

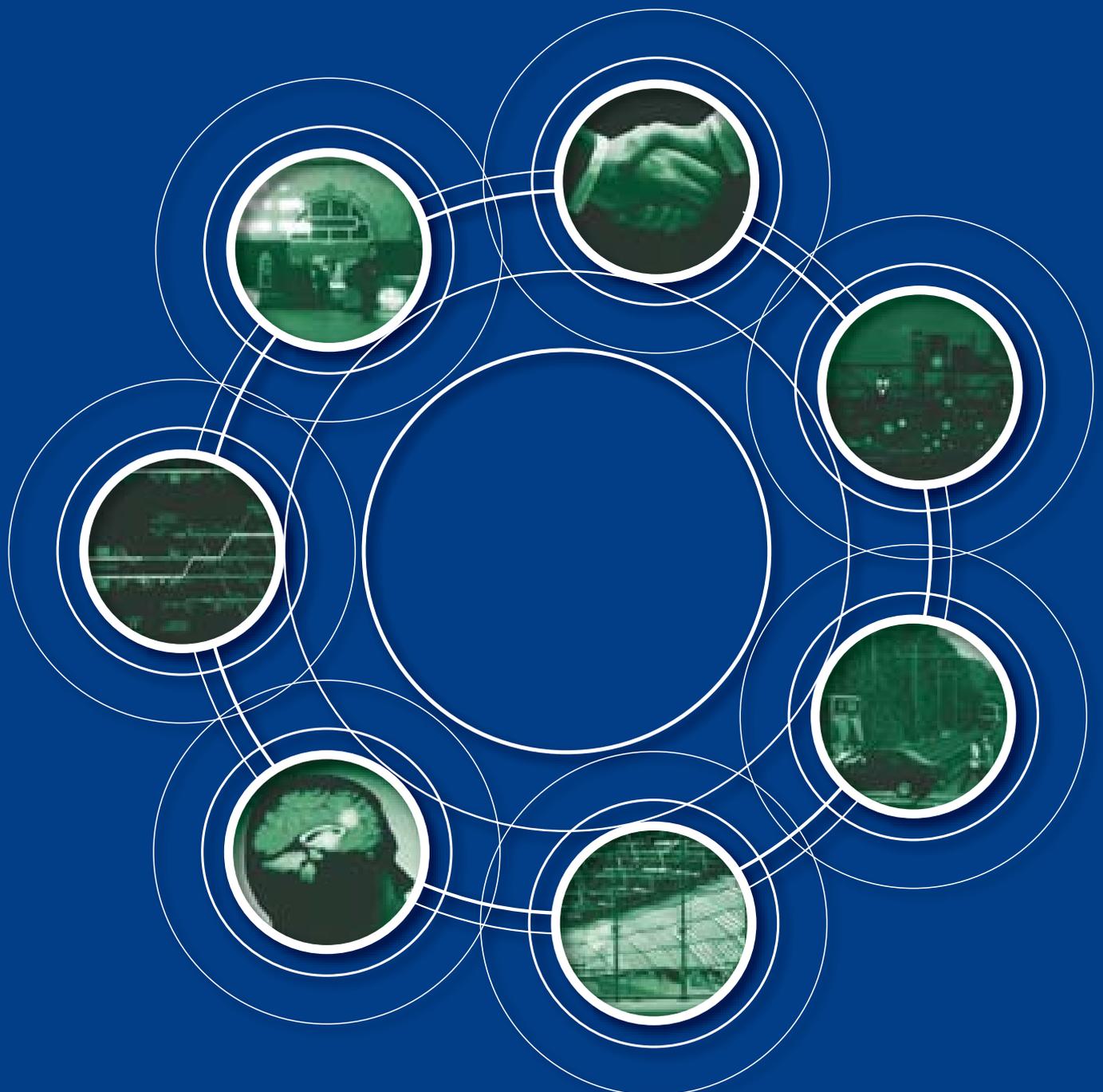


Rail Safety & Standards Board

Research Programme

Management

Principles of decision making - Modelling societal concern for the rail industry





Principles of decision making – Modelling societal concern for the rail industry

Research aims

The purpose of this paper is to outline Rail Safety and Standards Board's (RSSB's) response to the attached report, and to summarise the actions being taken by RSSB.

The report was commissioned under the Railway Safety Research Programme (RSRP), and prepared by Risk Solutions. The aim of the work was to investigate the feasibility of providing a practical tool, which can be used to gauge the relative significance of societal concerns about different types of accidents in the rail industry.

Risk Solutions combined literature reviews and original thinking to build on work previously carried out for the Health and Safety Executive (HSE) to provide a tool for comparing the concerns about accidents in different industries. Whilst there is a vast literature available on the factors which influence people's reactions to accidents with different characteristics, there is a notable absence of work which has proposed ways of converting this body of academic knowledge into practical tools which can assist decision makers in real situations.

This report contributes to the suite of projects aimed at resolving the underlying challenges that the industry faces in making the right decisions about investments and operations, which affect safety. These challenges arise from the context of the legal framework, stakeholders with differing objectives, as well as the practices, perceptions and incentives within the industry, its funders and regulators. RSSB is leading the pulling together of these projects, in consultation with industry and other stakeholders with the aim of achieving a practical, agreed

and consistent approach to decision making.

One of the issues on which clarity is being developed is the list of factors that decision makers should take into account. For many decisions, which affect safety, a relatively straightforward view on the balance of safety, performance and financial impacts is appropriate. However, there may be circumstances where other less tangible factors such as those considered within this report rightly have an influence.

RSSB welcomes this study, which has proposed one potential method for taking a view on some of these softer and more subjective factors, which can influence a decision on safety. Whilst the model would appear to be an attempt to quantify these soft factors, it must be recognised that the intention is not to reduce what is a complex issue into a number, which can be plugged into a quantitative analysis as input to a decision. The aim is rather that by taking a semi-quantitative view, decision makers could be presented with a picture which represents the levels of concern about particular accident types relative to one another, and therefore providing more information for them to determine the extent to which their decision is affected by these softer factors. Although industry stakeholders have reviewed the model, it is important to note that at this stage the model is a proposal, which has yet to be fully tested for the feasibility of capturing public views, and being used by decision makers.

Next steps

The next steps in this area are for RSSB, together with stakeholders, to review this work alongside other research that has been commissioned to develop alternatives



and against the findings emerging from discussions with the HSE on the factors that duty holders are expected to take into account. Further development and feasibility work would then be required to take forward the concepts before they can be incorporated into the emerging guidance on decision-making, which will be published by RSSB. Key elements of any further development would include:

- A further review of the six high-level concern factors against other work, and with decision makers to determine that they are the right factors to take into account, and to create a clear reasoning for why they are valid. In particular the size of accident factor is of a different nature to the other five, which are more directly about people's reactions rather than a given attribute of an accident.
- The design and testing of the method for obtaining inputs from members of the public must ensure that valid results are obtained, but also that the process of obtaining views does not in itself heighten concern about the safety of the railway.
- Discussions with those industry decision makers who are the potential users of the outputs from the model, in order to determine the circumstances in which it would add value, and the manner in which it would be used.

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RISK SOLUTIONS

Modelling Societal Concern for the Rail Industry

A report for RSSB

March 2004

T224 Pt 5

Issue 2

Executive Summary

Safety decision making is a key research topic in the Rail Safety and Standards Board (RSSB) research programme. The HSE guidance document Reducing Risks Protecting People introduced the concept of “societal concern” as a factor that should be evaluated in determining whether or not an organisation is managing safety to as low as reasonably practicable (ALARP). As a result RSSB is undertaking research into how evaluation of societal concern can be incorporated into their safety decision making framework.

The work reported here has been undertaken by Risk Solutions and builds on our previous research experience of modelling societal concern for the HSE. This previous work was completed in May 2002 and subject to external peer review by the HSE. As a result of the, in parts sceptical, feedback from the peer review process the HSE has not pursued this avenue of research further. However, following a presentation to RSSB on our overall philosophy/approach in attempting to model societal concern and a demonstration of the work to date, interest was expressed in exploring whether or not something could be done that could be applied to the railway industry. This report is the result of the feasibility or “proof of concept” work that Risk Solutions has undertaken in support of this.

In developing a model of societal concern for application to the railway industry we have addressed the criticisms of the previous work that emerged from the HSE’s peer review process. This involved bringing the literature review up to date, changing the model structure and construct to be simpler and more transparent, and clarifying how the numerical scores generated by the model are derived.

The literature review involved identifying all the factors believed to affect societal concern. In the event we were reassured that no additional factors were identified that we had not previously identified. The academic literature on societal concern can be grouped into three camps. The first group believe that societal concern is driven by the ‘psychometric paradigm’ which is, in turn driven by cognitive and psychological processes. The second camp advocates the application of ‘cultural theory’ in understanding societal concern whereby an individual’s perception of risk is driven by the social aggregate of which they are a part. The third camp believes that predicting societal concern mechanistically is not possible as it is driven by too many unrelated factors. The main point here is that there is no general consensus on how societal concern should be measured or addressed.

From our research nobody has attempted to model societal concern in a form that can be used to inform safety decision making. In this respect the work reported here is entirely innovative.

The starting premise of our work is that in order to understand what society is concerned about you must ask them. What our model does is provide a framework that will allow us to ask society what it is concerned about, but in a comprehensive and systematic way. In this way the attitudes of different ‘societies’ and changes in societal concern over time can be tested against a consistent framework or benchmark. For this to work we must be confident that all the factors that can influence societal concern are included in the framework and on the basis of our literature review we have confidence that this is the case.

Basically our model considers societal concern to be driven by two main dimensions:

- Dread
- Beliefs and/or values

The first dimension is to do with characteristics of the risk and the psychological or reactive response to this. We characterise this by the following factors:

- Scale or size of the risk
- The repugnant nature of the harm caused by the risk
- The extent to which there is evidence that the risk is ‘real’ or immediate rather than theoretical

The second dimension relates to people’s moral or political positions and how this can influence their concerns. We capture this by the following characteristic factors:

- Extent to which they have choice over their exposure to the risk
- The extent to which they trust third parties to communicate the risks and manage them effectively
- The perceived equity or fairness associated with the risk exposure to society

We presented our initial thinking on this topic to a selection of RSSB staff in March 2004 and tested an early version of the model by running a ‘mock’ focus group workshop. In this workshop we considered a set of scenarios that had been developed to represent types of hazardous events, as described in the Safety Risk Model, and scored the societal concern factors according to guidance we provided. The results from this initial exercise provided valuable feedback on (a) whether or not the set of societal concern factors was comprehensive, (b) how easy it was to interpret the parameter descriptions and the guidance on scoring to be applied, and (c) whether or not the outputs provided something useful that could be used to inform safety decision making. The model was revised in line with the constructive feedback received at the workshop and this has been provided to RSSB in the form of a beta test /evaluation version.

In light of the experience from our efforts on this research and the feedback from the workshop, we believe the model we have produced is worth taking forward. We consider that the use of scenarios or stories to capture groups of SRM hazardous events will enable societal concern around safety issues on the railway to be explored in a way that is meaningful to the general public, and that the model could then be used to explore the relative importance of each scenario from a 'societal concern' perspective, as opposed to the hard quantitative information that is readily available in the Railway Group Safety Plan.

To this end we have recommended further research activities to:

- Validate the societal concern framework and construct
- Develop a set of scenarios that fully captures all the SRM hazardous events
- Undertake a piece of research into the management responses that are possible against each of the societal concern drivers, and under what circumstances they may be considered.
- Apply the model in a series of workshops so that the societal concern associated with each of the scenarios developed by the previous activity can be evaluated, and use the results from this to rank the scenarios from a societal concern perspective.
- For those scenarios deemed to have high societal concern, use the model outputs to evaluate the reasons behind this.

Title	Modelling Societal Concern for the Rail Industry
Customer	RSSB
Customer reference	T224 Pt 5

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1 Introduction

Safety decision making in the railway industry is based on guidance provided by the Health and Safety Executive (HSE) in its publication Reducing Risks Protecting People (R2P2). This guidance indicates how organisations should be evaluated in order to determine whether or not they are discharging their health and safety management obligations under the Health and Safety at Work etc Act 1974. The guidance also indicates how risks should be managed in order to meet the as low as reasonably practicable (ALARP) requirement.

In R2P2 the HSE indicate that societal concern should be taken into account, together with individual risk, in determining whether or not a risk is being managed to ALARP. The Railway Group Safety Plan 2003/04 describes how the railway industry has interpreted this in order to inform safety decision making. Specifically the railway group uses the financial measure of £1.30 million per equivalent fatality saved for prevention of single fatalities and a higher value of £3.64 million per equivalent fatality saved for prevention of multiple fatalities or where risk is close to intolerable. In this sense the higher value placed on equivalent fatalities for multiple fatality incidents is a proxy for the perception that there is higher societal concern associated with such scenarios.

Whilst the rationale for constructing a safety decision making framework in this fashion can be presented, there has been considerable controversy about the application of a higher VPF value as a proxy for societal concern. Consequently RSSB are keen to undertake research into other ways in which societal concern can be incorporated into the industry's safety decision making framework.

Risk Solutions undertook some research for the HSE, completed in May 2002, into how societal concern could be evaluated or modelled. This research resulted in the construction of a tool that captured all the factors understood to have some impact on societal concern, and attempted to combine these factors in a meaningful way so that a measure of societal concern for a particular issue could be determined. In practice the tool worked as a vehicle for eliciting views or beliefs about the relative importance of the individual factors, and modelled how these factors combined to give a measure of societal concern. A critical underlying assumption in the work was that in order to determine how concerned society is about a particular issue you need to ask them!

The tool (*hereafter referred to as the 'HSE model' although this should not be interpreted as meaning it has been endorsed by the HSE*) was developed as a "proof of concept" in order to explore whether or not there was some potential for taking it forward and developing it further. To this end the model was used in several small 'focus-type' groups involving HSE staff and subsequently the HSC. At the time there was considerable enthusiasm for taking the work forward and the HSE were keen to explore whether or not it could be used to help them internally to prioritise their future research programme. With this in mind the HSE submitted the work to date to independent peer review. Unfortunately some of the peer review comments were

critical of certain aspects of the model and, as a result, the HSE have not progressed the work further.

Despite the HSE experience, RSSB wanted to explore whether or not there was any mileage in adapting or refining the approach previously developed – for application to the railway industry. This was tested in a workshop held in January 2004, where we presented the overall approach and discussed how it could be adapted. As a result of the feedback from this workshop, we were invited to submit a proposal for taking the work forward.

This report is the main deliverable from the research commissioned against our proposal.

There are five main parts to this work and this is reflected in the structure of the report. Firstly we felt that the criticisms levelled at our approach by the HSE's peer reviewers needed to be addressed. A summary of the main points raised by the peer reviewers is provided in section 2 where we also indicate our response to these criticisms and how they have been addressed in the new model.

A specific aspect of the HSE model that was criticised was the method that was used to propagate scores up through the model. In particular there was concern that we had not been open enough in determining how the scores should be propagated and the validity of the selected approach. We address this point in section 3 where we have developed an approach for the RSSB model that is completely transparent, can be modified and controlled by the user, and present our justification for why this approach meets the needs of the model.

The RSSB model is considerably simpler than the HSE model. The structure of the new model is presented in section 4 where we also describe the parameters that have been used to construct the model. Section 5 provides some guidance on how the model should be used. Finally in section 5 we suggest ways in which the model could be used in the context of safety decision making in the railway industry and the implications for further work which are then, in turn, articulated in the recommendations in section 6.

We have also included four Appendices. The first provides a bibliography of literature relevant to our research, the second gives a detailed description of the functions and operation of the beta version of the spreadsheet model, the third details the scenarios developed for use in our workshop held with RSSB staff in March 2004 and the fourth shows the modelled results of that workshop.

2 Literature Review and Response to Peer Review

2.1 Introduction

The original model that we developed for the HSE was subject to their peer review exercise. This involved five reviewers; we believe both internal to the HSE and external experts in the field of research about societal concern about risk. The reviewers responded anonymously, with the exception of Dr Andrew Weyman. Three of the reviewers expressed concern that the body of literature reviewed was too limited, and helpfully provided further references. We have addressed this concern by widening the literature review, and our findings are described below. A full bibliography of references is provided in Appendix 1.

The second common theme amongst the reviewers was concern over the lack of validation of the HSE model. We freely acknowledge that this was the case – indeed the model development was only ever considered to be a first stage and we made clear in our report to the HSE that much further work to validate the model would be required, involving focus groups and possibly questionnaires. To date this has not been carried out.

Section 2.2 contains a table summarising the main peer review comments, together with how we addressed them in development of the model for the rail industry. Section 2.3 covers our main findings from the widened literature review, while Section 2.4 describes the impact of these findings on the parameters we included in the model we developed for the rail industry.

2.2 Peer Review Comments and Our Responses

	Comment Summary	Our Response
Reviewer 1: Dr Andrew Weyman		
1.1	More work is needed to turn the model into a usable tool.	We agree, and hoped to do more work on this for the HSE
1.2	From the final report, it is not clear whether model is to be used for prescriptive or descriptive purposes. The way the tool could be used to aid decision-making does not come across in report.	We will make clear our recommendations on how the rail industry model should be taken forward and the uses to which it can be put, see Section 6 of this report.
1.3	Recommends a number of references to bolster literature review.	We have followed these recommendations and included the references in our bibliography.
1.4	The model is too complicated – unless it is simpler and more transparent it will not be understood and accepted by the public. Simple models may be just as accurate because there is no right way of propagating scores through the logic tree. Underlying elements could be given equal weights and simply added – this can give just as good results as more complex combination methods.	We have created a considerably simpler model for the rail industry. We have considered in detail the propagation methods, see Section 3 of this report.
1.5	Model should be seen as a starting point for further discussion and research. Need to appreciate how the model represents the “risk game” (1, 58).	We agree.
Reviewer 2		
2.1	The model is poorly justified, alternative structures have been ignored and multiple representations of particular gates and parameters have undue influence on model output.	We had considered alternative structures, but this may not have come across in the final report. We have reviewed how multiple representations of the same parameter impacted on the model and used a different approach for the rail industry model – each parameter feeds into the model only once.
2.2	Sample size for testing is not statistically representative	We had not conducted a full model validation exercise, which was recommended as a further piece of work.

	Comment Summary	Our Response
2.3	The model is fundamentally flawed.	No answer to this one, apart from Reviewer 3's comment 3.1 below!
2.4	Critical of the guidance given and how the anchors of the scales are defined.	We have carefully reviewed the use of anchors and developed a completely new set for the rail industry model, appropriate to the railway context.
2.5	Critical of the use of the spider diagram outputs, as the graphs can be sensitive to relatively small changes in inputs.	The six parameters illustrated on the spider diagram in the rail industry model are now selected from the same level in the model hierarchy, so carry similar weight within the model. The individual parameters shown on the diagram all depend on other user inputs. However the graphs may still be sensitive to relatively small changes in these inputs, dependent on the alpha values chosen. This is a real effect, which should reflect the fact that levels of concern may be particularly sensitive to certain issues.
Reviewer 3		
3.1	Does not think the approach is fundamentally flawed (esp. the use of fault tree idea).	Contradicts comment 2.3!
3.2	Concerned primarily with model validation or lack of it.	See 2.2
3.3	The process of combining factors through gates leads to averaging, so that the more gates between the bottom and top the less its impact on the final numbers. This therefore makes the precise hierarchy of the various gates critical.	We agree. The far simpler structure of the new model, with a maximum of 5 hierarchical levels addresses this issue.
3.4	Concerned that the 'second tier' gates, while supposed to be largely independent, are too closely linked with gates in common, so are actually correlated.	All the branches of our new model are now entirely independent in terms of the factors that feed into them – no factor feeds into the model in more than one place (although there may be correlations in reality between some of the factors), so this problem has been resolved.
3.5	Sensitivity to some parameters is very low.	We have addressed this in our new model through the use of a simpler structure. The selected α -value (see Section 3 of the report) will affect the sensitivity of the overall scores to individual values. The more 'OR-like' a gate, the more sensitive the model will be to the parameters that feed into it.

	Comment Summary	Our Response
3.6	Need more justification of why particular parameters have been selected for showing on the spider diagrams.	The original spider diagram in the HSE model showed factors from different levels of the hierarchy, but which were considered through literature review to reflect key aspects of societal concern. The new model keeps all these key factors at a single tier of the model, which makes more sense, and these are the factors shown on the spider diagram.
Reviewer 4		
4.1	The approach of putting the various broad concern factors into a logic-gate based model to be fundamentally flawed as this structure does not represent the way people actually think about and relate to risk. As such it is imposing a false structure.	We were not specifically attempting to model the cognitive processes used by individuals in assessing their level of concern. However we do hope that through calibrating the model it will act as a useful tool to rank concern levels.
4.2	The model does not reflect the many different types of harm that could result from a particular situation, about which people will have different views and concerns.	We agree. For this reason we have decided to express each issue or situation in terms of a scenario, providing an opportunity to consider different types of harm. Different types of harm are now explicitly included as factors in the model.
4.3	The model misses out on important aspects of how society and individuals respond to risk issues, particularly in terms of context dependence.	We have modified the way issues are presented to those using the model. We now recommend that scenarios are developed that provide contextual information to help people understand the situation and respond to it.
4.4	The model is not sensitive to the multidimensionality of trust, which has its own internal structure (40 – a reference published after the HSE model was produced).	We have explored various aspects of trust within the new model.
4.5	The spider diagrams are interesting and thought provoking. The idea of the model as a tool to stimulate and structure focus group type discussions is useful. This could be a way forward for using it. It could be used to take frequent ‘testings’ of opinion as new risk issues emerge – based on hybrid groups containing a range of experts and members of other stakeholder groups. It could also be used as a tool to support group discussions and results fed back into the conversation in some sort of problem structuring workshop.	We agree. We have found the tool to be very interesting as a way of getting people to think more deeply about an issue. The precise way the tool can be used is discussed in Section 6 of this report.

	Comment Summary	Our Response
4.6	Recommends a large extra body of literature.	Listed in the bibliography in Appendix 1 of this report.
Reviewer 5		
5.1	Generally supportive of the objective of the tool in principle and the approach in general.	Good!
5.2	The literature base used is restricted, and the approach uncritical. Needs a wider database for framing the basic data-input questions used. More validation needed.	We have widened the literature review. We agree that more validation is required.
5.3	Scales are ambiguous and may be difficult for respondents to answer without very careful wording. Phrasing of the ‘risk issue’ under consideration will also be critical to the responses obtained. Therefore needs extensive piloting.	We have revised the scales, testing them in our workshop (with only industry experts present) and revising them again in light of this experience. We have also given considerable thought to the phrasing of the issues and settled on the concept of scenarios to provide context. However we agree with the need for extensive piloting, see Section 6 of this report.
5.4	Need to consider more carefully which of the factors should be incorporated for normative purposes – just because people believe something does not mean this is the right basis for policy-making e.g. at the extreme, racist/ sexist beliefs.	See Section 6 of this report.
5.5	Criticises the arbitrary nature of the tree structure. Implicit weighting according to the tier in the tree that a factor appears. Spider diagram is misleading because the 6 axes chosen do not actually all have equal weight in determining the overall concern measure – some of the axes have a much greater influence on the overall concern index.	We have taken all these issues on board in the design of the new model, which has a much simpler tree structure and shows a single tier of the hierarchy on the spider diagram. In the new model as currently formulated (with α -values as provided) the six axes all have identical influence over the overall concern index.
5.6	‘Informed choice’ (voluntariness), ‘significant risk’ and ‘concern characteristics’ capture three of the most important issues identified in previous literature as influencing risk concerns.	We have captured these as: <ul style="list-style-type: none"> – Voluntariness = ‘Personal Choice’ (which includes both choice and information characteristics), – Significant Risk = ‘Scale of Accident’, ‘Fear Factors’ and ‘Immediacy of Threat’

	Comment Summary	Our Response
		– Concern Characteristics = ‘(Lack of) Trust’ and ‘Outrage’
5.7	No direct media questions in the tool – media and risk amplifications effects are unlikely to be reflected in the model in its present form. Media effects are difficult to predict but they are triggered by well know factors, some of which are much more specific than the general concern characteristics represented in the current version of the tool e.g. disagreement amongst experts, human interest stories, impacts on families or young children, hints of corruption or blame for major risk management failures.	We have not directly incorporated media into the new model. However the factors mentioned as concern characteristics are all captured within the questions asked of users.
5.8	Considers that there is synergy between factors e.g. dreaded hazard plus blame for poor risk management plus expert disagreement over effects likely to create an amplification of concern that is not adequately reflected in the model.	Amplification and attenuation effects can be incorporated explicitly (see Section 3 for discussion of the methodology for doing this) but as yet we have not included any in the rail industry model.
5.9	Model does not deal with attenuation effects – where a risk is genuine but ignored (hidden hazards). This may be due to marginalisation, lobbying by strong interest groups, strong cultural norms. Model would probably still show a concern rating even though ‘society’ is actually not very concerned with that issue.	See response to 5.8 above
5.10	Endorses the tool in principle but thinks major revisions and further development needed before it can be used by HSE or others.	We have completely redeveloped the model for the rail industry, but would recommend considerably more work before the tool can be used ‘in anger’ – see Section 6 of this report.

2.3 Literature Review Findings

2.3.1 Scope of the Literature Review

There is a large body of literature from the social science and psychology fields concerning how lay people (and experts) understand and think about risks. For the purposes of this study we have collected a range of material, broadening the scope considerably since we conducted our study for the HSE, and also including reports that had not been published at the time of our earlier work. We have included a full bibliography in Appendix 1 of this report, which has expanded from our original set of around 25 papers to a current set of 65. To do full justice to this range of literature would have absorbed the entire budget of our present project and more, so we have had to limit the scope of the literature review to the salient questions relevant to this study. These are:

- Are there any existing attempts to model ‘societal concern’, generated by others, of which we were previously unaware?
- Can we draw on a consensus on the nature of societal concern in developing our model?
- Have we missed any key parameters relating to societal concern in formulating our model?
- Are there any important ideas about the nature of societal concern that we did not incorporate in our previous model, or that invalidate a modelled approach?

2.3.2 Models of Risk Perception and Societal Concern

Several models of risk perception aim to explain why the risk perceptions of lay people fail to agree with the risk assessments of risk experts. The primary source for our thinking is the work of Slovic et al (7, 19, 58, 59, and 60) and is known as the ‘Psychometric Paradigm’. This focuses on the characteristics of the hazard itself, rather than the characteristics of the individuals who are doing the perceiving, and surmises that there are inherent properties of different hazard types that cause them to be perceived as more or less risky. Characteristics of the hazard used in the psychometric paradigm include things such as ‘dread’, ‘unknown effects’, ‘catastrophic risk’, ‘high risk to future generations’, ‘inequity’, ‘involuntary exposure’.

Several models of risk ranking have been developed (18, 28). This research indicates that while the public may not correctly identify the scale of the risk (with very low risks tending to be overestimated and very high risks tending to be underestimated), different risks tend to be ranked in the same order as would be given by a formal risk assessment. However people from different countries and cultures may rank risks differently, so such rankings or evaluation of concerns is not directly transferable (59)

An alternative view of risk perception, known as ‘Cultural Theory’ focuses on the individual doing the perceiving (31). Here individuals are supposedly divided into four ‘cultural types’: individualist, egalitarian, hierarchical and fatalistic. The cultural type of the person will affect their perception of risk and their views about what should (or

should not) be done to manage the risks. However there is little empirical evidence to support either the hypothesis that people can be characterised in this way or that these characterisations are strongly correlated with risk perception (56).

A major criticism of the psychometric paradigm and the cultural theory is that an individual's reactions to a particular event are extremely context specific (20, 21, 24, 26). In this view attempting to model the level of concern society may have about a hypothetical event in an abstract way is simply wrong-headed, as the only way to understand what people will think about something is to use focus groups and questionnaires to ask them in a very context-specific way, and to involve lay people directly in the decision-making process.

Despite considerably widening our literature review, we found no examples of researchers developing the type of societal concern modelling tool we have developed here, nor is there a clear consensus on how to model how lay people think about risk.

2.3.3 New Thinking on Societal Concern

Recent studies published by the HSE have explored the issue of societal concern in some detail (1, 3, 40). "Taking Account of Societal Concerns about Risk" (1), considers how society's views of different types of risk should influence the way such risks are regulated. The study separates risks into three distinct types: directly perceptible risks, risks perceived with the help of science and virtual risks.

The first of these are those risks which people can easily see, and can either choose to take or not to. They argue that regulators have difficulty in regulating this type of risk because people will change their behaviour to retain a given level of risk. Individuals can directly weigh up and see the benefit to themselves of the risky activity, and attempts by the state to regulate these types of risks are seen as 'nannying'. Examples include: wearing seatbelts, taking part in dangerous sports.

The second are those risks that people cannot easily see for themselves, and that may therefore be imposed upon them against their will. These are risks that have only been identified by the use of science such as epidemiological studies. The issue for regulators here is that the beneficiaries of the activity are often not those bearing the risk of the harm. Although the risks may be very small, the fact that the risk-taker has no choice and perceives little or no benefit to themselves of being exposed to the risk makes these risks less acceptable or tolerable. Examples include: nuclear waste deposits, cancer-causing chemicals, asbestos.

The third are risks about which there is considerable disagreement and uncertainty (as well as potentially serious consequences). Here the 'filters' that people use will strongly influence their responses. These filters are affected by the cultural type (the authors use the four groups identified in Cultural Theory to classify individuals), so different types of people will respond differently to these types of risks, depending on, for example, how implicitly trusting they are of authority. The difficulty for regulation is that the more research is done to see if there is a real effect, the more this reinforces the idea that there is something to worry about - why do all that research if there is no problem? People are also more willing to believe bad news than good news, so one lone voice preaching disaster is louder than a hundred saying there is no problem.

Examples include: genetically modified organisms; mobile phone masts, pesticides in food.

The second study, “Understanding and responding to societal concerns” (3), concludes that:

- the technical analysis of risk provides society with only a narrow view of an issue which, although helpful in some circumstances, ignores the culture and context of risk taking behaviour. The concentration of technical analyses upon probabilities and consequences is of limited use in understanding social orientation;
- we live in a pluralist society with different values, world views and aspirations, and therefore multiple perspectives need to be heeded in decision making;
- risk decisions, whether by experts or the laity, are driven by values and beliefs first and facts second;
- the social acceptability of hazards is not for professionals (including academics) to determine, and can only be arrived at following appropriate discourse with all stakeholder groups.

They take a holistic view of the various academic theories of risk perceptions, regarding them all as useful interpretations in different ways, and retaining a place for technical risk assessment and cost benefit tools amongst the range of ways of examining risk. However they do not give a practical guide as to how their aspirations of taking account of these disparate societal views should be taken on board by regulators.

The third of the studies published by the HSE, “Perceptions of, and Trust in, the Health and Safety Executive as a Risk Regulator” concerned its own role and perception by the public. This was a major study involving considerable direct focus group research as well as a large questionnaire-based survey, delving into the detailed anatomy of ‘trust’. The study showed that public trust in the HSE as a regulator was very high, primarily due to the lack of perceived ‘vested interest’. Where individuals had direct experience of the HSE’s activities these tended to be focused on workplace inspections, which some viewed as unnecessarily intrusive and ‘nannying’. But this was balanced by the view that the public and employees needed protection against potentially ruthless employers who would otherwise not behave responsibly with regard to health and safety.

2.3.4 Parameters of Societal Concern

Throughout our literature review we were on the lookout for any parameters that might help to characterise the public’s concern about a risk that we had failed to include in our earlier HSE model. One very useful reference (49) contains a review of a large body of risk perception research up to 1999. We were reassured to discover no new parameters over and above those we had originally included.

One area we had not fully considered in developing our earlier model, however, was the issue of amplification or attenuation of risks. These are not simply inverses of each other. Certain hazards may be attenuated in the minds of the public and decision makers for a variety of reasons, including cultural ‘blind spots’ (such as the risk of guns

in the US) or the fact that the hazard affects a marginalised group of people, such as illegal immigrants (29). The public may be indifferent to a genuine hazard, and societal concern might thus be suppressed. Other hazards may be amplified through the media, which is not a simple one-way process, but involves feedback between the media and responses of the public (9, 36, 38). There may also be synergies between different aspects of a particular hazard that serve to amplify it (38), for example where there is expert disagreement over the risks, the impact is particularly ‘dreadful’ and there is blame attached to risk managers for failing in a duty of care – for example, BSE.

Our original HSE model did not explicitly take account of amplification or attenuation effects, and we have sought to remedy this in developing our new model by devising a mechanism for these.

2.4 Selection of Model Parameters

The parameters contained in the original HSE model are listed in the table below, together with our comments in light of the literature review findings and appropriateness to the rail industry context. We also present the parameters that we included in the new rail industry model.

Original HSE Model Parameter	Comments	Rail Industry Model Parameter
Involuntary exposure to risk	Relevant	3.4 Lack of control
Lack of personal control over exposure and outcomes	Relevant	4.7 Choice – how much choice did people have over whether they took part in the activity that resulted in an incident
(Scientific) uncertainty or controversy about the probability or consequences of exposure - extent of precautionary approach	Relevant	5.5 Expert disagreement – how much do experts agree or disagree about what should be done to manage the risk
Lack of personal experience with the risk (fear of unknown)	Relevant	5.3 Experience – how much direct experience do people have of the risks
Difficulty in imaging risk exposure	Relevant	5.4 Accessibility of Information – how easy is it for people to find out about and understand the risks
Effects of exposure delayed in time	Relevant	4.4 Insidious Harm – will the incident result in the release of something that will have long term impact on health or the environment
Genetic effects of exposure / threats to future populations	Not so relevant ¹	4.4 Insidious Harm – incorporates all long term types of exposure.
Infrequent but high consequence/ catastrophic events vs many small	Relevant	3.1 Individual Accident Size – captures the total number of people likely to be

¹ More global, long term effects or those likely to require the precautionary principle to be invoked are considered unlikely to be relevant to the railway – see earlier Risk Solutions report on T224 Pt 4.

Original HSE Model Parameter	Comments	Rail Industry Model Parameter
events		harmed in a single incident.
Benefits not highly visible	Not relevant	
Benefits go to others (inequity)	Relevant	5.1 Inequity – whether the people who benefit from the activity are also the people taking the risk
Accidents caused by human failure rather than natural causes	Relevant	4.12 Failed responsibility – incorporates lack of appropriate controls and deliberate human harm.
Particularly horrifying harm eg severe paralysis, permanent brain damage, terminal cancer	Relevant	5.1 and 5.2 – Degree of immediate harm caused by an incident, either trauma injury or burn injury.
Birth defects, foetal/genetic affects	Not so relevant	4.4 Insidious Harm – captures longer term impacts and covers releases such as nuclear material due to a rail accident.
Social disruption (upheaval/ disturbance)	Not relevant	
Vulnerability of those exposed/ at risk eg children, particular vulnerable social group	Relevant	5.9 Vulnerability – are those involved in an incident from a particularly vulnerable social group
Potential for global calamity	Not so relevant	4.6 Many People Exposed – is a large proportion of the population exposed to the risk. This is more a measure of 'likelihood of harm' than of global calamity which is not really relevant to the rail industry.
Consequences irreversible	Not so relevant ¹	4.4 Insidious Harm – captures longer term impacts and covers releases such as nuclear material due to a rail accident.
Environmental / ecological impact	Not so relevant	5.11 Landscape Destruction – incorporated but may not be very relevant.
Amenity impact	Not so relevant	5.11 Landscape Destruction – incorporated but may not be very relevant.
Level of harm resulting from exposure to risk	Relevant	3.1 Individual Accident Size and 4.3 Immediate Harm together capture this.
Confidence/ trust in those responsible for managing this hazard/ risk and those enforcing any standards/ regulations ie Confidence in the authorities or industry or experts to understand and manage the hazards and risks in a responsive and timely way	Relevant	4.1 (Lack of) Trust in Management, into which is fed views on management record and how incentivised the management is to manage the risks.
Possible differences in opinion within society - local factors vs whole population vs cultural	Not so relevant – not modelled explicitly, as we are	

Original HSE Model Parameter	Comments	Rail Industry Model Parameter
aspects	modelling the hazard rather than the people responding to it. However the model could be used to explore whether there are particular groupings in society with different responses, using demographically selected focus groups..	
Accident history - especially in recent memory	Relevant	4.5 Recent Accidents – do people recall any accidents like this one. 5.6 History of Bad Advice – do people consider that they do not trust the reassurances they are given due to accident history 5.7 (Poor) Management History – does the management have a poor track record
Risk increasing or decreasing	Not so relevant – applies mainly to major changes in the risk profile. We already capture changes to control strategies through 5.12 (Poor) Controls	

We did not add any extra parameters as a result of the literature review, although within the railway context we have slightly modified some of the original parameters, and have found that others are not relevant. As an example, the issue of human agency or blame has been made specific to blame of the rail industry, rather than referring to deliberate or negligent actions by third parties. This followed our experiences of trialling the model in a workshop environment, where the impact of apportioning blame to any human agency led to counter-intuitive outcomes. The human agency issue feeds the ‘Outrage’ parameter of the model. This means that any ‘Outrage’ arising from the modelling of this parameter refers to outrage towards the rail industry, or specific rail industry members, rather than general feelings of outrage.

A full description of the parameters incorporated into the rail industry model, and the structure of the model, is provided in Section 4.

3 Score Propagation

3.1 Introduction

The idea behind the HSE model was to start with a range of factors influencing the level of societal concern that might be felt about any given risk issue. These factors were progressively combined in a hierarchical tree. At the top of the tree all factors are combined into something representing “overall societal concern”. Each combination point, or “gate” within the tree represents an intermediate factor. We have used a similar approach in developing the Rail Industry model, but we have completely reviewed and revised the way in which scores are propagated through the model, and our approach is described in this section.

We have carried out a detailed examination of different methods of propagating scores at the gates in the tree model, in order to select the most appropriate method. The starting point for our approach was the method used in the HSE model. Some of the peer review comments on the HSE model were relevant to score propagation methods. These comments are paraphrased below in section 3 and formed the basis of our exploration of possible methods.

3.2 The HSE Model Score Propagation Approach

At the bottom of the hierarchical structure of the HSE model, there is a set of basic factors. For each issue considered, these factors are given a score, representing how strongly people feel about this factor in relation to the issue in question. The factors are combined through ‘gates’ as one moves up the hierarchy. At each gate the scores are combined in some manner, to assign scores to the intermediate factor, and ultimately a score to overall societal concern. There are many different methods by which the scores could be combined, and we considered a number of them in developing both the HSE model and the model for the rail industry. All the methods we considered share the following feature, namely that all the scores are on the same scale. For example the scale could run from $s = 0$ (lowest) to $s = 1$ (highest). This can then be transformed for presentational purposes to

$$S = A s + B$$

For example the scale in the HSE model was chosen (largely arbitrarily) to run from 1 to 7, so this would require $A = 6$ and $B = 1$.

One straightforward manner for combining scores is to make the output of the gate the arithmetic average of the inputs. For a gate with N inputs, the formula is

$$G_N(s_1, \dots, s_N) = [s_1 + \dots + s_N]/N$$

This can easily be generalised to a weighted average of the inputs

$$G_N(s_1, \dots, s_N) = [w_1 s_1 + \dots + w_N s_N]$$

where the N weights sum to 1.

In producing the HSE model we did not adopt this method. This was because it has the feature that the influence of any one input to a gate tends to be “diluted” by all the others, and it is difficult for a high score on one factor out of many to give a high score for societal concern. We believed that this did not reflect what could happen in the actual causation of societal concern.

Instead we chose a structure with two sorts of gates, whose approximate definitions were as follows:

OR-GATE – it is sufficient for any one of the inputs to be reasonably high to get a reasonably high output;

AND-GATE – it is necessary for all of the inputs to be reasonably high to get a reasonably high output.

The use of the logical terminology “OR” and “AND” comes from the idea that in the limit in which all scores are either 0 or 1, the gate behaviour is given by the truth tables of classical logic. However this way of combining scores does not mean that we think that people actually use classical logic when reacting with concern to risk issues. Nor does it mean that the score propagation methods we use are invariant under Boolean transformation.

One idea to be tested was that from fuzzy logic, where the OR- and AND-gate outputs were taken to be the maximum and minimum of the inputs respectively. This reduces to the truth-tables as required and is also Boolean invariant. However the method was rejected for the following reason: at any gate the output depends only on the factors affecting the maximum or minimum input branch. All the rest of the information lower down in the tree has no effect, except when it changes sufficiently to make its branch the maximum or minimum.

We then looked at the idea of associating the OR gate with the arithmetic mean of the inputs and the AND gate with the geometric mean. The use of the means had the required feature that the output score remains between 1 and 7. The geometric mean is always lower than the arithmetic mean, in line with the requirement that the AND gate score should be lower than the score if the gate were OR. The 1 to 7 scale was also taken to be essentially logarithmic, so that, for example a score of 5 for an issue means that there is ten times as much concern as a score of 4 (This assumption however is not necessary for the method to be selected; it is enough that it gives a plausible mapping of parameter scores onto the overall concern score). Therefore, the scores are first subjected to the mapping:

$$s \rightarrow r = 10^{(s-4)}$$

The r-scores are then averaged (arithmetic for OR, or geometric for AND), and then the resulting output r-score is mapped back onto an s-score:

$$r \rightarrow s = \log_{10}(r) + 4$$

This is called the “log” method.

An alternative method we explored is simply to apply the averaging directly to the s-score. This is called the linear “lin” method. We therefore have two alternative methods here: “mean-log” and “mean-lin”.

A useful way of looking at the properties of these methods is to see how they map ($a=7$, $b=1$) through the AND and OR gates, that is, how they combine the highest and lowest possible scores. This can be summarised as follows:

a=7, b=1		
	log	linear
AND	4	2.6
OR	6.7	4

The result that the log method gives the same result for AND that the lin method gives for OR is general, in both cases the combined score is $(a+b)/2$. This table suggests that if one wants a method which distinguishes more strongly between the two types of gates, then one should use a “hybrid” method, using the log result for OR and the linear result for AND. This was the choice that was made in the HSE model

3.3 Formulation of the Rail Industry Model

3.3.1 Peer Reviewers’ Comments

The reviewers’ comments relating to the form of the gates in the tree structure can be paraphrased as follows.

- A Not enough thought has been given to alternative hierarchical structures and score propagation methods.
- B In similar applications, simple weighted sums have proven to give good results.
- C The model tends to pull the top scores to the middle of the score range, with specific influences further down the tree being diluted.
- D The gates as used in the model do not properly capture the amplification and attenuation effects that can occur.

Another useful suggestion given to us when presenting the model to interested parties is:

- E Consideration should be given to tailoring the score combination method to specific gates, instead of just having a choice of two types of gate.

Comments B and C tend to cancel each other out – as mentioned above, the use of simple weighted sums dilutes specific influences and tends to pull scores towards the centre of the range. The present note can be seen as an initial response to comment A, exploring a wider range of score propagation methods, and a description of what we are proposing for our new model. As will be seen, the recommended method allows

for gates to be tailored to specific needs, as suggested in comment E. Amplification and attenuation effects are considered in Section 6.

3.3.2 Probability Formulae

Although the HSE model tree, with its OR-gates and AND-gates, looked like a fault tree, as widely used in risk assessment, we were at pains to say that it was not a fault tree, and that the scores being propagated were not probabilities. In starting this review of methods, we wondered if the formulae for combining probabilities could nevertheless be used as a method for combining the scores. The scores are still not to be interpreted as probabilities, and the choice of the method would purely be on the grounds that it captured better our intuitions of what we meant by “OR” and “AND” in the context of the reflection of societal concern. For gates with 2 inputs, the formulae are:

$$f_{\text{OR}}(a, b) = [a + b] - ab$$

$$f_{\text{AND}}(a, b) = ab$$

Note that in probability theory these are only correct if the two inputs are statistically independent, and this is also true for concern scores. For example, the concern caused by a factor and itself is the score of the factor, and not the square of this score. In a tree, independence is guaranteed if all the base factors are independent, and if the intermediate gates being combined have no base factors in common.

The probability method and that used in the HSE model are compared on the tables below, for gates with two inputs. For probability combinations, the 1 to 7 scores are mapped onto a 0 to 1 scale, combined, and then mapped back.

The probability formulae give a greater split between “OR” and “AND”, and therefore will work more strongly against the centralising tendency in the tree. This is particularly evident for the cases where the two inputs have the same score, x . In this case the output scores for both types of old gate are x . This is a feature of using means – whichever particular type of mean is used, the mean of the same number repeated however many times is that number. By contrast the probability AND gate gives x^2 , and the OR gate $x(2 - x)$.

OR-GATE		arith mean of antilogs as in HSE model						
	1	2	3	4	5	6	7	
1	1.00	1.74	2.70	3.70	4.70	5.70	6.70	
2	1.74	2.00	2.74	3.70	4.70	5.70	6.70	
3	2.70	2.74	3.00	3.74	4.70	5.70	6.70	
4	3.70	3.70	3.74	4.00	4.74	5.70	6.70	
5	4.70	4.70	4.70	4.74	5.00	5.74	6.70	
6	5.70	5.70	5.70	5.70	5.74	6.00	6.74	
7	6.70	6.70	6.70	6.70	6.70	6.74	7.00	

		combined as probabilities						
	1	2	3	4	5	6	7	
1	1.00	2.00	3.00	4.00	5.00	6.00	7.00	
2	2.00	2.83	3.67	4.50	5.33	6.17	7.00	
3	3.00	3.67	4.33	5.00	5.67	6.33	7.00	
4	4.00	4.50	5.00	5.50	6.00	6.50	7.00	
5	5.00	5.33	5.67	6.00	6.33	6.67	7.00	
6	6.00	6.17	6.33	6.50	6.67	6.83	7.00	
7	7.00	7.00	7.00	7.00	7.00	7.00	7.00	

AND-GATE		geometric mean - in HSE model						
	1	2	3	4	5	6	7	
1	1.00	1.41	1.73	2.00	2.24	2.45	2.65	
2	1.41	2.00	2.45	2.83	3.16	3.46	3.74	
3	1.73	2.45	3.00	3.46	3.87	4.24	4.58	
4	2.00	2.83	3.46	4.00	4.47	4.90	5.29	
5	2.24	3.16	3.87	4.47	5.00	5.48	5.92	
6	2.45	3.46	4.24	4.90	5.48	6.00	6.48	
7	2.65	3.74	4.58	5.29	5.92	6.48	7.00	

		combined as probabilities						
		1	2	3	4	5	6	7
1		1.00	1.00	1.00	1.00	1.00	1.00	1.00
2		1.00	1.17	1.33	1.50	1.67	1.83	2.00
3		1.00	1.33	1.67	2.00	2.33	2.67	3.00
4		1.00	1.50	2.00	2.50	3.00	3.50	4.00
5		1.00	1.67	2.33	3.00	3.67	4.33	5.00
6		1.00	1.83	2.67	3.50	4.33	5.17	6.00
7		1.00	2.00	3.00	4.00	5.00	6.00	7.00

3.3.3 Generalised Formulae

The two probability gates were then compared with the simple method of taking the arithmetic mean – in fact the mean gate is halfway between the AND and OR gates:

$$f_{\text{mean}}(a, b) = [f_{\text{AND}}(a, b) + f_{\text{OR}}(a, b)]/2$$

This suggests a generalisation of the gate formulae, involving a parameter, α , which interpolates between three gates considered already, such that

$$\alpha = 1 \quad \text{gives an OR gate}$$

$$\alpha = 0.5 \quad \text{gives a mean gate}$$

$$\alpha = 0 \quad \text{gives an AND gate}$$

For gates with 2 inputs, the required formula is:

$$f_{\alpha}(a, b) = \alpha [a + b] - (2\alpha - 1) a b$$

For 3-input gates, the generalised formula is:

$$f_{\alpha}(a, b, c) = \alpha (2\alpha + 1) [a+b+c]/3 - \alpha (2\alpha - 1) [a b + bc + ca] \\ + (2\alpha - 1)^2 a b c$$

Although it is not used in the tree we are currently using, the analogue for a 4-input gate is:

$$f_{\alpha}(a, b, c, d) = \alpha^2 [a+b+c+d] - \alpha (2\alpha - 1) [a b+ac+ad+bc+bd+cd] \\ + \alpha (2\alpha - 1) [abc+abd+acd+bcd] - (2\alpha - 1) abcd$$

Having available a range of gates, from pure-OR, through simple mean, to pure-AND allows us to implement in a direct way the suggestion that individual gates be tailored to meet the needs of the specific input-output combination. Of course this does introduce more complexity into the model, and scope for more arbitrary choices, unless a sound method for eliciting and validating the values of α is developed.

All of these gates are symmetric in their inputs – at each gate the inputs carry the same weight. We have seen that the mean-gate can be readily generalised to having different weights for the inputs, if it were felt that some factors had a greater effect on the output than others. For present purposes it is useful to rewrite this using weights that sum to the number of inputs rather than to one, simply to make the arithmetic simpler. For a 2-input gate we write for the generalised mean

$$f_{0.5}(a, b) = [u a + v b]/2$$

where $u + v = 2$

A generalisation of the product of the two scores is then: $a^u b^v$. The α -formula is then generalised to include weights as:

$$f_{\alpha}(a, b) = \alpha [ua + vb] - (2\alpha - 1) a^u b^v$$

3.3.4 Amplification and Attenuation

Amplification and attenuation of societal concern by cultural and other external factors are the subjects of social science research (9, 26). An example of amplification might be the risk to children of harm from abduction by strangers, which is extremely low and no different now from 30 years ago. However parents today are much more concerned about this risk than earlier generations, due to high profile media responses to individual events. An example of attenuation might be the level of concern over the dangers of alcohol in our society. Here cultural norms result in a level of acceptance of harms due to abuse of alcohol that are higher than might be expected by objectively measuring the level of risk.

The phenomena of *mutual* amplification and attenuation are captured by the OR- and AND-gates respectively, where the outputs are respectively greater than and or less than the mean of the two inputs. What is not dealt with, are amplifiers and attenuators which by themselves have no impact on societal concern, but which can respectively increase or decrease the effects of primary causes of concern. If we call the score of the main factor, m, and that of the amplifier or attenuator, a, two schemes for such score combinations are shown on the tables below.

Amplification

		m		
		0	$\frac{1}{2}$	1
a	0	0	$\frac{1}{2}$	1
	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{5}{8}$	1
	1	$\frac{1}{2}$	$\frac{3}{4}$	1

		Attenuation		
		m		
		0	1/2	1
a	0	0	1/2	1
	1/2	0	3/8	3/4
	1	0	1/4	1/2

The formulae for these two gates are:

$$f_{\text{amp}}(m, a) = m + \frac{1}{2} a (1 - m)$$

$$f_{\text{att}}(m, a) = m [1 - \frac{1}{2} a]$$

The amplification gate is characterised by the value to which $m=0$ is amplified by $a=1$. Let us call this β . In the example above, $\beta = \frac{1}{2}$. The attenuation gate is characterised by the value, γ , to which $m=1$ is attenuated by $a = 1$; in the above, $\gamma = \frac{1}{2}$.

The gate formulae can then be generalised to all values of β and γ between 0 and 1:

$$f_{\text{amp},\beta}(m, a) = m + \beta a (1 - m)$$

$$f_{\text{att},\gamma}(m, a) = m [1 - (1 - \gamma) a]$$

3.3.5 Score Propagation in the Rail Industry Societal Concern Model

Following on from comments on the score propagation methods used in the HSE societal concern model, we considered a wider range of possible propagation gate. We have chosen the α -formulae for the gates within the Rail Industry Societal Concern Model, allowing a range of behaviours from pure-OR and pure-AND. Setting up the model therefore involves deciding what value of α is most suitable for each of the gates in the model.

The likely impacts of attenuations and amplifications could be quite a subtle issue. We would not like to second guess, at this stage, which branches would benefit from attenuation or amplification without some more detailed thought. We believe this is a task for the next phase of work. At present we have not introduced the added refinement of weights, amplification or attenuation into our model. We would recommend that this issue is reviewed and considered in more depth. If it is then felt that these are required, they can be added using the formulae given in this section.

3.4 Use of the Alpha Factor

3.4.1 Deriving α -values for the Model

We have provided a set of α -values in the model we have developed for RSSB. These are described in detail in section 4 of this report. It should be noted that changing the

α -values will alter the outputs of the model; in essence it will change it into a different model. Therefore we recommend that RSSB should review the α -values we have provided in the model in detail. Each gate may have ‘AND-like’ characteristics, i.e. a high value output would be expected only when all the inputs are also high, ‘OR-like’ characteristics, i.e. a high value output would be expected when only one of the inputs is high, or ‘arithmetic mean-like’ characteristics, i.e. the output should be the average of the inputs. Depending on the values of α selected, the gate will exhibit these characteristics more strongly or more weakly, so:

α between 0 and 0.3 = ‘AND-like’ gate

α between 0.4 and 0.6 = ‘Arithmetic mean-like’ gate

α between 0.7 and 1 = ‘OR-like’ gate

Once the characteristics of the gate have been agreed, the precise value of α should be selected. After a set of values has been settled on, the model should be tested ‘in anger’ against a range of risk situations and, if necessary, the values refined. After this process, the model should be ‘fixed’ – perhaps given a version name, and those particular α -values recorded to ensure future replicability of any findings made using the model.

It may be possible to develop the values in a focus group situation. To do this, an initial set of α -values is provided. Then the group is invited to consider how the output of a gate changes as the inputs are changed, and to comment on whether the results ‘feel right’. The model can be tested iteratively, together with some test ‘issues’ until the group is happy that the outputs reflect their levels of concern about these issues. The sensitivity of these group-based choices could then be explored using @Risk in order to be certain that appropriate α -values have been chosen.

We recommend that RSSB undertake an exercise to determine appropriate α -values in order to have more confidence in the model results.

3.4.2 Model Sensitivity to α

We have not conducted a full sensitivity analysis of the model, as this would be a detailed task outside the scope of our current project. However we have carried out a small sensitivity exercise to explore the sensitivity of the model to some of the top gates. The sensitivity tends to depend on the overall score: a lower score will be more sensitive to small changes in α , and the lower down the gate is in the model hierarchy the less the top tiers will be sensitive to changes in α . As a rule of thumb, changes in α -values of 10% have an effect of 3-10% on the output of gate above, and an effect of 1-5% on the output of gates two tiers above.

4 Model Structure and Parameters

A detailed description of the spreadsheet form of the model is included in Appendix 2. The following section discusses the model structure, the parameters that contribute to the level of societal concern about an issue, and also how the various parameters are combined together.

4.1 Model Structure

The structure of the prototype model is shown in Figure 1. The figure has been colour-coded to enable the easy identification of the different items within the structure. In contrast with the model developed for the HSE, each factor at the bottom of the hierarchy feeds into the model only once, to allow greater transparency for any weighting applied within the model. If the factors feed in in more than one place, this results in an implicit weighting.

In addition, in response to peer review comments as discussed in Section 2, we have ensured that the six factors to be represented on the spider diagram, which provides a visual representation of the ‘anatomy of concern’ are all at the same level in the model hierarchy.

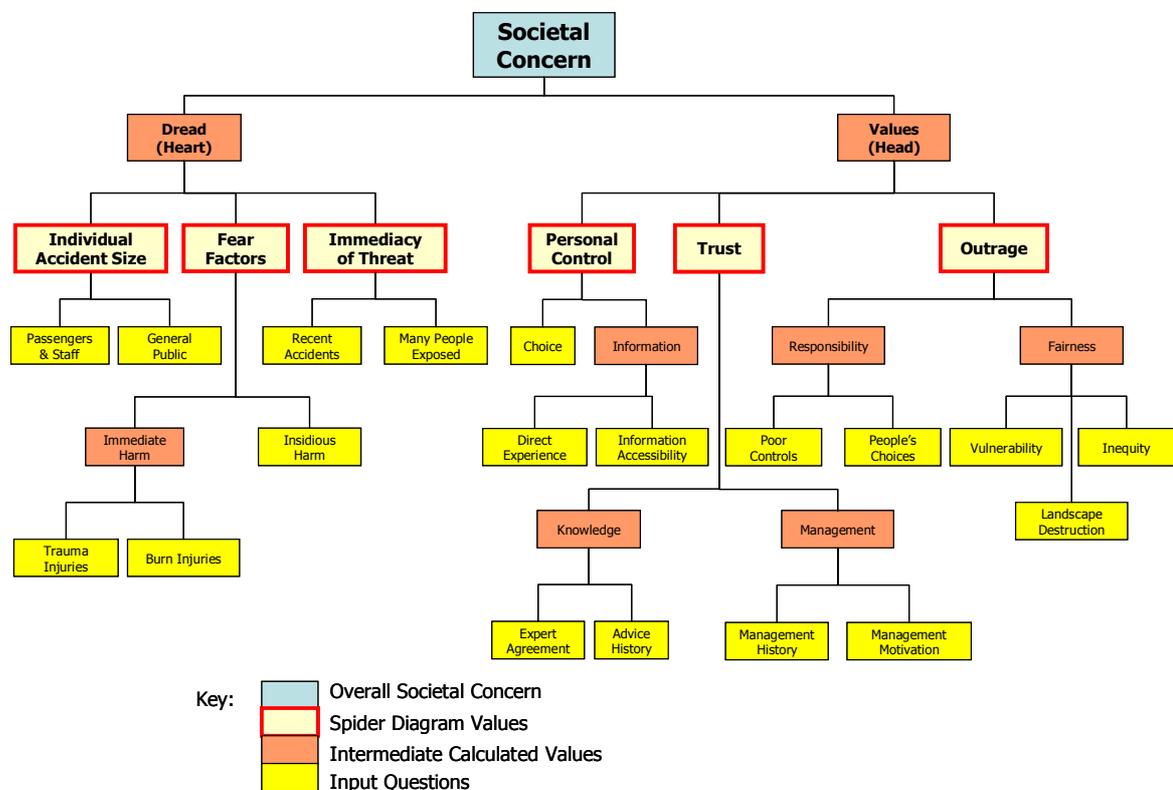


Figure 1 Model Structure

4.1.1 Operation

For each specific scenario, users are asked to score nineteen questions on the Data Entry screen of the model against a scale of 0 – 10. Guidance is provided to assist the user in selecting a score that they feel is appropriate via the use of anchor descriptions for score values 0, 5 and 10. For some of the questions, users have been provided with additional guidance for intermediate values. These scores feed into the yellow input boxes shown in Figure 1. When the model is run, a number of different calculations are performed, including:

- Input scores are normalised on a scale of 0 – 1.
- Scores are combined through gates using probability based arithmetic. The score propagation formula used is briefly described in sub-section 4.1.2, while a more in-depth discussion is contained within Section 3.

4.1.2 Gate Calculations

The formula used is dependent on the number of parameters that feed into it. The current model structure has either two or three inputs per gate. The formulae used are shown here:

$$\underline{2 \text{ Gate}} \quad f_{\alpha}(a, b) = \alpha[a + b] - (2\alpha - 1)ab$$

$$\underline{3 \text{ Gate}} \quad f_{\alpha}(a, b, c) = \frac{\alpha(2\alpha + 1)[a + b + c]}{3} - \alpha(2\alpha - 1)[ab + bc + ca] + (2\alpha - 1)^2 abc$$

Each gate can vary across the range between ‘pure AND’ through ‘arithmetic mean’ to ‘pure OR’, via the use of the user defined variable, α . The impact that different values of α have on the formula is demonstrated by manipulating the general 2 Gate formula.

$$f_{\alpha}(a, b) = \alpha[a + b] - (2\alpha - 1)ab$$

$$\alpha = 0 \quad f_{\alpha}(a, b) = ab \quad \text{Analogous to an ‘AND’ gate}$$

$$\alpha = 0.5 \quad f_{\alpha}(a, b) = \frac{(a + b)}{2} \quad \text{Arithmetic Mean}$$

$$\alpha = 1 \quad f_{\alpha}(a, b) = a + b - ab \quad \text{Analogous to an ‘OR’ gate}$$

Initial values of α have been selected for use in the prototype model. These values and their impact on the associated gates are discussed in Section 4.3.

4.1.3 Model Outputs

The six high-level factors affecting societal concern are shown outlined in red in Figure 1 above. The calculated value of each factor is presented graphically to the user on a spider diagram, created automatically by the model. A value representing the overall level of societal concern is also calculated.

It should be noted that different scenarios may produce similar overall societal concern scores. However, the anatomy of the concern, or the relative importance of the six factors on the spider diagram, may look very different.

4.2 Major Contributing Parameters

This section describes the input parameters for the model, the questions used to elicit the input values and also the area of the model that each parameter influences.

Issue ID	User Input Parameter	Question	Top Level Parameter Influenced
4.1	Passengers & Staff	How many members of the travelling public or railway staff might be harmed by an incident such as this?	Individual Accident Size
4.2	General Public	How many members of the general, non-travelling public might be harmed in an incident such as this?	Individual Accident Size
4.4	Insidious Harm	How far could such an event result in the release of any harmful and/or long-lasting substances into the environment?	Fear Factors
4.5	Recent Accidents	How often do you think events like this happen?	Immediacy of Threat
4.6	Many People Exposed	What proportion of the general population has a chance of being involved with an event such as this?	Immediacy of Threat
4.7	Lack of Choice	How much do you feel that the people affected had a choice about whether they took part in the activity that ultimately resulted in this incident?	Lack of Personal Control
5.1	Injury Type - Trauma	How badly mutilated do you feel people might be if they were involved in such an event?	Fear Factors
5.2	Injury Type - Burns	How badly burned do you feel people might be if they were involved in such an event?	Fear Factors
5.3	No Direct Experience	What is the extent of your knowledge or personal experience of this type of event?	Lack of Personal Control
5.4	Information Inaccessible	How freely available is information about these types of events?	Lack of Personal Control
5.5	Expert Disagreement	How much do you feel that experts tend to agree with one another about what should be done to manage the risk associated with this type of event?	Lack of Trust
5.6	History of Bad Advice	Where advice or information is available, do you trust it?	Lack of Trust

Issue ID	User Input Parameter	Question	Top Level Parameter Influenced
5.7	Poor Management History	Do you believe the rail management team have the competence to manage safety effectively?	Lack of Trust
5.8	Adverse Incentives	Do you believe the rail management team are motivated to do everything they can to improve safety?	Lack of Trust
5.9	Vulnerability	Do you believe that particularly vulnerable people (babies and young children, the disabled, the elderly) will be involved in such events?	Outrage
5.10	Inequity	Are the people exposed to the risk those who benefit from the activity that leads to the exposure?	Outrage
5.11	Landscape Destruction	How much impact do you feel that such an event would have on the environment and the landscape?	Outrage
5.12	Poor Controls	How far do you feel that the right things are being done to prevent such events from occurring	Outrage
5.13	Human Choices	How far do you feel that this incident was the rail industry's fault?	Outrage

4.3 Parameter Combination

This section describes for each gate in the model tree:

- The contributors brought together at the gate;
- The initial alpha value selected for each gate and the gate type this results in; and
- The reasons for the choice of gate structure.

The model is described from the top down, beginning with an examination of the overall societal concern factor. Figure 2 shows how the model is divided into two areas encompassing the 'dread' factors and the 'value' factors. Seven input parameters feed upwards through the model tree to the three 'Dread' factors. The remaining twelve parameters inform the 'Values' side of the model. Each side of the model will be examined separately.

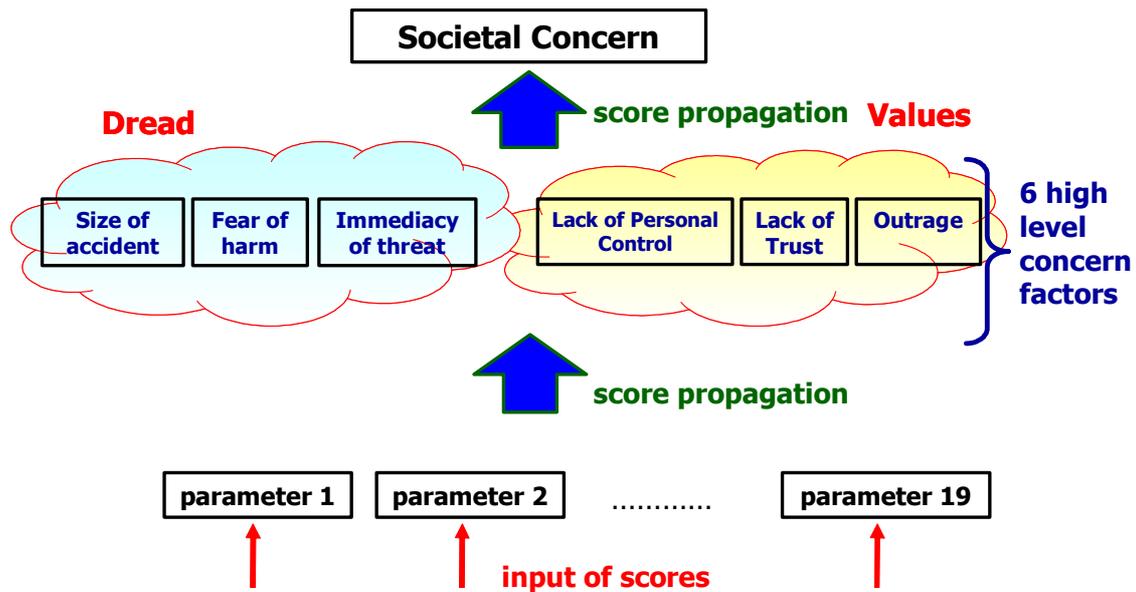


Figure 2 Model Arrangement and Score Propagation Paths

The six high level concern factors that together feed into the overall measure of societal concern are illustrated on a spider diagram, to help visualise the ‘anatomy’ of the concern. Examples of these spider diagrams, derived from our workshop with RSSB staff, are provided in Appendix 4.

4.3.1 Societal Concern

Gate 1 Overall Societal Concern

Current α value = 0.5

There are two contributors to the overall level of societal concern calculation:

- Gate 2.1 Dread (or Heart)
- Gate 2.2 Values (or Head)

The level of societal concern is calculated by combining together the top-level results from the two sides of the model – dread and values. An α value of 0.5 has been selected for this gate, allowing an arithmetic mean calculation to be performed. The selection of the α value also ensures that equal weighting is accorded to both sides of the model.

Gate 2.1 Dread (or Heart)

Current α value = 0.6

Gate 2.1 combines the three high-level ‘dread’ factors together using an α value of 0.6. This value results in the 3-gate formula becoming slightly weighted towards the ‘OR’ condition. This means that a single high score in any of the contributing factors will result in a slightly higher value for Dread than a simple average.

The factors that contribute to the level of ‘dread’ are:

- Gate 3.1 Individual Accident Size
- Gate 3.2 Fear Factor
- Gate 3.3 Immediacy of Threat

Here, 'Individual Accident Size' represents the extra concern people have over potentially 'catastrophic' risks, where many people may be killed in one incident, as opposed to 'chronic' risks where people are affected one at a time (see for example 39, 47, 57, 60, 61) and represents people's gut reaction to these incidents, hence it feeds into the 'dread' side of the model. These three gates are influenced by: the number of people who might be involved in an event; the immediate levels of harm that might be experienced; the proportion of the population at risk from the event; and any knowledge of recent similar events.

Gate 2.2 Values (or Head)

Current α value = 0.6

Gate 2.2 combines the three high-level 'values' factors together, using an α value of 0.6. This value results in the 3-gate formula becoming slightly weighted towards the 'OR' condition. This means that a single high score in any of the contributing factors will result in a slightly higher value for Values than a simple average.

The factors that contribute to the level of 'values' are:

- Gate 3.4 Personal Control Factor
- Gate 3.5 Trust Factor
- Gate 3.6 Outrage Factor

These three gates bring together factors associated with: the amount of information and personal control of a situation people feel they have; their trust in 'expert' knowledge and the management of the rail system; their feelings of outrage related to the parties responsible for an activity or event and the fairness of an outcome.

4.3.2 'Dread' Factors

Gate 3.1 Accident Size Factor

Current α value = 1.0

The parameters that contribute to the accident size factor are:

- Gate 4.1 Passengers and Staff
- Gate 4.2 General Public

The Accident Size Factor is informed by the two input questions relating to the number of people affected by an event. A differentiation is made between people who have chosen to be in the rail environment i.e. passengers and staff, and the general public who may have no control over their involvement in an event. A further refinement could be to separate out passengers from staff, leading to a 3-gate. This

would allow separate weightings for harm to passenger, staff and the non-travelling public, if this was considered appropriate.

The initial α value selected for this gate is 1.0, making it analogous to a pure 'OR' gate. This means that if the user feels that either a large number of passengers and staff, or a large number of the general public will be affected by the event a high score will result.

Gate 3.2 Fear Factor

Current α value = 0.8

The factors that contribute to the fear factor are:

- Gate 4.3 Immediate Harm
- Gate 4.4 Insidious Harm

The Fear Factor is informed by the calculated value of immediate harm, which aims to relate the severity and type of injury suffered by people due to the event. The second factor is insidious harm, concerning the release of harmful substances to the environment. A high score for this question will relate to a fear of long term damage or contamination of the environment.

The α value selected for use in the proto-type model is 0.8, which means the gate characteristics are weighted towards an OR type calculation, because either immediate or insidious harm will lead to fear of the consequences.

Gate 3.3 Threat Factor

Current α value = 0.3

The parameters that inform the threat factor gate are:

- Gate 4.5 Recent Accidents
- Gate 4.6 Many People Exposed

The questions provided to elicit the user's perception of the immediacy of the threat examine the perceived frequency of the event and also the proportion of the general population who may be involved in such an event. The users' knowledge of recent accidents or events similar to the scenario is likely to influence their response to the 'Recent Accidents' parameter question.

The α value selected for the initial model runs is 0.3. This is closer to an 'AND' type gate. Thus a user needs to consider both that there have been accidents like this recently (a measure of perceived frequency) *and* that many people are exposed to the risk to lead to a high threat factor. This is not a pure 'AND' gate, because some threat may be felt if many people are exposed, even if the user cannot recall any recent accidents.

Gate 4.3 Immediate Harm

Current α value = 0.7

The input parameters that inform the immediate harm gate are:

- Gate 5.1 Trauma Injuries
- Gate 5.2 Burn Injuries

The immediate harm gate provides a relationship between the type and extent of injuries suffered as a result of the event. The two input questions are designed to deal with how intrinsically horrifying the type of injuries sustained are to the user.

The α value selected for the immediate harm gate in the proto-type model, is 0.7. This value provides an 'OR' bias to the calculation, meaning that either trauma or burn injuries could result in a high score being calculated at this gate, as users may be horrified by either. However if both are present we assume this leads to an even greater level of concern, so the gate is not a pure 'OR'.

4.3.3 'Values' Factors

Gate 3.4 Lack of Personal Control Factor

Current α value = 0.5

The personal control gate aims to bring together the users' concerns regarding the lack of choice people have about being involved in an event and also the availability and quality of information relating to the event type.

The parameters that input into the personal control gate are:

- Gate 4.7 Lack of Choice
- Gate 4.8 Lack of Information

The α value used for the initial model runs was 0.5, resulting in a calculation of the arithmetic mean of the two contributing factors.

Gate 3.5 Lack of Trust Factor

Current α value = 0.8

The two inputs to the trust factor gate are both calculated values:

- Gate 4.9 No Trust in Knowledge
- Gate 4.10 No Trust in Management

Trust in knowledge is affected by the user's perceptions of the credibility and reliability of expert knowledge. Their perception of the accuracy of similar historical advice is also likely to affect the scores awarded to this area. The user's opinion regarding the competency and motivation of the people in charge of the rail industry is elicited by the questions that input into the management trust factor.

The α value selected is 0.8, making the gate biased towards an 'OR' calculation, i.e. either no trust in knowledge, or no trust in management could result in a high lack of

trust factor. However failure of trust in both areas leads to an even higher factor, unlike a pure 'OR' gate.

Gate 3.6 **Outrage Factor**

Current α value = 0.95

There are two calculated inputs to the outrage factor, comprising:

- Gate 4.11 Fairness Factor
- Gate 4.12 Fault Factor

The fairness factor relates to whether the user feels that the people involved in the event stood to gain from being involved with the original activity and whether they considered them to be particularly vulnerable. A higher level of sympathy may be experienced if the people involved are considered to be part of a vulnerable group, i.e. children, elderly etc. The immediate and long term impact of current actions on the environment is also an aspect brought out by the fairness factor.

The fault factor represents the user's perception of who or what is responsible for an event. Did the controls in place fail or were they inadequate, or did the choices or decisions made by the rail industry lead directly to the event occurring.

The α value of 0.95 selected for this gate leads to a strong 'OR' bias for the result. A feeling that the event was either someone's fault or it was unfair will result in a high score for outrage being calculated by this gate.

Gate 4.8 **Availability of Information**

Current α value = 0.2

The availability of information gate combines the effect of two input parameters concerned with the user's personal knowledge or experience of the event and the accessibility of related information. The direct inputs into this gate are:

- Gate 5.3 No Direct Experience
- Gate 5.4 Information Inaccessible

The initial α value selected was 0.2, leading to an 'AND' bias for the gate calculation. Thus someone would need to feel that not only did they have no direct experience of the issues, but also that there was no information available, in order to generate a high score here.

Gate 4.9 **Trust in Knowledge/Information/Advice**

Current α value = 0.6

The input parameters for Gate 4.9 are:

- Gate 5.5 Expert Disagreement
- Gate 5.6 History of Bad Advice

Gate 4.9 is influenced by two input parameter questions that examine the confidence the user has in the advice or information provided on a particular issue. Past experience or knowledge of 'poor' advice will influence the user's response to the questions concerned. Conflicting advice or lack of a consistent message will also affect the scores that input into this gate.

The α value of 0.6 produces a slight bias towards the 'OR' condition, so if one or other of the inputs scores highly, a higher output would result than if a simple mean were calculated. This reduces the 'watering down' effect of the simple arithmetic mean.

Gate 4.10 Trust in Management

Current α value = 0.7

The input parameters for the Trust in Management gate are:

- Gate 5.7 Poor Management History
- Gate 5.8 Adverse Incentives

These two input parameters explore the user's perception of the extent of the rail industry management's motivation to improve safety and also their competence in doing so. Any knowledge of historical performance has the potential to influence the responses to these questions.

The initial value of α selected was 0.7. Thus either poor management history or adverse incentives can result in a fairly high score for lack of trust in management, and if both are present the score is even higher.

Gate 4.11 Fairness Factor

Current α value = 0.9

The fairness factor has three inputs comprising:

- Gate 5.9 Vulnerability
- Gate 5.10 Inequity
- Gate 5.11 Landscape Destruction

The α value selected for the 3 Gate fairness factor was 0.9, providing a strong 'OR' bias to the calculation. The input parameters examine the users concerns relating to the vulnerability of the groups involved, whether those affected by the event gain any benefit from the activity and any impact the event has on the environment. If any of these factors is high, then this will result in a high level of 'unfairness', which in turn feeds into the 'outrage' gate.

Gate 4.12 Fault Factor

Current α value = 0.8

The fault factor or failed responsibility gate examines whether the user considers that the controls in place to minimise the chances of the event occurring are adequate. It also aims to elicit whether the user considers that a particular choice or decision has led to the event. The input parameters feeding this gate are:

- Gate 5.12 Poor Controls
- Gate 5.13 Human Choices

The α value selected leads to an 'OR' bias in the gate calculation, so if the controls are considered to be poor or someone was specifically responsible for the event occurring this will lead to a high fault factor. However, if both are present this will result in an even higher score.

5 Guidance on Model Use

A fundamental premise of this research is that if you want to understand what society is concerned about you should ask it! Our approach has been to construct a systematic framework that will facilitate this and allow the reasons for societal concern to emerge from the discussions. We believe that a systematic framework is required so that it is completely transparent what factors have been considered in any facilitated evaluation. Furthermore, a consistent framework means that the exercise will be repeatable and can be run with different ‘societies’ and at different times. By analysing the results from these exercises it should be possible to assess the relative level of societal concern associated with various risk issues and, in turn, this can be used to inform decision making.

In this section we describe how the model can be used to facilitate discussions to elaborate societal concern over particular issues or scenarios. We also describe how this can then be used to inform safety decision making for the railway industry.

5.1 Using the Model in a Focus Group Environment

5.1.1 Development and Use of Scenarios

From the literature review, and our personal experience with using the HSE model in a workshop environment, we have discovered the importance of the context within which hazards are considered. We reviewed RSSB’s Risk Profile Bulletin Version 3 to explore the types of hazards the rail industry may wish to use the model to assess. It rapidly became clear that not only are there a very large number of individual hazards, but that the hazard descriptions provide very little of the type of information that members of the public might want or need in order to decide how strongly they feel about a particular incident. For example they contain no information about the reason an accident occurred – who was to blame, what precisely went wrong and why, or much about the type of people involved (beyond adult, child, passenger, trespasser, worker), or whether one company rather than another was responsible, what actually happened – the nature of the harm and numbers of people involved and so on. These nuances may affect peoples’ responses to a particular incident, or they may not.

At this stage in the development of our tool, our primary purpose has been to make sure the model has the ‘granularity’ to distinguish between different types of hazards present in the railway context, and to explore whether more detailed descriptions of different scenarios surrounding ostensibly similar hazards will lead to different modelled outputs.

The first step was to select a small subset of the over 100 hazardous events listed in the Risk Profile Bulletin, against which the model could be tested. We tried to select hazardous events covering as broad a range as possible. Thus we sought to cover all the following:

- Different types of person: Passenger, Staff, Non-travelling public, Children

- Different types of train: Passenger/ Freight
- Different types of harm: electrical/ fire/ impact/ substance
- Different blame allocation: Own fault/ Caused by Railway
- Different levels of risk: High frequency events/ High consequence but low frequency events

We agreed the following list of hazardous events:

1. Passenger slips, trips & falls - HEN 14
2. Fire on passenger train - HET 18 (could be caused by passenger/ railway fault)
3. Passenger train collision with road vehicle on level crossing - HET 10 (could be HST or Commuter train, and fault of road vehicle or railway)
4. Child trespasser electric shock - HEN41/ HEN 42/HEN43 depending on cause of electric shock
5. Hazardous substance leakage on mainline railway - HEN 54
6. Adult trespasser struck/ crushed while on mainline railway - HEM 25
7. Worker struck while leaning out of on-track maintenance vehicle - HEM 24
8. Passenger falls from platform & struck by train - HEM 08
9. Derailment of freight train on passenger line - HET13 FTP

As already discussed, these hazardous events are difficult to think about in detail – from the descriptions we do not know enough about the situation to make judgements and answer the types of questions posed in the model. Our solution has been to develop scenarios that describe a realistic situation in which the hazardous event might take place. This helps to focus thinking. A listing of the scenarios we developed during this project is given in Appendix 3.

For future usage of the model, we strongly recommend the development of a range of appropriate scenarios to help focus thinking and explore the dimensions of a hazard in a particular set of circumstances. RSSB's Strategic Risk Model contains detailed information on the precursors for each hazardous event. These data should be considered when developing scenarios, to ensure they are realistic.

More experience of the use of such scenarios is also needed, to understand the impact of changing the wording or emphasis, or putting in more information about whose fault an incident was or the exact nature of the harms caused. At present the scenarios we have developed leaves some of this to the imagination of the group, and this could lead to inconsistencies in assumptions between different groups.

We believe that, with appropriately worded scenarios, the model should be able to discriminate between events where the outcome is similar but the underlying causes are different, particularly those events where different levels of blame may attach to the rail industry or the individuals affected by the incident themselves.

At present, the model has not been designed to give more or less weight to different types of people involved such as passengers, staff or non-travelling members of the

general public. The only types of people for which the model truly discriminates are those from vulnerable groups, defined as the very young, very old or the disabled. However, separating out other groups in the model would allow different weighting to be applied to them, if it was felt this better reflected the levels of concern that might arise.

5.1.2 Scoring the Parameters

A description of how to use the spreadsheet model is given in Appendix 2.

At present we have only explored the use of the model as a tool to use in a workshop or focus group environment. In this situation the group is invited to answer the questions posed by the model collectively, in the context of a specific story or scenario presented by the facilitator. This often leads to lively discussion, and it is important that where there is strong disagreement within the group, or where the scenario is obviously too ambiguous for the group to come to a single score decision, this is recorded by the facilitator.

Where strong disagreement occurs, the facilitator should explore with the individuals what it is that leads them to take their different views. The reasoning should be recorded, and the model can be run firstly taking one point of view and then taking the other to explore what difference the disagreement makes to the output of the model

Where there is ambiguity in the scenario, the record of the discussion can help to refine the scenario for future use.

Once all the parameters have been scored and the model run, the spider diagram generated is again a useful starting point for discussions. Does it look as expected? Are there any surprises, for example any of the key factors unexpectedly high or low? If so, the facilitator can explore with the group which of their responses led to that particular aspect of the result. When several hazards have been scored, the group can review the ranking of the hazards in terms of their overall societal concern scores – does the ranking order the hazardous events correctly in the view of the group? Are there clear differences between the spider diagrams? Would the group expect different actions to be taken for the different hazards? How do these relate to the model outputs?

As experience with use of the model develops, patterns may emerge, with characteristic spider diagrams for different ‘classes’ of hazard.

5.2 Using the Model to Aid Decision Making

In this section we describe our initial thoughts as to what could be done with the model and what the associated next steps should be, in the context of safety decision making in the railway industry.

There are three main aspects of our thoughts that will be discussed separately:

- How do we validate the model and its inputs?
- What use can be made of the model outputs?

- How can the railway industry use this to inform its safety decision making processes?

5.2.1 Validation of the Model and its Inputs

We have already indicated in section 2 how we have addressed the HSE peer review comments on our overall approach. These have been taken on board in developing the RSSB model. From this exercise we are confident that the list of societal concern factors in the new model is comprehensive and complete. We have restructured the overall approach and simplified it to make it more transparent. We believe that the introduction of the alpha factor at each 'gate' in the model to represent its 'AND'ness or 'OR'ness is a big step forward.

The validation questions that remain include the following:

1. How can we be sure that we have modelled the right parameters under each gate?
2. How do we derive the alpha factors at each gate?

On the first question we do not claim that we have applied a rigorous and strongly defensible approach to justify the model construct. It has been developed on the basis of the collective judgement of Risk Solutions' staff drawing on our general risk management experience and our general awareness of the academic literature in this field. We do not believe that any such construct will ever be able to deflect criticism levelled at how one construct has been chosen over another. Rather we believe that the critical issue is whether or not the model produces results that appear to be sensible and consistent so that relativities between different issues can be explored and changes over time evaluated.

In summary, we are confident that our model represents all the relevant societal concern parameters and we believe that our construct for how these parameters combine is as good a starting point as can be determined at this stage. The validity of our construct is something that can be tested and validated over time by running the model in anger with a series of focus groups type workshops and evaluating the reproducibility of the results.

As far as the second question is concerned we can anticipate ways in which the alpha factors could be elicited for each gate in a workshop environment. However at this stage in the research and given the immaturity of our approach, we believe that a simpler strategy should be adopted. It would be a relatively easy exercise to use a Monte Carlo sampling technique (such as applied in @Risk) to explore the sensitivity of the model results for scenarios that have already been scored (RSSB workshop on 11th March 2004), for various values of alpha at each gate. The model is constructed in Microsoft Excel so we could specify a range of values for alpha at each gate, where the range would reflect our view of the uncertainty around the 'AND'ness or 'OR'ness of each gate, and by running the model with @Risk we could determine which alpha values the model is most sensitive to. Armed with this information we could then focus on the most important alpha values and explore other methods to determine them more accurately.

5.2.2 Use of the Model Outputs

We believe that the model can be used to:

- Inform the relative societal concerns around safety issues faced by the railway industry
- Determine, for a specific safety issue or concern, the ‘anatomy’ of this concern. On the basis of this ‘anatomy,’ appropriate management responses can be designed.

We have explained earlier in section 5.1 the role that scenario development would have in our approach to understanding societal concern. Figure 3 shows how we would group sets of hazardous events (as described in the Safety Risk Model) into a scenario or story, which would form the basis for the evaluation in a workshop environment.

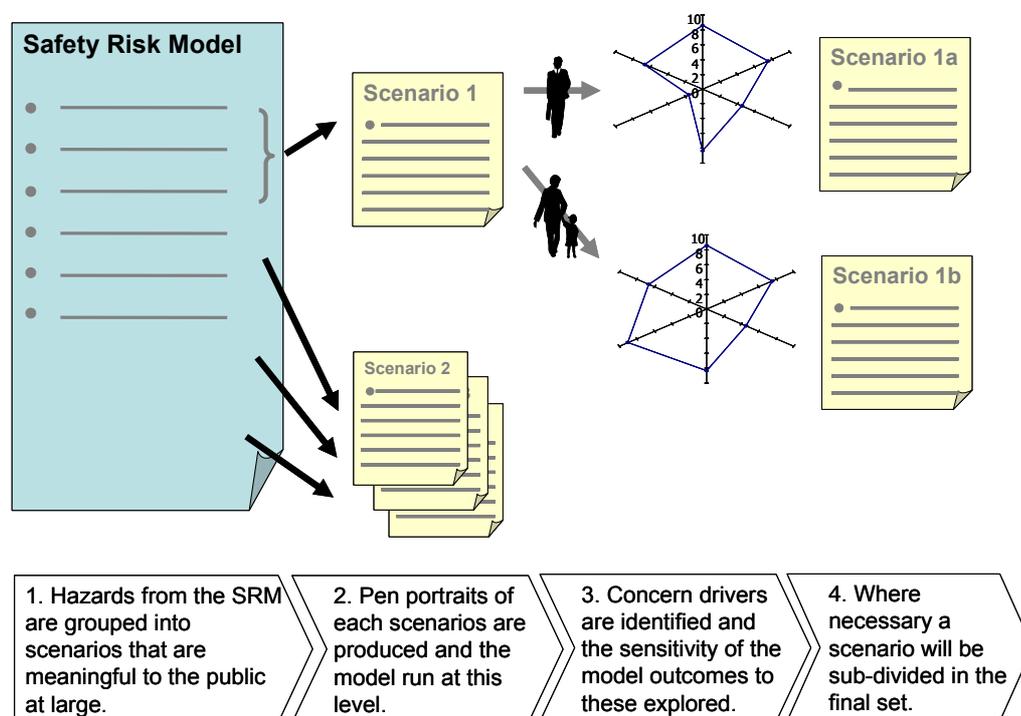


Figure 3 Developing & Evaluating Scenarios

We believe that the grouping into scenarios is absolutely critical to our approach because the definitions of the Safety Risk Model hazardous events are too railway specific and meaningless to the public. The group’s views on the issues surrounding each scenario can be explored using the framework determined by our model and in addition any bipolar responses (and reasons for varying responses) can be identified. If this exercise were run for a set of scenarios that covered all the SRM hazardous events, then the relative results could be compared and contrasted.

At the highest level the aggregate societal concern score for each scenario can be compared in order to rank them. Whilst we would always urge caution in over-interpretation of the absolute scores we have no problem in them being used as a vehicle to rank the issues. In addition to this we could supplement the ranking that emerges with information gleaned during the focus groups workshops to highlight how the absence or presence of particular facets of each scenario can affect its overall

ranking. For example Figure 3 illustrates that for scenario 1 the anatomy of the societal concern can be shaped by whether or not a child is involved in it.

An extremely useful variation to the activity described above would be to run the exercise for distinct groups of people. As a starter for 10 we believe it would be useful to run the exercise with the following groups:

- Railway industry managers (policy and decision makers)
- Railway industry engineers/operators (with detailed knowledge of the safety issues)
- Front-line railway staff
- General public - (with beliefs/perceptions)
 - users of the railway
 - non-users of the railway

This would be an extremely useful exercise because it would allow us to explore:

- The extent to which these groups ranked the safety issues (scenarios) differently?
- The extent to which the societal concern ‘anatomies’ differ

This latter point would be particularly useful in that it might indicate how different management strategies may need to be designed for different groups in society. We describe this further below.

The model generates spider diagrams to represent the societal concern anatomy. Figure 4 is an example of this.

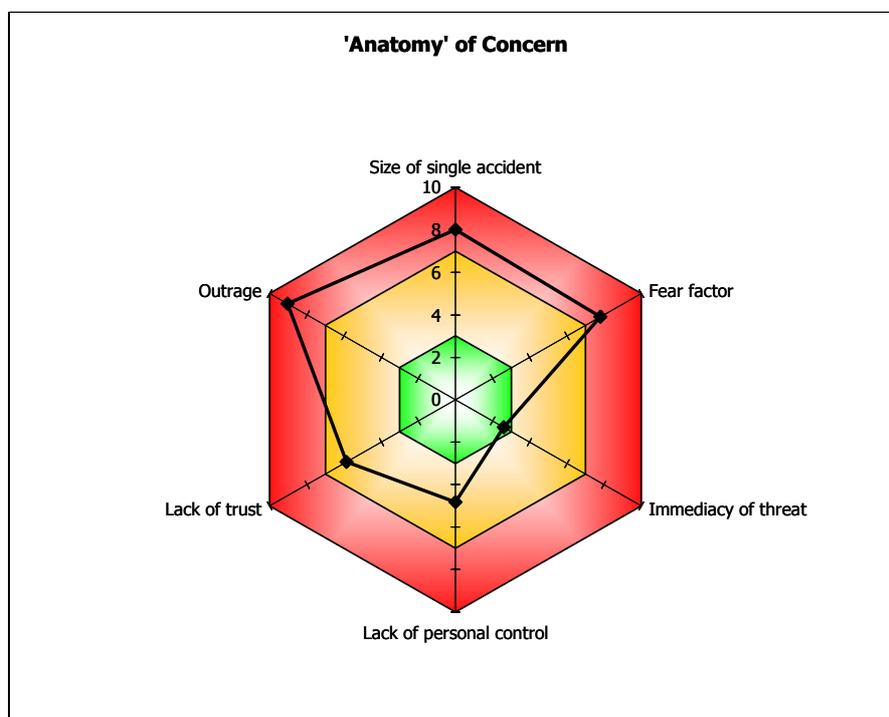


Figure 4 Anatomy of societal concern

Depending on the shape of the spider diagram, and in particular the score on each of the societal concern ‘dimensions’, different management responses or strategies may be appropriate. We have not explored this in detail but the colour scheme shown on the figure above could be used to guide or inform the need for managerial response to particular concerns. For example if “lack of trust” scored high for a particular issue and this, in turn was driven by trust in management, then consideration might be given to a communication campaign that opens up management performance to public scrutiny.

A valuable exercise would be to explore the managerial responses available as options to address each of the societal concern dimensions in the spider diagram. This would help inform the extent to which the railway industry could do something to address the societal concern associated with a particular issue, as opposed to having to live with as a fact of life but over which the industry has no control.

5.2.3 Using the Model for Safety Decision Making

So how would all this hang together in a form that could be used in a practical form for safety decision making in the railway industry? Here we provide some initial thoughts on this as a basis for further discussion.

Firstly the use of scenarios or stories to capture groups of SRM hazardous events will enable societal concern around safety issues on the railway to be explored in a way that is meaningful to the general public.

Our model can then be used to explore the relative importance of each scenario from a ‘societal concern’ perspective, as opposed to the hard quantitative information that is readily available, for example in the Railway Group Safety Plan which shows factual data about the risk arising from different types of incidents on the railway. The societal concern ranking of these scenarios can then be contrasted with the relative quantitative ranking of each risk.

By gaining experience over a wide range of scenarios, it may be possible to develop ‘reference anatomies’ for different types of accidents. If we explore the possible managerial responses that are available for each dimension of societal concern, then it could be envisioned that particular management strategies could be adopted for these societal concern anatomies. It may also be possible to help a particularly decision by using a focus group or groups to explore that specific scenario in great detail. Where little can be done because the societal concern is driven by a factor outside the direct control of the railway industry (e.g. some people believe that it is just wrong to have a national asset such as the railway run by anyone other than the state), then the reasons for action or inaction will be transparent.

6 Recommendations

On the basis of the work done to date and the discussion provided above we believe that there is value to be gained in pursuing this research further. In particular we have the following recommendations to make as areas for further research:

- R1. The alpha factors at each gate should be reviewed in detail, perhaps using focus groups to inform the choices made. The sensitivity of the model results to the choice of alpha factors at each gate should be explored using a tool such as @Risk.
- R2. The introduction of amplification and attenuation effects should be considered, the relevant branches of the model where this would be appropriate identified, and the possible impacts explored.
- R3. The use of weighting should be considered, particularly in relation to the different groups of people who may be involved in an incident, i.e. passengers, staff and the non-travelling public.
- R4. A set of scenarios or stories should be developed to capture the full set of the SRM hazardous events, drawing on the SRM precursor events to ensure the scenarios are realistic. This set of scenarios would form the basis for evaluation of societal concern in focus groups.
- R5. The model should be run in a series of focus groups with randomly selected members of the public to test the ease of interpretation of the scenarios and the questions asked by the model, and the reproducibility of the results.
- R6. The model should be run in a series of focus groups with specific groups that have vested interests in some aspect of the railway industry. This would test the relative perceptions of societal concern between each group.
- R7. For the dimensions of societal concern that our model presents as the societal concern anatomy, alternative managerial responses that are possible should be explored and described. This would help decision makers to interpret and use the outputs of the model.

Appendix 1: Bibliography

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Appendix 2: The Spreadsheet Model

Worksheet Descriptions

The spreadsheet model, 'RSSB Societal Concern Model Version 1.0.xls' consists of the following worksheets:

- 1. Results:** This is a hidden worksheet where the calculations are stored. It consists of a table that replicates the 'Data Entry' sheet, where the values entered by the user are copied. These are divided by 10 to generate scores between 0 and 1. A separate table carries out the gate calculations, using these 0-1 values and draws on the values of α shown on the 'Tree Picture Version' sheet. At the bottom of the 'Results' sheet is a table showing the main outputs of the model – the overall societal concern score and the 6 high-level parameters, which are also illustrated on an adjacent spider diagram.
- 2. Version Control:** This worksheet records the changes that were made in the development of the model, and the checking that was carried out.
- 3. Tree Picture Version:** This worksheet contains the model and its calculations presented in a visually intuitive format. The calculations are identical to those carried out in the 'Results' sheet. This sheet is where the α -values can be changed manually to alter the model. It shows instantly the impact of the changed values on the scores, drawing on the input parameter scores contained in the 'Data Entry' sheet. Changing α -values on the 'Tree Picture Version' sheet has no impact on any scenario results already generated, but will alter any future results. As a default this sheet is protected, to avoid inadvertent alteration of the α -values.
- 4. Data Entry Sheet:** This worksheet is where the user enters the details of the scenario they wish to test. Data is entered into the yellow shaded cells. All other cells are protected as a default, to avoid inadvertent erasing of the issue descriptions and the descriptions of the anchor scores. Each test scenario **must** be given a name, and this name **must** be different from any other worksheet in the workbook, otherwise the macro that runs the model will crash.

Function of the Macro

The macro to run the model performs the following functions:

1. Unhides the 'Results' sheet
2. Copies the 'Results' sheet to a position immediately after the 'Data Entry' sheet
3. Renames the new copy to the same name as the 'Test name' entered by the user on the 'Data Entry' sheet
4. Copies the user entered scores from the 'Data Entry' sheet onto the appropriate cells in the new copy of the 'Results' sheet

5. Copies as Values the α -values contained in the 'Results' sheet, which are linked directly to the α -values on the 'Tree Picture Version' sheet, thus fixing those values for that particular test.
6. Rehides the 'Results' sheet
7. Places the cursor on the newly copied sheet at an appropriate position to present the results of the test run, including the spider diagram.

Model Status

The model is a prototype and is not intended at this stage for use by general users or 'in anger' to answer questions or guide decision making. As such a lower level of operational robustness, error handling and quality assurance is required. We do not guarantee that the model is entirely 'bug free'. However we have used several quality assurance measures to ensure the model should perform as expected under most circumstances, as described in the quality plan below.

Quality Plan

The following quality assurance measures have been used to assure the quality of the model:

- Colour coding of spreadsheet cells: yellow shading for user inputs, orange shading for intermediate calculations or fixed data, blue shading for results, grey shading for headings.
- Checking by a named individual: Sara Ring has checked all calculation cells in the spreadsheet and also checked the operation of the macro.
- Use of comments: the macro contains some comments that describe the functions of the different parts.
- Error handling: The user is warned that the test name must be different from any other worksheet in the workbook, although this is not enforced and an error will occur in the macro if this is not the case, or if the name is left blank. The user is prevented from entering anything other than a whole value between 0 and 10 as the parameter scores. None of the calculations can result in a division by zero.

Using the Model

To use the model, the user fills in the yellow-shaded cells on the 'Data Entry' sheet. First enter the name of the test – this should be short as it will become the name of the worksheet containing the results - then a more detailed description of the scenario. Then enter the parameter scores, by answering each question and giving the answers a score between 0 and 10. Once all the parameters have been given a score, press the purple 'Run Model' button. The macro is activated and a new sheet appears in the workbook, with the results of that scenario run. To save results, it is a good idea to copy these results sheets into a separate workbook.

Appendix 3: Scenarios

Scenario 1: HEN 14 – Passenger Slips, Trips & Falls - 1

Imagine a regular commuter has cut his journey a little bit fine and is running over a pedestrian bridge to catch a train that is just pulling into the station. He is carrying a briefcase in one hand and an umbrella in the other, so he is not holding on to any handrails. While running down the stairs onto the platform he trips. He falls down several steps head first, trying to break his fall with his arms but getting tangled with his belongings.

Scenario 2: HEN 14 – Passenger Slips, Trips & Falls - 2

Imagine an elderly woman with a heavy shopping bag walking down the platform towards the exit from the station. It has been raining and the platform is wet but there are no warning signs. She slips on the wet surface and falls heavily.

Scenario 3: HEN 14 – Passenger Slips, Trips & Falls - 3

Imagine a mother with a small child and some luggage climbing up the stairs towards a platform. It has been raining and the stairs are wet. Despite the warning signs the woman is unable to hold the handrail due to her encumbrances. She slips on a stair and falls forwards, dragging her child with her.

Scenario 4: HET 18 – Fire on a Passenger Train – 1

Imagine a train full of passengers, travelling at speed between two stations some distance apart. A fault on the train causes a fire to start. Smoke begins to fill one of the carriages, and the passengers become very concerned. The guard is nowhere to be seen. One of the passengers pulls the communication cord.

Scenario 5: HET 18 – Fire on a Passenger Train – 2

Imagine a train running quite late at night, with people returning home after a night out. Many of the passengers have been enjoying an evening of drinking. In one of the carriages, a group of youths who have obviously had too much to drink are smoking, ignoring the no smoking signs and the disapproval of their fellow passengers. One of them throws a cigarette end away and it falls into a pile of newspapers that have been discarded on the floor by an earlier passenger. He is too drunk to notice the paper catch fire, and no-one realises the danger until the flames are fairly large.

Scenario 6: HET 18 – Fire on a Passenger Train – 3

Imagine a passenger on a non-smoking service who is desperate for a cigarette. He goes into the toilet cubicle and lights up. On finishing his smoke, he stubs out the cigarette in the hand basin and throws stub into the bin. Unfortunately he has not entirely extinguished the stub, and once he has returned to his seat the rubbish in the bin starts to smoulder and eventually flames leap out of the cubicle.

Scenario 7: HET 10 – Passenger Train Collision with Road Vehicle on Level Crossing – 1

Imagine a high speed train is approaching a level crossing. For some reason the barrier fails to lower. A car approaches the level crossing without realising there is a problem. The driver of the train sees the car and puts on the emergency brakes, but it is impossible to stop the train in time. As the car traverses the crossing the train hits it, causing part of the train to derail and considerable damage to the train and the car.

Scenario 8: HET 10 – Passenger Train Collision with Road Vehicle on Level Crossing – 2

Imagine a high speed train is approaching a level crossing. A car is also approaching the crossing. The driver of the car is in a hurry. He sees the barriers have been lowered, but believes that the car could get across before the train arrives. He weaves round the barrier and attempts to cross the tracks, but the train hits the car, causing part of the train to derail and considerable damage to the train and the car.

Scenario 9: HEN 41/42/43 – Child Trespasser Electric Shock – 1

Imagine a group of young children have found a hole in a fence near to their school playground. Beyond the hole is the railway track. The children squeeze through the hole and start to explore the tracks. They are unaware that there is a live rail, and, neither hearing nor seeing a train, they start to cross the tracks. The first child steps over the rails and is OK, but the second child steps onto the live rail and is electrocuted.

Scenario 10: HEN 41/42/43 – Child Trespasser Electric Shock – 2

Imagine a group of teenagers who are playing truant from school. They know there is a way to get down onto the railway line, where they enjoy playing games of chicken and showing off near trains. They climb over a fence and start to dare each other into risky behaviour around the tracks. One of the teenagers slips over while horsing around near the live rail, falls onto the rail and is electrocuted.

Scenario 11: HEN 54 – Hazardous Substance Leakage on Mainline Railway – 1

Imagine a freight train carrying a poisonous chemical, in reinforced flasks, across the country from the chemical plant where it was produced to the factory where it will be used. The train is travelling at around 75mph when for some reason it is derailed. The trucks with the flasks are thrown at speed into a concrete structure alongside the track. One of the flasks ruptures, and the chemical begins to leak into the atmosphere.

Scenario 12: HEN 54 – Hazardous Substance Leakage on Mainline Railway – 2

Imagine a freight train carrying nuclear fuel, in reinforced flasks, across the country from the power station where they have been used to a reprocessing plant. The train is travelling at around 75mph when for some reason it is derailed. The flasks are thrown at speed into a concrete structure alongside the track. One of the flasks ruptures, and some radioactive material is released.

Scenario 13: HEM 25 – Adult Trespasser Struck/ Crushed on Mainline Railway – 1

Imagine a man walking home from the pub late one night. He decides to take a short cut across the railway track rather than walk an extra half mile out of his way to get to the nearest footbridge and then home. There are signs warning against members of the public walking near the track, but he ignores them as he has walked this way many times before, he knows the track is not electrified, and trains are few and far between. He is listening to a walkman and does not hear the freight train's approach. His dark clothing makes him invisible to the driver, and the train hits him at full speed.

Scenario 14: HEM 25 – Adult Trespasser Struck/Crushed on Mainline Railway – 2

Imagine a man going home very late from work. He arrives at the local station which is unstaffed, looks at the clock and realises he has missed his last train home. He decides the quickest route is to walk along the track, directly to the next station which is near to his house. As he walks down the track the train he thought he had missed, which was actually running a few minutes late, approaches from behind and hits him.

Scenario 15: HEM 24 - Worker Struck While Leaning Out of On-Track Maintenance Vehicle – 1

Imagine the driver of a tamper, working in a 10-mile possession. He leans out of his cab to inspect the work on the track behind him, rather than getting out of the cab and going round to the back of the machine. He does not realise that a train delivering rails is travelling through the possession in the opposite direction, on the track adjacent to the tamper, and is struck as he leans out.

Scenario 16: HEM 08 – Passenger Falls from Platform and Struck by Train - 1

Imagine a passenger standing near the platform edge. The wind blows up and their hat blows off their head and onto the track below. The passenger decides to retrieve the hat by leaning out over the edge of the platform and reaching for it. While they are doing this a train is pulling into the platform. The driver sees the passenger and sounds the horn but is unable to stop. The passenger is startled by the horn and overbalances, falling into the path of the train.

Scenario 17: HEM 08 – Passenger Falls from Platform and Struck by Train - 2

Imagine a crowded platform at a busy commuter station, early in the morning. A train is due to arrive any minute. Passengers are continually arriving at the platform and jostling to find a place to stand near the platform edge. As the train is pulling in to the station, a passenger is jostled by the pressing crowd and falls from the platform into the path of the train.

Scenario 18: HET13 FTP – Derailment of Freight Train on Passenger Line – 1

Imagine a freight train travelling late at night over a passenger line. A problem with one of the axles causes the train to derail, stranding the freight train across the passenger tracks. Other traffic on the line is very light, so no other train is involved.

Scenario 19: HET13 FTP – Derailment of Freight Train on Passenger Line – 2

Imagine a freight train travelling over a busy passenger line just as rush hour traffic is starting to build up. A broken rail causes the train to derail, directly into the path of oncoming commuter trains.

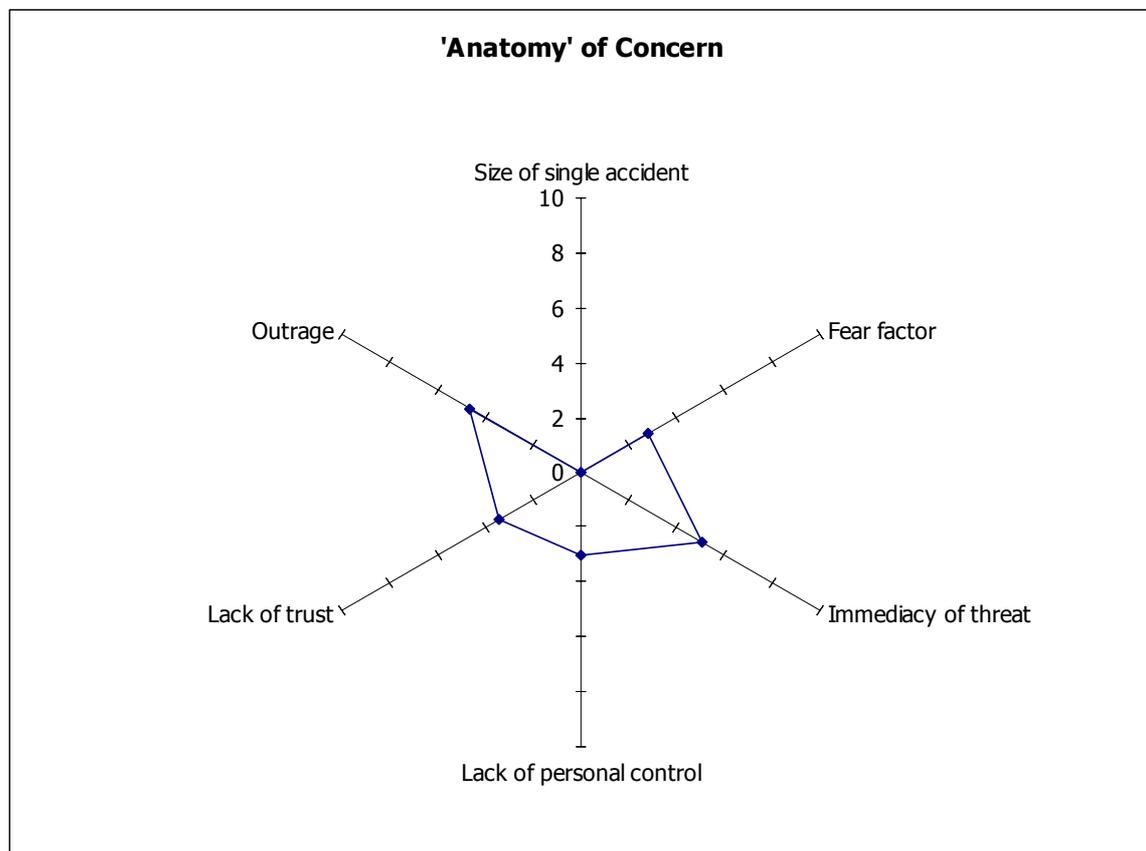
Appendix 4: Examples of Model Results

The following pages show examples of the model outputs for scenarios explored during a workshop held with RSSB staff on 11th March 2004.

Scenario 1 – Whole Group: Imagine a regular commuter has cut his journey a little bit fine and is running over a pedestrian bridge to catch a train that is just pulling into the station. He is carrying a briefcase in one hand and an umbrella in the other, so he is not holding on to any handrails. While running down the stairs onto the platform he trips. He falls down several steps head first, trying to break his fall with his arms but getting tangled with his belongings.

Scenario 1 Results

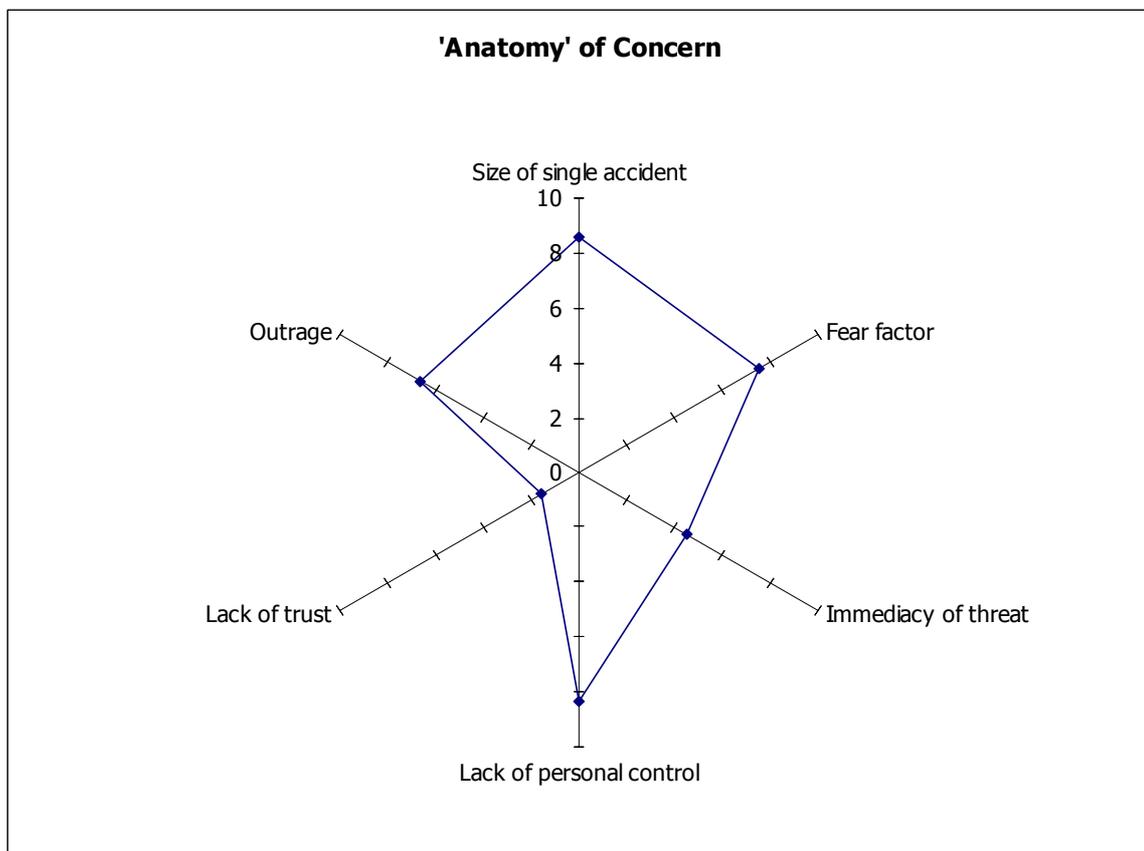
Overall Concern	3.8
Size of single accident	0.0
Fear factor	2.8
Immediacy of threat	5.0
Lack of personal control	3.0
Lack of trust	3.4
Outrage	4.6



Scenario 7 – Groups A and B: Imagine a high speed train is approaching a level crossing. For some reason the barrier fails to lower. A car approaches the level crossing without realising there is a problem. The driver of the train sees the car and puts on the emergency brakes, but it is impossible to stop the train in time. As the car traverses the crossing the train hits it, causing part of the train to derail and considerable damage to the train and the car.

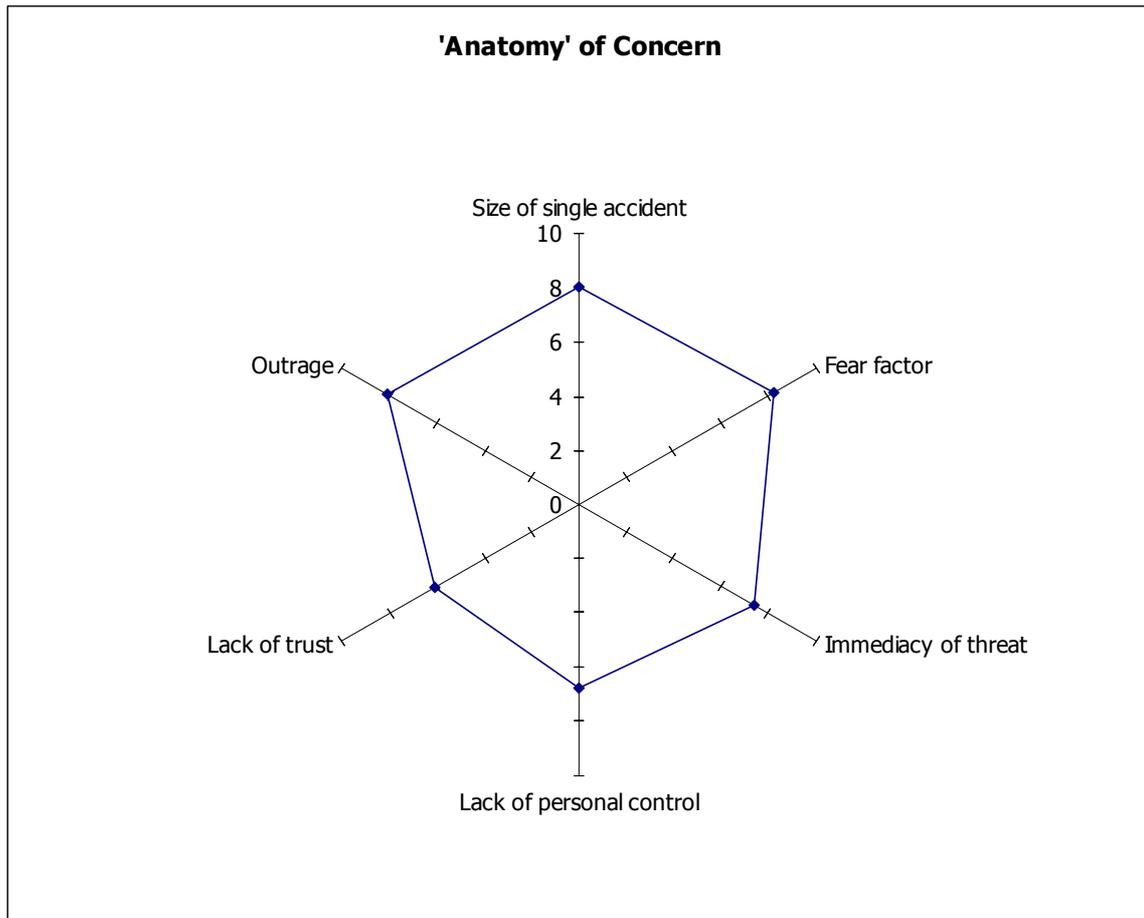
Scenario 7 Group A Results

Overall Concern	7.0
Size of single accident	8.6
Fear factor	7.5
Immediacy of threat	4.5
Lack of personal control	8.4
Lack of trust	1.5
Outrage	6.6



Scenario 7 Group B Results

Overall Concern	8.0
Size of single accident	8.0
Fear factor	8.2
Immediacy of threat	7.4
Lack of personal control	6.8
Lack of trust	6.1
Outrage	8.1

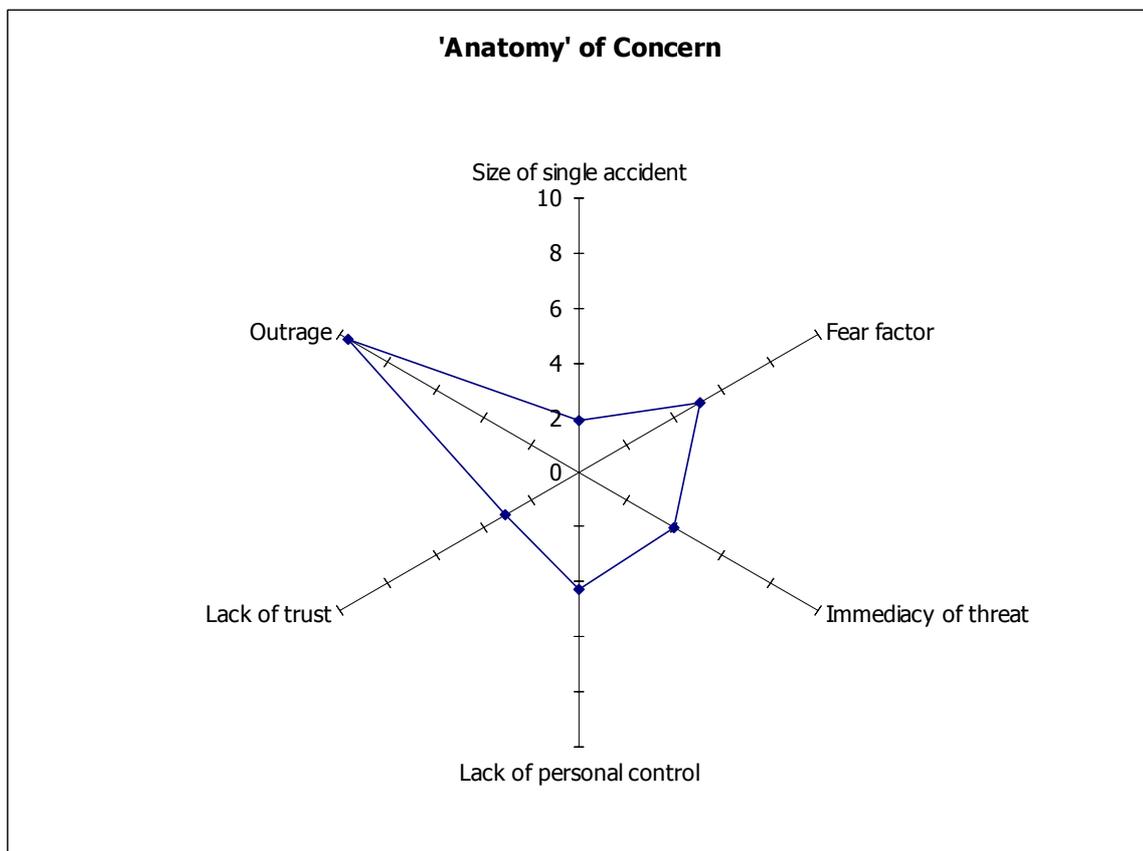


The difference between Group A and Group B's assessment of Scenario 7 hinged on whether they believed the rail industry staff had been doing all they could to try to prevent such accidents from occurring. Group B had less faith in the staff than Group A and this is shown by the difference in the 'Lack of Trust' scores for the two Groups.

Scenario 9 – Groups A and B: Imagine a group of young children have found a hole in a fence near to their school playground. Beyond the hole is the railway track. The children squeeze through the hole and start to explore the tracks. They are unaware that there is a live rail, and, neither hearing nor seeing a train, they start to cross the tracks. The first child steps over the rails and is OK, but the second child steps onto the live rail and is electrocuted.

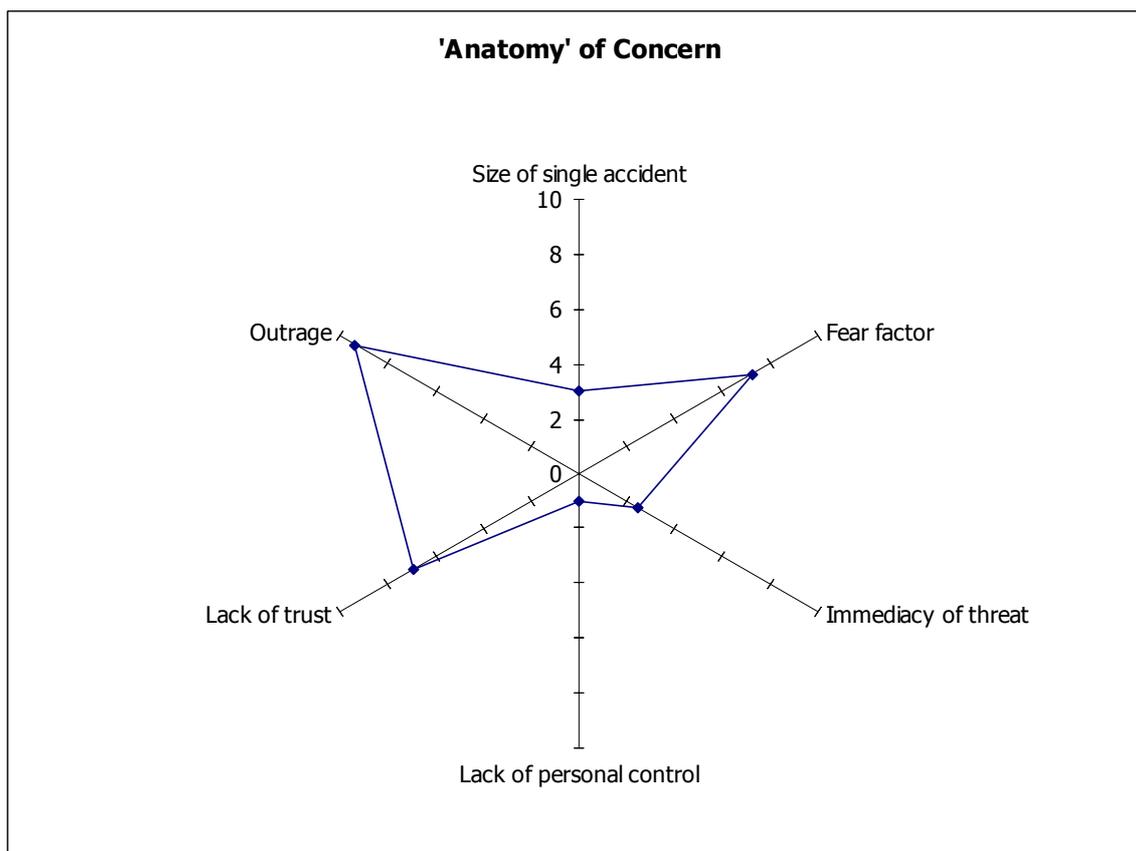
Scenario 9 Group A Results

Overall Concern	5.4
Size of single accident	1.9
Fear factor	5.0
Immediacy of threat	4.0
Lack of personal control	4.3
Lack of trust	3.1
Outrage	9.7



Scenario 9 Group B Results

Overall Concern	5.9
Size of single accident	3.0
Fear factor	7.2
Immediacy of threat	2.5
Lack of personal control	1.0
Lack of trust	6.9
Outrage	9.3



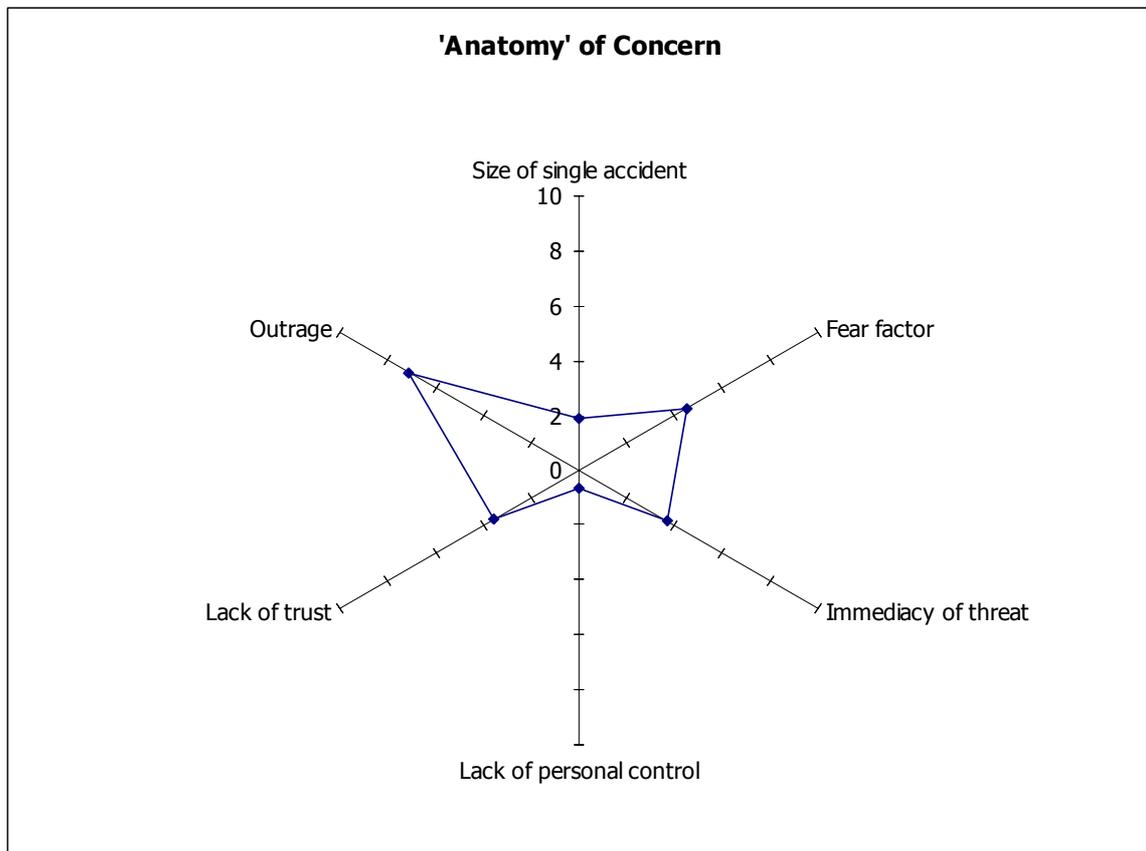
Here, the difference between Group A and Group B's assessment of this scenario primarily hinged on whether small children can be said to take responsibility for their own actions, and again on trust of railway staff. Group A were more trusting that railway staff were attempting to do the right thing, hence generated a lower 'Lack of Trust' score. They also assumed that small children did not have real control over their actions, so scoring 'Lack of Personal Control' more highly.

It is illustrative to compare Group B's assessment of Scenario 9 with Group A's assessment of Scenario 10 (overleaf). The main difference between the scenarios is that in Scenario 10 older children (teenagers) are involved, and they make a conscious decision to trespass on the railway. The results are very similar in shape, but with the overall level of concern and the values of each axis on the spider diagram being lower where teenagers are involved. This reflects a view that younger children are less responsible and deserve more protection from society than older children who deliberately seek to cause trouble

Scenario 10 –Group A: Imagine a group of teenagers who are playing truant from school. They know there is a way to get down onto the railway line, where they enjoy playing games of chicken and showing off near trains. They climb over a fence and start to dare each other into risky behaviour around the tracks. One of the teenagers slips over while horsing around near the live rail, falls onto the rail and is electrocuted.

Scenario 10 Results

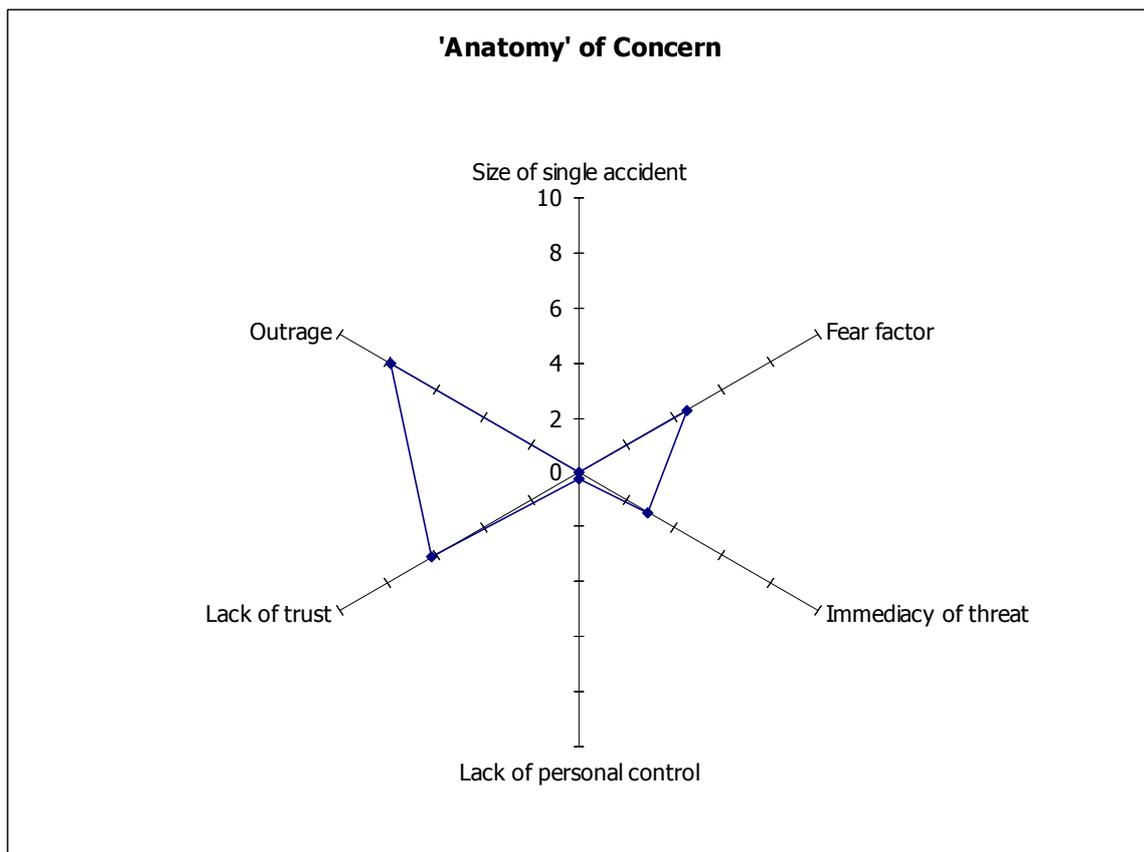
Overall Concern	4.3
Size of single accident	1.9
Fear factor	4.5
Immediacy of threat	3.6
Lack of personal control	0.7
Lack of trust	3.5
Outrage	7.1



Scenario 13 – Group B: Imagine a man walking home from the pub late one night. He decides to take a short cut across the railway track rather than walk an extra half mile out of his way to get to the nearest footbridge and then home. There are signs warning against members of the public walking near the track, but he ignores them as he has walked this way many times before, he knows the track is not electrified, and trains are few and far between. He is listening to a walkman and does not hear the freight train's approach. His dark clothing makes him invisible to the driver, and the train hits him at full speed.

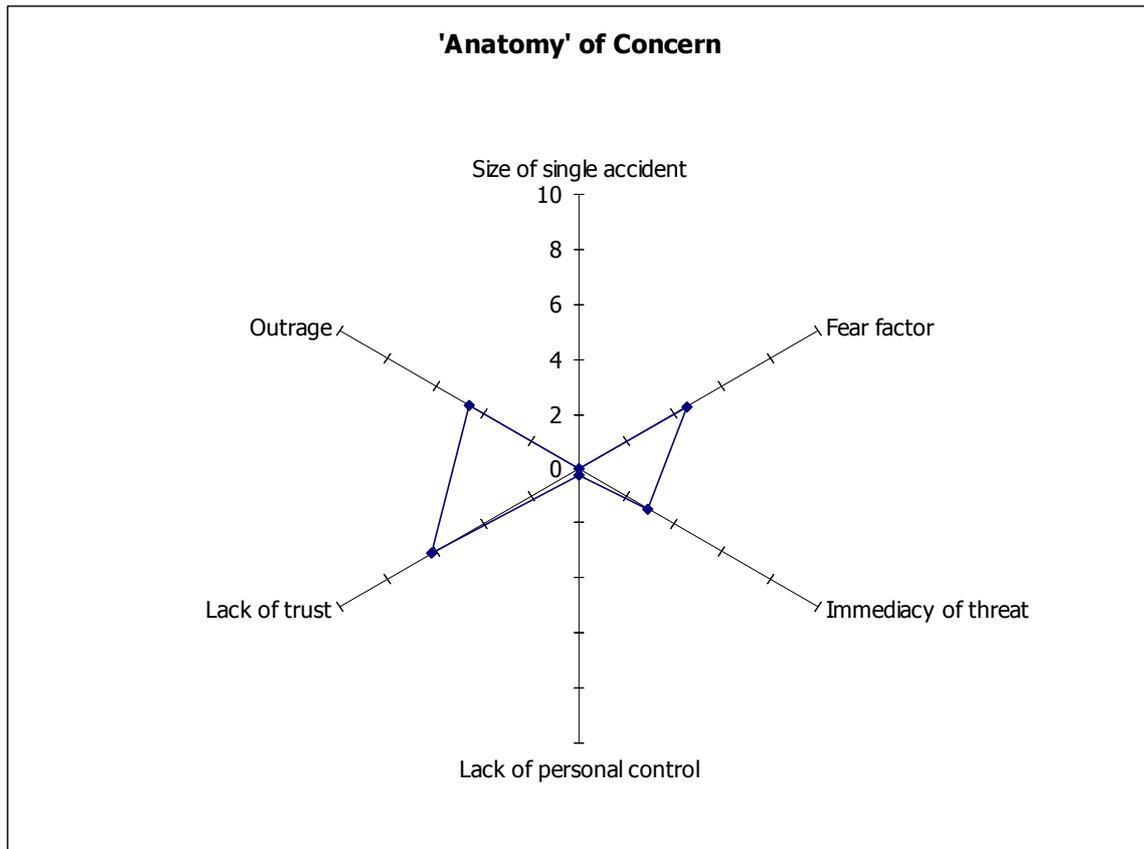
Scenario 13 Results

Overall Concern	4.4
Size of single accident	0.0
Fear factor	4.5
Immediacy of threat	2.9
Lack of personal control	0.2
Lack of trust	6.1
Outrage	7.9



Scenario 13a Results

Overall Concern	3.8
Size of single accident	0.0
Fear factor	4.5
Immediacy of threat	2.9
Lack of personal control	0.2
Lack of trust	6.1
Outrage	4.6

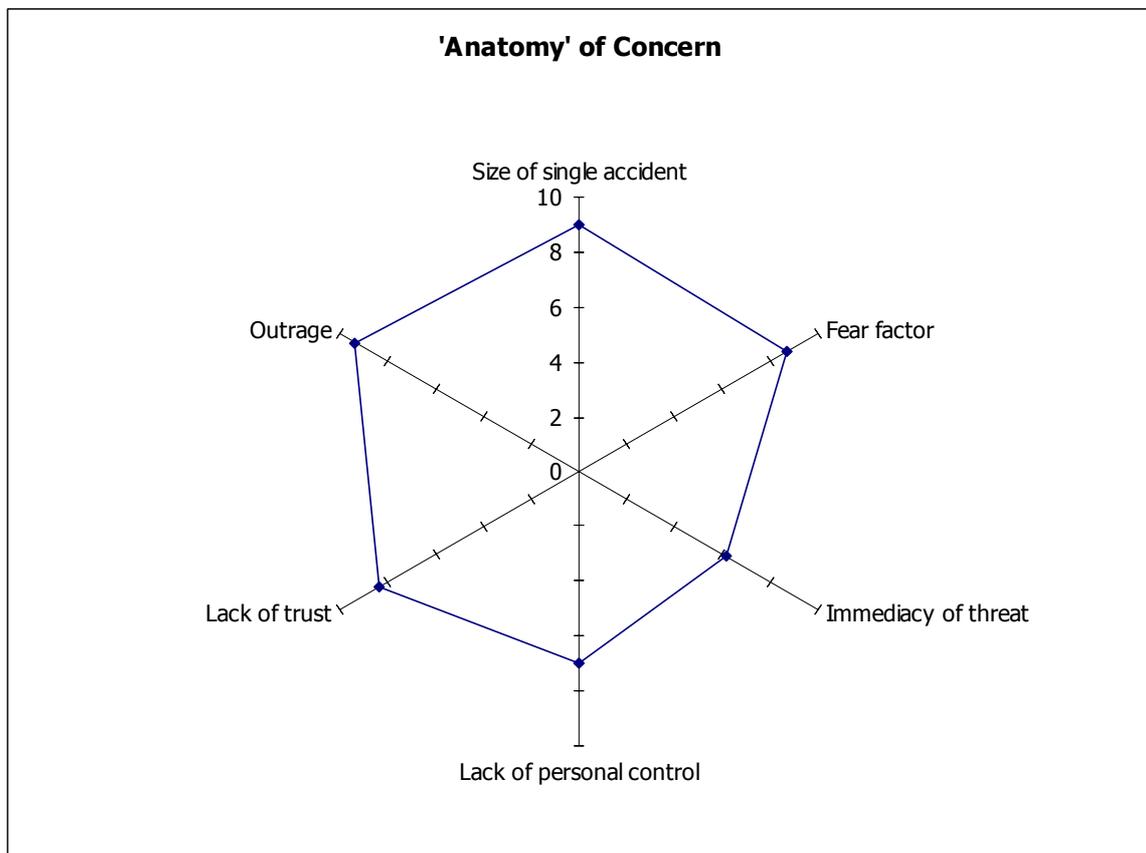


The group that considered Scenario 13 was unable to agree on the scoring of one of the parameters, question 5.9, regarding whether vulnerable people are involved. The incident related to a drunken man who trespasses on the railway and is hit by a train. Some members of the group believed that being drunk conferred vulnerability onto the man, and therefore scored 5.9 high – giving a score of 8. The effect of this is shown as the results of Scenario 13, and leads to a high ‘Outrage’ score. The remainder of the group believed that the railway has no particular duty of care to look after people who choose to drink too much, and therefore he did not count as ‘vulnerable’ in the same way as a child, or an elderly or disabled person would. They therefore scored 5.9 low – giving it a score of 1. The effect of this, shown as the results of Scenario 13a, is to lower the ‘Outrage’ score.

Scenario 19 – Group B: Imagine a freight train travelling over a busy passenger line just as rush hour traffic is starting to build up. A broken rail causes the train to derail, directly into the path of oncoming commuter trains.

Scenario 19 Results

Overall Concern	8.6
Size of single accident	9.0
Fear factor	8.7
Immediacy of threat	6.2
Lack of personal control	7.0
Lack of trust	8.4
Outrage	9.3



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