the J-value framework to level crossing safety and loss

13. The J-value provides an objective assessment tool which can be applied across all industries. It is a new approach, but it is based on established economic theory. The J-value has the considerable advantage when compared with other methods, such as conventional CBA, that no explicit assumptions have to be made about the difficult issue of the monetary value to be attached to saving a human life. Also, unlike other approaches, the J-value allows immediate fatalities and potential loss of life in the longer term (such as when the hazard includes exposure to a carcinogen that might be carried on a goods train), to be measured on the same scale. Ways to reduce risks can then have their cost effectiveness assessed fairly.
14. The J-value balances safety spend against the extension of life expectancy it brings about. At the core of J-value is the concept of the life-quality index (Nathwani et al., 2009), placing a monetary value on all future years of life based on discounted income, the share of wages in the economy and the work-life balance (ratio of time spent working to time not working). The J-value is found by dividing the actual cost of the safety measure by the maximum that it is reasonable to spend. A value of less than one indicates that the spend is justified. A value greater than one suggests that spending resources may not be justified. The objective decision is then simple. If the J-value is much more than one, the starting point for any decision is that the resources should not be committed to reducing this risk. If it is less than one, there is a strong case to be made for spending money.

15. The J-value approach has been extended so that it can take account of not only health and safety risks but environmental consequences also. Thus, for example, the J-value framework can assess how much resource might be committed cost-effectively to reducing the risk of level crossing accidents involving off-site damage (as in the case of the Lac-Megantic rail crash), both in terms of impact on human health and the environmental losses that might be associated with such events.

**Improved Life Expectancy versus Prevented Fatality**

16. As noted above, improved life expectancy is a much better characterisation of the benefits to be gained from a safety system than "lives saved". In fact, nobody's life can ever be saved: the best that can be done is to return an individual's life expectancy back to what it was in the absence of the specific hazard being considered.

**Objectivity of J-value Input Parameters**

17. Input parameters to the J-value are all measurable economic and actuarial parameters: GDP per head, share of wages in GDP, work-life balance, the characteristics of the exposed population, such as initial life-expectancy, the probability of the risk occurring without the proposed safety measure, the cost of the safety measure and the residual probability of occurrence.

**Making the Best Overall Use of Resources**

18. One important feature of the J-value is that it allows a level playing field to be defined across all industries. By using the extension in life expectancy as a measure, the J-Value can put level-crossing safety on the same footing as medical treatments, fire safety, transport safety generally, nuclear safety, or the safety of chemical plant.

**Factoring Wider Considerations into the Decision**

19. It is, of course, accepted that both industry and Government may wish to take account of other factors when making decisions about how best to use resources to reduce risk on level crossings. These might include socio-political issues and corporate considerations, such as the avoidance of negative and damaging public perception. However, the J-value allows a clear baseline to be defined. Then if other considerations have an influence on the final decision, these can be viewed in an open and transparent way against the backdrop of an objective assessment of how best to use scarce resources.

**References**

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