Understanding Risk Data: Techniques for Presenting Risk to a Non-Technical Audience

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Conveying risk information to non-technical decision makers is a challenge that influences every level of an organization. Bridging the gap between the technical safety and other personnel is critical to enable effective decision-making and an area that Safety Engineers play a central role. There are examples from industry incidents where senior management decisions regarding budgets, manning, operating philosophy, timescales and go/no-go decisions, based on risk data they receive, have made significant contributions to Major Accidents. This paper looks at areas where this understanding of risk is crucial, and presents communications methods from a variety of scenarios. This includes a recent Case Study with the Computer Infographics developed for a leading North Sea operator's HSE team to share findings from a Quantitative Risk Assessment of a Semi-Submersible floating production facility.

Traditionally the technical information received by an organization's board level can be difficult to interpret, summarized very heavily and is often influenced by the agendas of the authors. Technical personnel are not always the most gifted when communicating messages to non-technical audiences. By understanding the requirements of the audience and applying advanced presentation techniques, the outputs from technical assessments can be made accessible without the need for in depth technical knowledge, thus presenting the results directly to the audience to draw their own conclusions. Building on experience of using graphical techniques, such as bowties, the case study of the floating production facility used computer infographics to facilitate the conveying of important technical risk messages to all levels of the organisation. This focused on highlighting key areas, presenting non-biased information, and making consequences of risks clear.

The work presented in this paper has shown that infographics can be a powerful tool for conveying complex technical risk information and, to be successful, required a well-organized structure and concise presentation. Information density must be considered with care; too much information can be as harmful to successful communication as too little information. By careful attention to detail, complex technical risk information can be conveyed graphically enabling a message to be conveyed that can be understood across a diverse range of audiences.

Keywords: Risk, Communication, Infographics

Introduction

Conveying risk information to non-technical decision makers is a challenge that influences every level of an organization. Bridging the gap between the technical safety team and other personnel is critical for effective, informed decision-making and an area in which we, as Technical or Process Safety Engineers, play a central role. There are examples where lack of clear, usable risk information available to senior managers has been a contributing factor in major accidents such as Texas City and the space shuttle Challenger.

The question of how to communicate risk effectively with non-technical audiences, particularly with stakeholders and the public has become more prominent in recent years. This has led to increased research in this field, along with new strategies for the effective communication of risk (Heath et. al 2010). This paper describes one approach by which appropriate risk information may be conveyed to a wide variety of personnel in their normal working environment. It is based on work carried out by ERM for a leading North Sea operator who wish to improve the understanding of technical safety risks throughout the organisation. It is recognised that there is a field of work on the representation and understanding of risk, far beyond the scope of this paper.

How is risk communicated

In our working lives, we discuss and use the term risk in many different contexts. We discuss business risk, social risk, economic risk, safety risk, environmental risk, military risk, political risk, and so on. We consider risk to be absolute but in reality, all individuals have their own perception and acceptance of risk. Risk is thus subjective and depends upon who is looking; "qualitatively, risk depends on what you do and what you know and what you do not know" (Kaplan and Garrik, 1981). Furthermore, when discussing risk, we need to be clear about whether we are trying to increase understanding, change behaviour, or encourage shared decision-making based on a common understanding. This subjective nature of risk makes it difficult to convey in a way in which the receiver of the risk information interprets the information as intended by the conveyor of the information. The way people receive information and interpret this information has a profound effect on their understanding of risk. We succumb to many forms of bias, which leads to misinterpretation, or dismissal of relevant information. These biases include (Howgego et al, 2015):

- Confirmation bias: "We only believe what we already think"

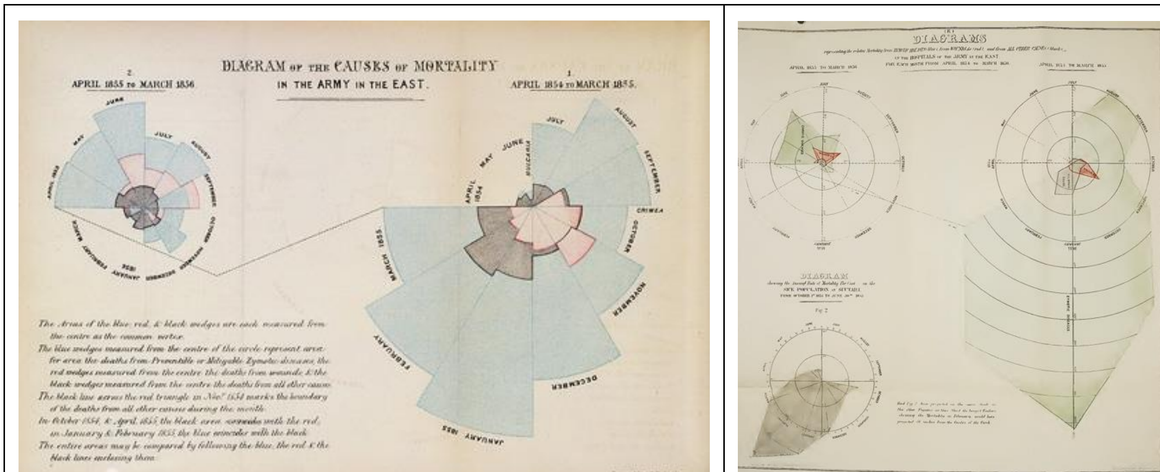
- Fixation error: “We are unable to understand a situation clearly because you are too involved in it”
- Outcome bias: “We are seduced by success”
- Group think: “We are wired to conform”
- The default mode: “Our minds are built to wander”
- Tech clash: “We don’t speak the technical language”

An example of the effect these biases can have our understanding is illustrated by our understanding of the risk of being killed on the roads. Most people believe the roads in the UK are becoming increasingly unsafe i.e. that there is an increased risk of being involved in a road traffic accident. This may or may not be true. The statistics (DoT, 2017) on road fatalities show that there was a 50% decrease in fatalities between the year 2000 and 2015. Even the number of cyclist deaths showed no sign of significant change during that period. A period during which road traffic increased by 10% and cycle use increased by 30%. Although the perception that the roads in the UK are less safe (in the sense of the probability of being involved in an accident) is difficult to verify from government statistics the risk of fatality from a road traffic has decreased.

The need to convey risk information in a simple clear and unambiguous way has been recognised for a long time. Florence Nightingale was an early pioneer of conveying fatality and risk data to non-specialist audiences, and she can be regarded as a pioneer, not only of establishing sanitation in hospitals, but also in applied statistics (Ims25, 2008). She meticulously gathered data relating death tolls in hospitals to cleanliness, and, because of her novel methods of communicating this data, was able to influence other people’s behaviour. She created graphs, which are often described as roses or coxcombs (see

Figure 1). These drawings were an early attempt to display fatality risk data in a pictorial form and are an early form of infographics. By conveying complex information in a pictorial way, she realized that she could grab the attention of the audience and there was less scope for misinterpretation of the message.

Figure 1 Presentation of Crimea Hospital Fatalities by Florence Nightingale



Over the years, there have been other attempts to develop methods for conveying complex risk information to non-specialist audiences. For example, in the 1970s Ronald A Howard at Stanford University developed the concept of the micromort (from micro- and mortality) as a unit of risk defined as a one-in-a-million chance of death. Micromorts can be used to measure the risk associated with various day-to-day activities, and enable the risks of different activities to be compared on a common basis, i.e. micromort enables us to translate risk between different aspects of life. A micromort can be seen as the average "ration" of lethal risk that people are exposed to daily. For a person in England and Wales this can be determined from the number of people who die from avoidable external causes. According to the UK Office of National Statistics, over 18,000 people died from avoidable injuries in England and Wales in 2013. This was out of a population of approximately 55 million, and corresponds to an average risk of 340 micromorts a year for each person, or roughly one micromort per day.

Every acute risk can be measured in micromorts. For example, the risk of death from a general anaesthetic in an emergency operation is given officially as 1 in 100,000, meaning that in every 100,000 operations someone dies from the anaesthetic alone. This is not as intuitively easy to grasp or compare as it could be. However, we can convert this risk into 10 micromorts, or 10 times the ordinary average risk of getting through the day without death by an avoidable external cause. Further data for hazards are presented in Table 1 (Blastland and Spiegelhalter, 2014)

Table 1: Micromorts per Hazard

Cause of Death	Micromorts	Exposure
Non-natural causes (England and Wales, 2010)	1	Per day
Giving birth (UK, 2010)	120	Per birth
Giving birth (World, 2010)	2,100	Per birth
Flying in Bomber Command in WWII	25,000	Per mission
Walking (UK, 2010)	1	Per 27 miles
Riding a motorbike (UK, 2010)	1	Per 7 miles
Driving (UK, 2010)	1	Per 333 miles
Train (UK, 2010)	1	Per 7,500 miles
Coal mining (UK,1911)	1,190	Per year
Coal mining (UK, 2006-10)	460	Per year
Commercial Fishing (UK, 1996-2005)	1,020	Per year
All occupation UK	6	Per year
All Occupation World	160	Per year

Although the micromort approach enables non-specialists to compare and contrast risk it has not been widely adopted. The offshore oil and gas industry, like other major hazard industries such as rail and civil nuclear power, has adopted Quantitative Risk Assessment, QRA, as the main analytical method for assessing and presenting technical safety risks. In recent years, the weakness of QRA as a risk communication tool has been widely appreciated and this has led to a search for new means of conveying information and the increasing adoption of new tools such as bowtie diagrams.

Risk Analysis and Presentation in the Oil and Gas Industry

Risk, as it relates to the oil and gas industry is a measure of the magnitude and likelihood of economic loss or human injury. It can be thought of as the product of probability and consequence. Risk can be described in qualitative terms (e.g. low, medium, high), such as is typically done in a process hazard analysis. Alternatively, in the case of a Quantitative Risk assessment, QRA, it can be described quantitatively (such as likelihood of a fatality per year). Risk can be measured in terms of fatalities, dangerous dose, or financial impact. QRA results are usually reported in two forms: individual risk and societal risk. The U.K. Health and Safety Executive define individual risk as “the risk of some specified event or agent harming a statistical (or hypothetical) person assumed to have representative characteristics”.

Two measures of risk of fatality are used widely in the offshore industry as follows:

- Individual risk per annum
- Potential Loss of Life

Individual risk per annum (IRPA) is an annualised frequency of fatality for a specific individual. An individual risk of 1 x 10^{-3} per year is considered a maximum level tolerable in the UK for a site worker (HSE, 2006). For the general public, the tolerable risk is generally taken as an order of magnitude less than this value. Risks above this level are deemed to be intolerable and must be reduced, regardless of the cost of risk reduction measures. This level effectively mean that an individual has a one in a thousand chance of becoming a fatality in any year. An IRPA of 1 x10^{-6} per year (one in a million chance of becoming a fatality in any year) is the lower threshold of risk below which the risk is considered broadly acceptable (HSE, 2001).

Location Specific Individual Risk (LSIR), the risk to a single hypothetical person who spends 100% of their time in a particular location, is typically reported as likelihood of death (or dangerous dose) per year, and can be presented in the form of risk contours (see Figure 2). Each contour ring on the plot represents a likelihood of death. For example, a hypothetical person on the inner ring of the contour plot in Figure 2 would have a 1-in-100,000 chance of being killed at the particular facility being considered. As the hypothetical individual moves, further away from the facility, their risk decreases (CPR, 1999). However, risk contours are not very useful for offshore structures that tend to have a relatively small footprint and a complex three-dimensional risk picture.

Potential Loss of Life (PLL) is defined as the statistically predicted number of lives lost (normally per year) as a result of accidental events and is proportional to the sum of all the IRPAs. By its nature, there is little if any benefit to be gained by setting explicit limit criteria for PLL.

The difficulty of presenting risk data led to the partnership between a leading North Sea operator and ERM to explore other ways to present risk data for a floating production facility (see Figure 3). The aim of this for the North Sea operator was to convey the risk information in a manner that can be readily understood by both technical and non-technical audiences, highlighting key risks and facilitating conversation. The objective was to provide transparency, not to persuade the audience of any one-view point.

Figure 2 Individual Risk shown on a Contour Map

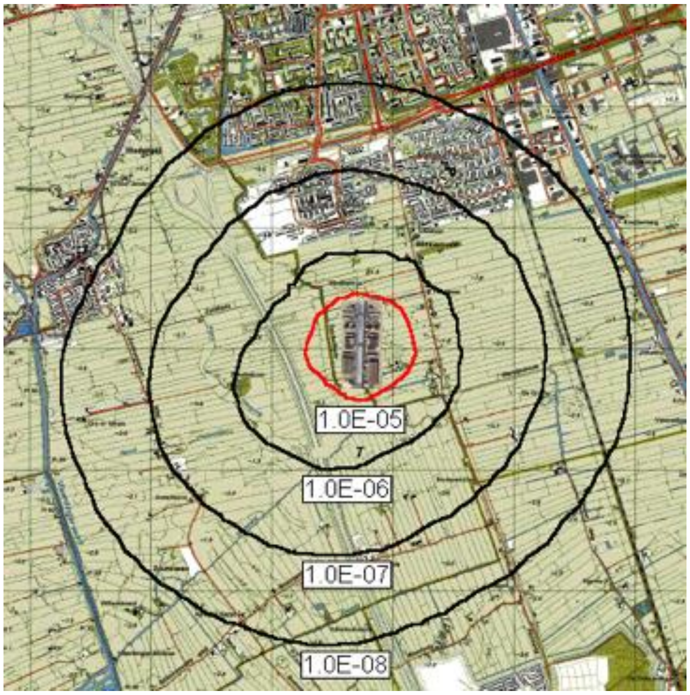


Figure 3 Floating Production Facility

Floating Production Facility

The floating production facility, illustrated in Figure 3, acts as the production facility to separate the gas, water and oil from a number of template and satellite wells. It is connected to the subsea template by flexible risers. The facility also has the necessary equipment to perform workovers, drilling, water injection and gas lift. The facility has an accepted safety case that includes a summary of the QRA carried out for the facility. Representative PLL and IRPA data for the facility are presented in Table 2 and Table 3. Whilst these tables are information-rich, they are difficult to interpret and understand.

Table 2 Overall PLL (per year) by hazard and worker group

Hazard	Stewards / Medic	Supervisors	Operators	Dive Support	Saturation Divers	Total
Explosions (in Process Area)	$7.4x10^{-5}$	$3.5x10^{-4}$	$5.6x10^{-3}$	$7.1x10^{-4}$	$5.9x10^{-5}$	**$6.8x10^{-3}$**
Explosions (in Turbine Hall)	$1.7x10^{-8}$	$6.1x10^{-7}$	$8.8x10^{-6}$	Negligible	Negligible	**$9.4x10^{-6}$**
Jet Fires & Smoke	$9.5x10^{-5}$	$1.9x10^{-3}$	$2.8x10^{-2}$	$2.1x10^{-3}$	Negligible	**$3.2x10^{-2}$**
Jet Fire Escalation	$4.7x10^{-6}$	$3.9x10^{-6}$	$2.1x10^{-5}$	$1.9x10^{-5}$	$5.9x10^{-6}$	**$5.4x10^{-5}$**
Smoke affecting the TR	$2.6x10^{-5}$	$2.2x10^{-5}$	$1.2x10^{-4}$	$1.1x10^{-4}$	$3.3x10^{-5}$	**$3.1x10^{-4}$**
Pool Fires	$1.1x10^{-5}$	$2.6x10^{-4}$	$4.6x10^{-3}$	$4.7x10^{-6}$	$1.5x10^{-6}$	**$4.8x10^{-3}$**
Riser Fires	$1.2x10^{-5}$	$6.1x10^{-5}$	$8.9x10^{-4}$	$5.8x10^{-4}$	$1.0x10^{-5}$	**$1.6x10^{-3}$**
Non-Process Pool Fire	$5.3x10^{-7}$	$7.9x10^{-7}$	$1.8x10^{-5}$	$6.4x10^{-6}$	Negligible	**$2.5x10^{-5}$**
Unignited Gas	$6.3x10^{-7}$	$1.6x10^{-5}$	$2.9x10^{-4}$	Negligible	Negligible	**$3.0x10^{-4}$**
Diving	-	-	-	-	$2.7x10^{-2}$	**$2.7x10^{-2}$**
Ship Collision	$1.8x10^{-5}$	$1.5x10^{-5}$	$8.1x10^{-5}$	$7.2x10^{-5}$	$2.2x10^{-5}$	**$2.1x10^{-4}$**
Loss of stability	$4.1x10^{-5}$	$3.4x10^{-5}$	$1.8x10^{-4}$	$1.6x10^{-4}$	$5.1x10^{-5}$	**$4.8x10^{-4}$**
Transportation	$5.3x10^{-4}$	$4.4x10^{-4}$	$2.4x10^{-3}$	$1.5x10^{-3}$	$5.6x10^{-4}$	**$5.4x10^{-3}$**
Total	**$8.2x10^{-4}$**	**$3.1x10^{-3}$**	**$4.3x10^{-2}$**	**$5.2x10^{-3}$**	**$2.7x10^{-2}$**	**$7.9x10^{-2}$**

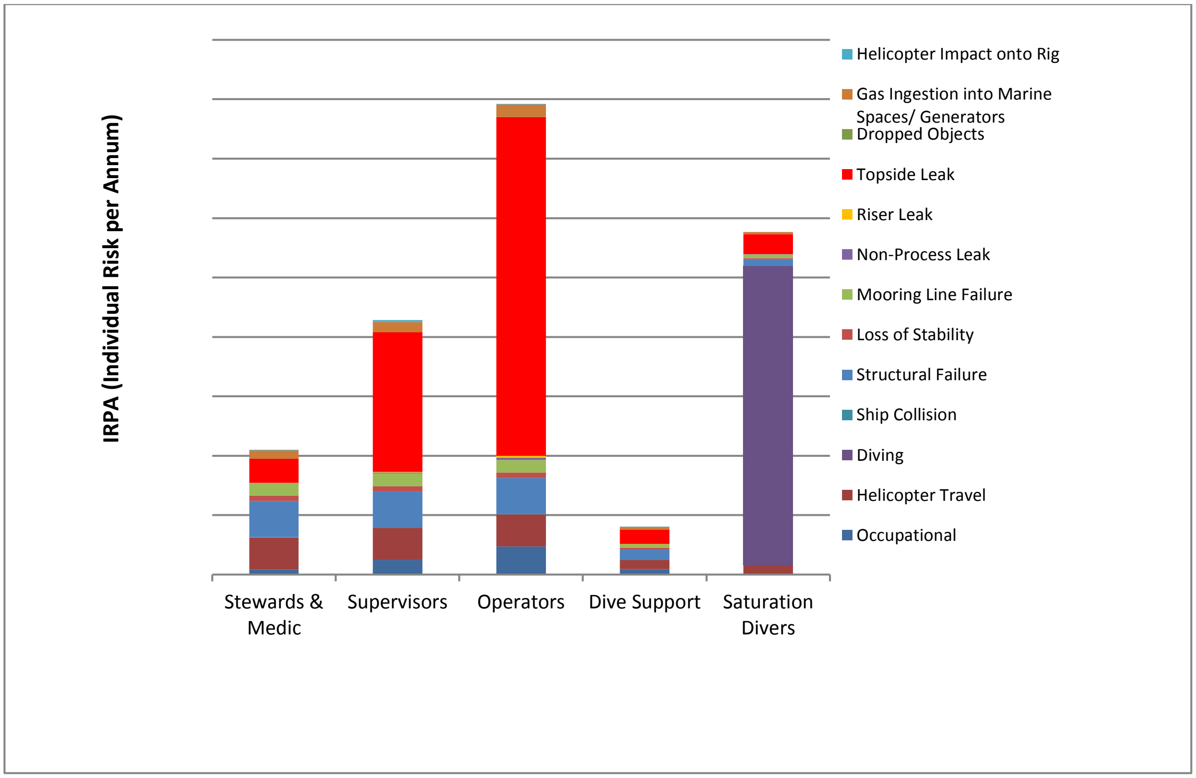
Table 3 Overall IRPA by hazard and worker group

Hazard	Stewards / Medic	Supervisors	Operators	Dive Support	Saturation Divers	Weighted Average
Explosions (in Process Area)	$5.0x10^{-6}$	$2.8\ x10^{-5}$	$8.3\ x10^{-5}$	$4.9x10^{-6}$	$1.1\ x10^{-6}$	**$3.6\ x10^{-5}$**
Explosions (in Turbine Hall)	Negligible	$4.9\ x10^{-8}$	$1.3\ x10^{-7}$	Negligible	Negligible	**$5.3\ x10^{-8}$**
Jet Fires & Smoke	$6.3x10^{-6}$	$1.5\ x10^{-4}$	$4.2\ x10^{-4}$	$1.4\ x10^{-5}$	Negligible	**$1.8\ x10^{-4}$**
Jet Fire Escalation	$3.1x10^{-7}$	$3.1\ x10^{-7}$	$3.1\ x10^{-7}$	$1.3\ x10^{-7}$	$1.1\ x10^{-7}$	**$2.1\ x10^{-7}$**
Smoke affecting the TR	$1.8x10^{-6}$	$1.8\ x10^{-6}$	$1.8\ x10^{-6}$	$7.2\ x10^{-7}$	$6.0\ x10^{-7}$	**$1.2\ x10^{-6}$**
Pool Fires	$7.5x10^{-7}$	$2.1\ x10^{-5}$	$6.8\ x10^{-5}$	$3.2\ x10^{-8}$	$2.7\ x10^{-8}$	**$2.7\ x10^{-5}$**
Riser Fires	$8.0x10^{-7}$	$4.9\ x10^{-6}$	$1.47\ x10^{-5}$	$4.0\ x10^{-6}$	$1.8\ x10^{-7}$	**$8.5\ x10^{-6}$**
Non-Process Pool Fire	$3.5x10^{-8}$	$6.3\ x10^{-8}$	$2.6\ x10^{-7}$	$4.4\ x10^{-8}$	Negligible	**$1.2\ x10^{-7}$**
Unignited Gas	Negligible	$1.3\ x10^{-6}$	$4.3\ x10^{-6}$	Negligible	Negligible	**$1.7\ x10^{-6}$**
Diving	-	-	-	-	$4.9\ x10^{-4}$	**Negligible**
Ship Collision	$1.2x10^{-6}$	$1.2\ x10^{-6}$	$1.2\ x10^{-6}$	$4.9\ x10^{-7}$	$4.1\ x10^{-7}$	**$8.1\ x10^{-7}$**
Loss of Stability	$2.7x10^{-6}$	$2.7\ x10^{-6}$	$2.7\ x10^{-6}$	$1.1\ x10^{-6}$	$9.3\ x10^{-7}$	**$1.8\ x10^{-6}$**
Transportation	$3.5x10^{-5}$	$3.5\ x10^{-5}$	$3.5\ x10^{-5}$	$1.0\ x10^{-5}$	$1.0\ x10^{-5}$	**$2.2\ x10^{-5}$**
Total	**$5.4x10^{-5}$**	**$2.5\ x10^{-4}$**	**$6.3\ x10^{-4}$**	**$3.6\ x10^{-5}$**	**$5.0\ x10^{-4}$**	**$2.7\ x10^{-4}$**

To overcome the problem of comprehensibility, the safety case also presents data in the form of graphs such as that shown in

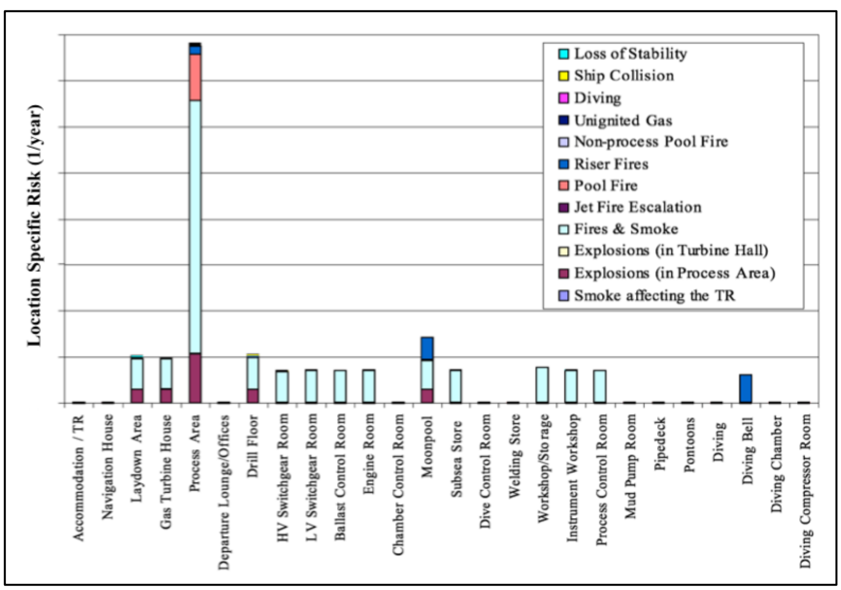
Figure 4. Whether this is any easier to understand than the tables of data is dependent on the reader, however, the format makes this data difficult to glean conclusions from and incorporate into the decision making process.

Figure 4 IRPA by Worker Group



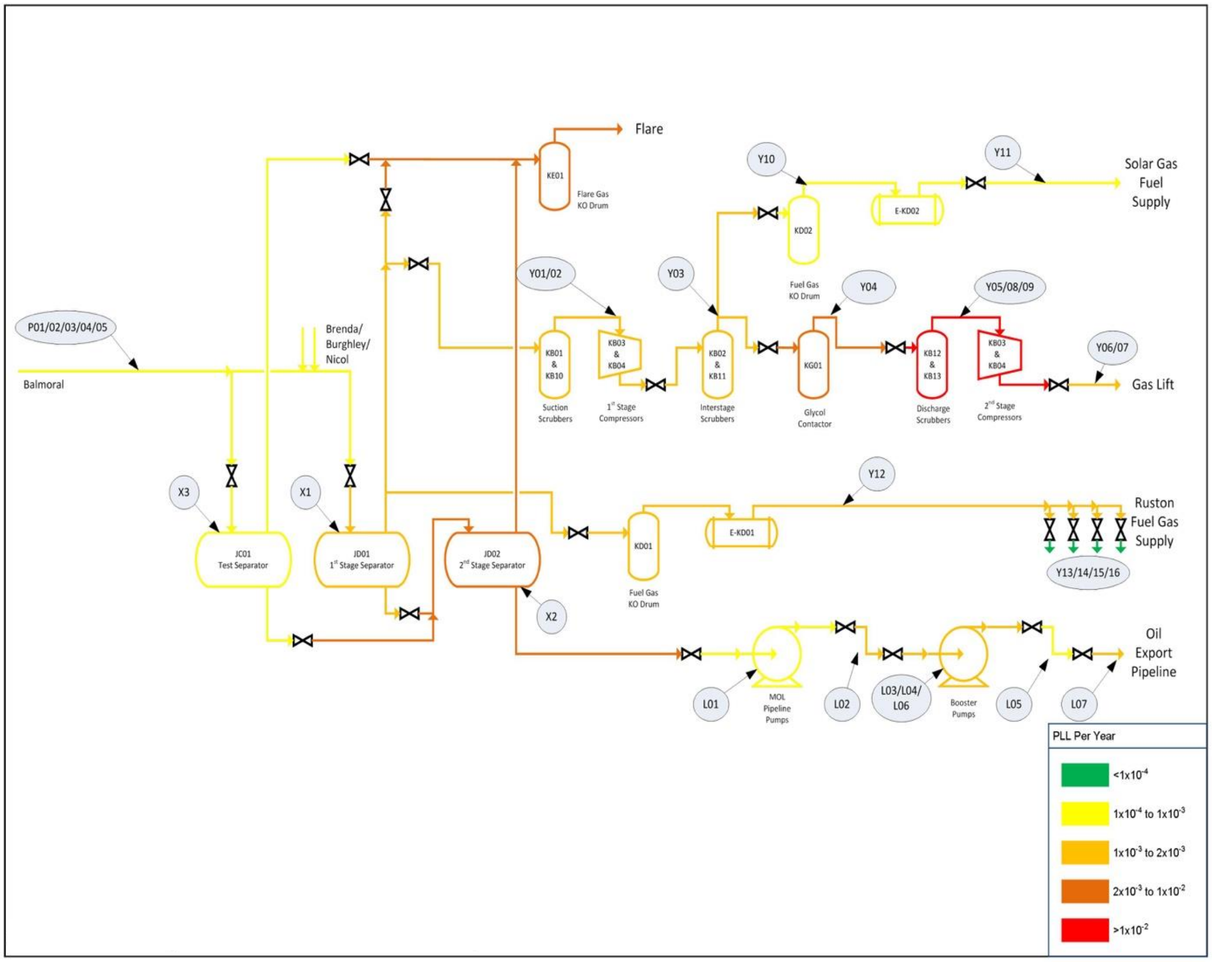
Another problem with the data presented so far is that it is difficult to relate the risk to the area of the facility in which an individual might be located. To overcome this, the facility's safety case also includes location specific individual risk (LSIR) data. It therefore provides a measure of the risk associated with different locations of an installation. LSIR data for facility is shown in Figure 5.

Figure 5 Floating Production Facility LSIR Data (per year)



With the process areas being such a dominant source of risk, there was an interest in trying to understand the contribution of different processes and different process areas to the overall installation risk. This resulted in a modified process flow diagram (PFD) being developed for the facility as illustrated in Figure 6. The PFD is colour-coded to show the risk as represented by contribution to PLL of each part of the process system. Even without an understanding of the meaning of the numbers in the key, the signal colour coding system enables a far greater understanding of the relative risks of different parts of the facility's process system.

Figure 6 Process Area by Contribution to PLL



Whilst Figure 6 was a significant improvement on the way of presenting risk data from the early means of tables and graph, there was room for further improvement and other ideas were explored. One concept was to retain the technical risk data but to relate this to the different areas of the platform through a set of maps. Examples of these risk maps (which later became known as LSIR Heat Maps) are shown in

Figure 7, Figure 8 and Figure 9. The figures are subtlety different from each other; for example, Figure 7 presents the risk data as a pie chart within a shaded box indicating the area that the risk data applies to, whereas Figure 8 and Figure 9 do not distinguish between the area by colour instead colours the area by the "level of risk". Figure 8 and Figure 9 use different colour schema for the "level of risk" with Figure 9 adopting a traffic light schema of red, orange, yellow and green to represent very high, high, medium and low risk area. It is interesting note that the same information is presented in all three figures but different people find different versions of the maps easier to understand.

Figure 7 LSIR Heat Map for the Float Production Facility 1st Tween Deck version 1

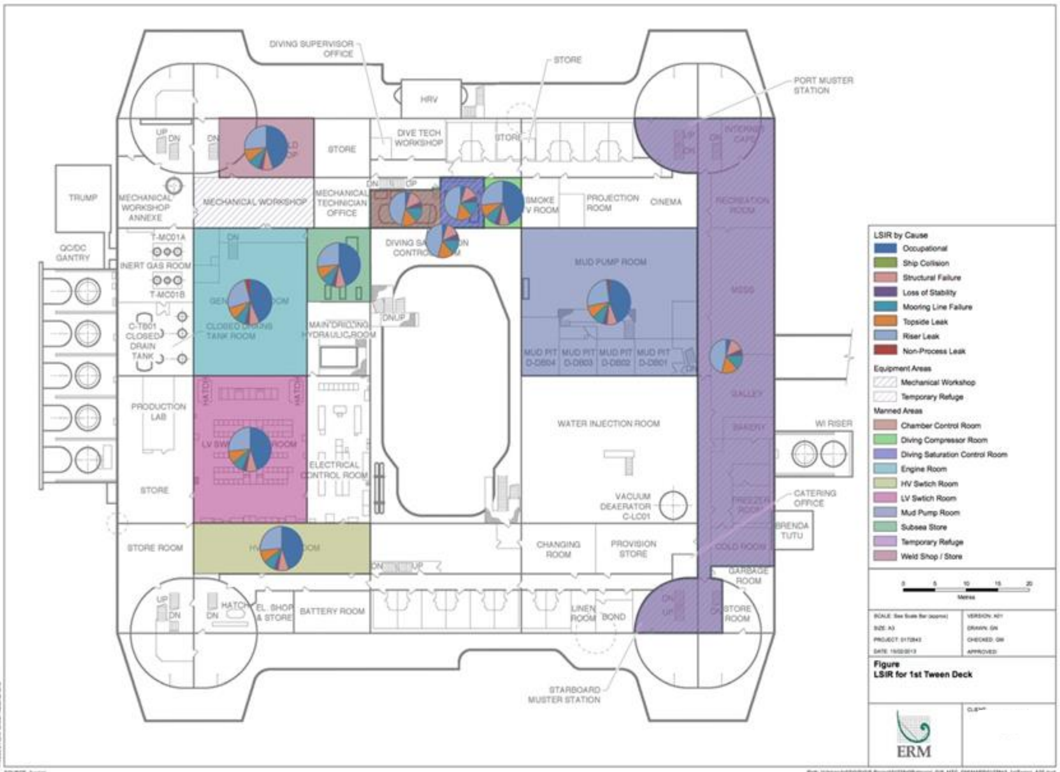


Figure 8 LSIR Heat Map for the Floating Production Facility 1st Tween Deck version 2

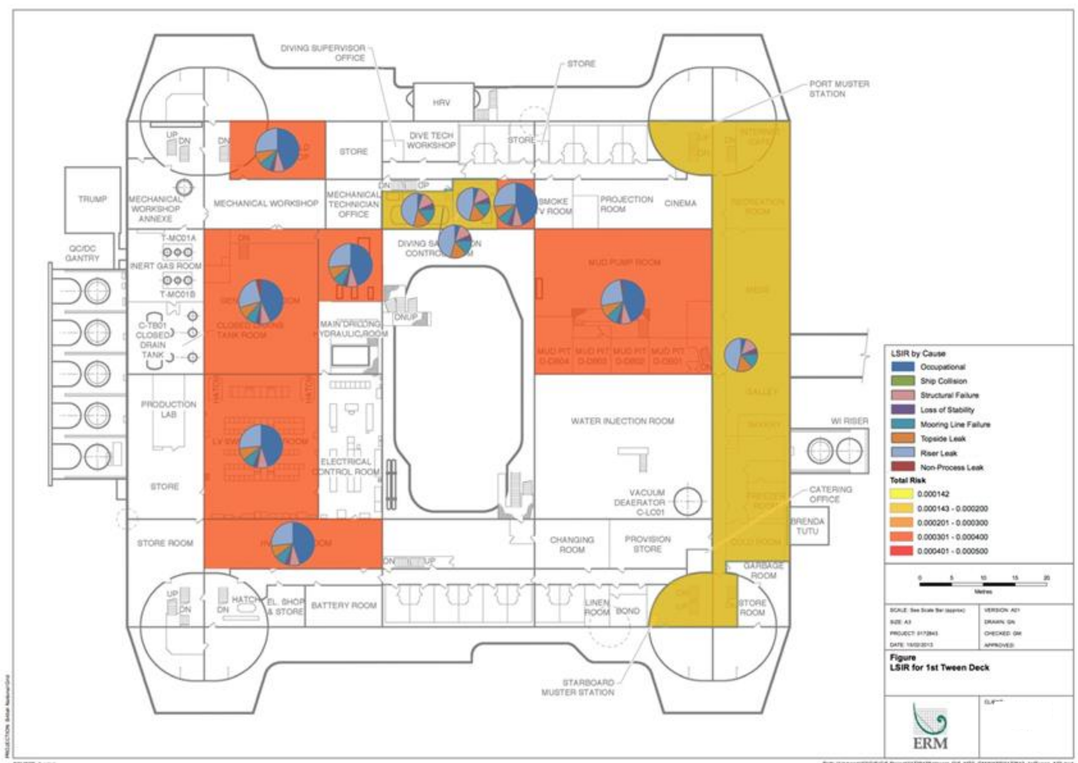
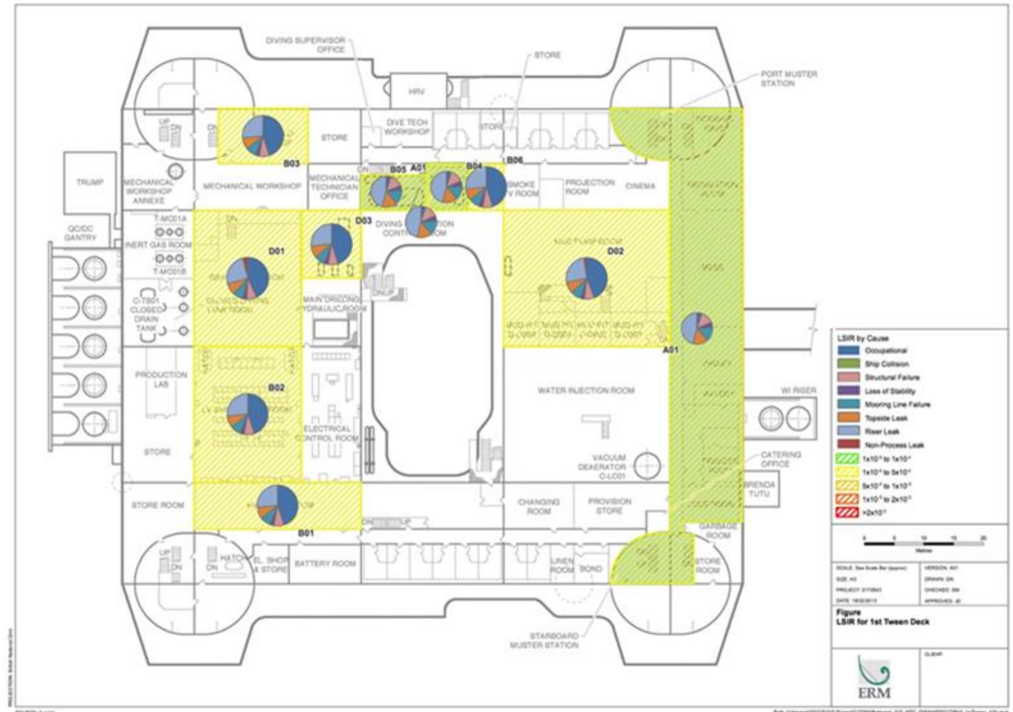
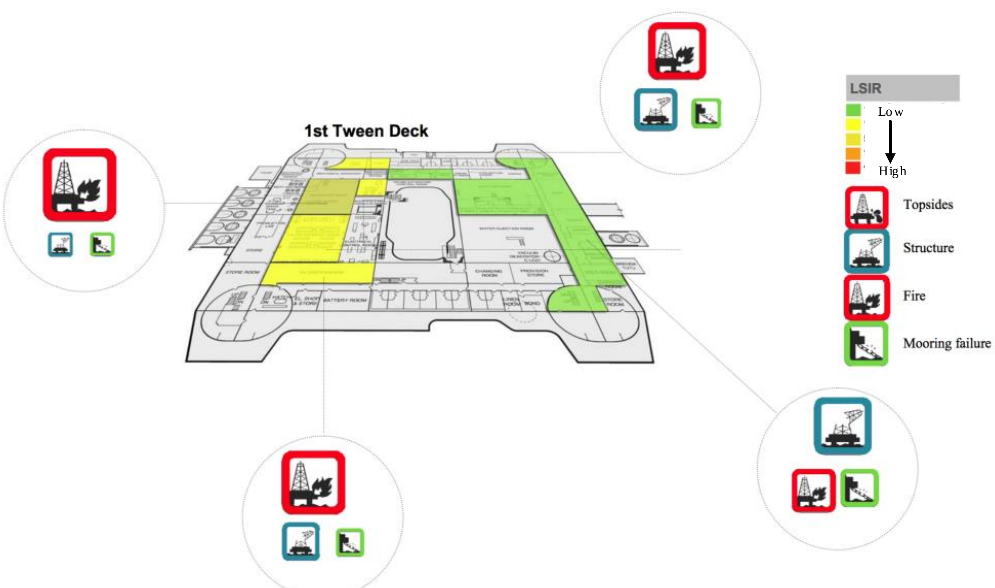


Figure 9 LSIR Heat Map for Floating Production Facility 1st Tween Deck version 3



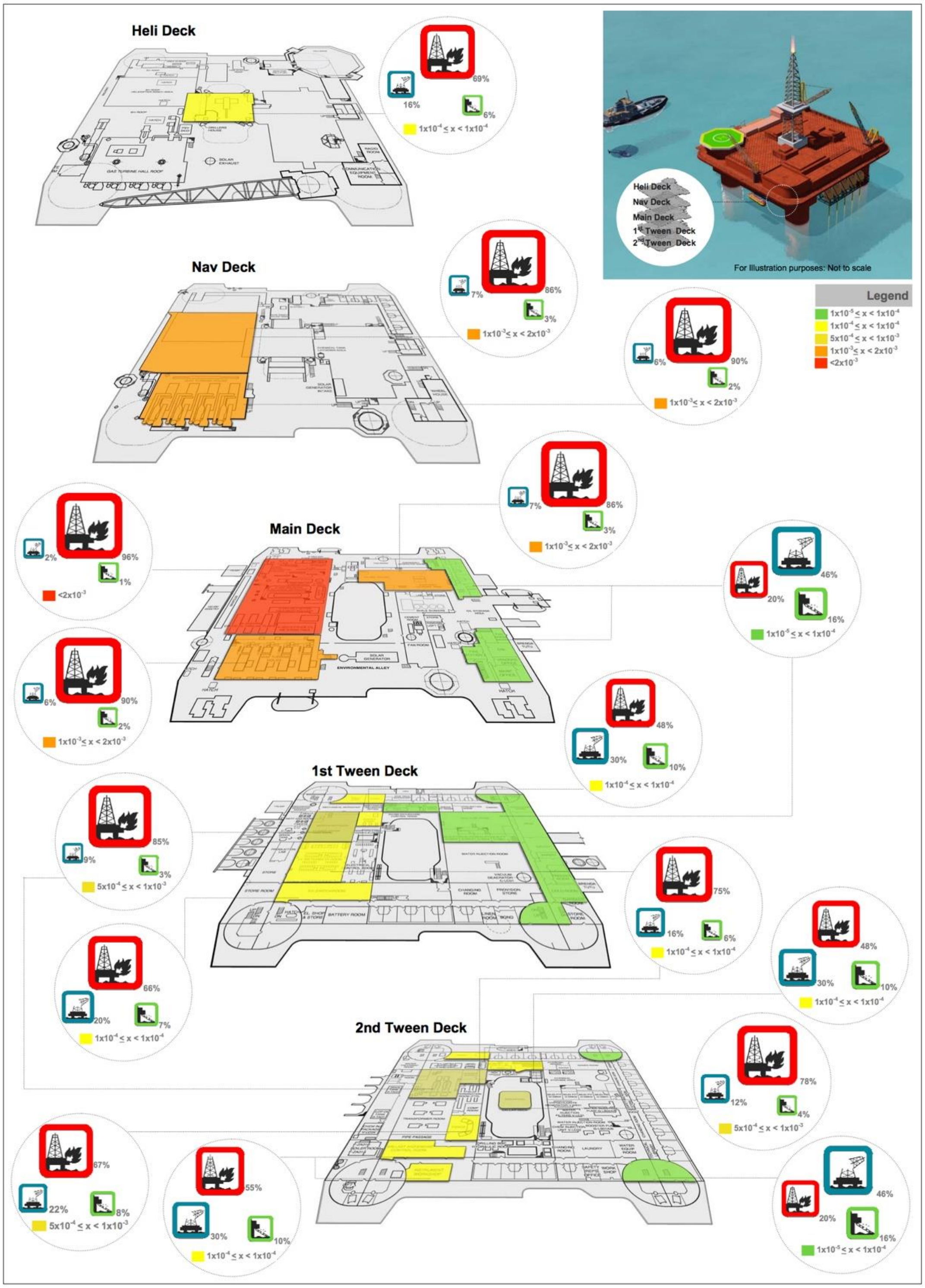
Although these figures are relatively easy to understand, through discussion it was recognised that the mini pie charts added little value in the way of conveying useful information. Various ways to simplify the LSIR Heat Maps were tried, and through trial and error, the Heat Map presented in Figure 10 was developed. In this version of the map, the source of the risk is represented by pictograms with the size of the pictogram being proportionate to its contribution to the LSIR. The pie charts have been replaced with representative icons, and the LSIR is represent by a signal colour coding system.

Figure 10 LSIR Heat Map for Facility's 1st Tween Deck version 4



Version 4 of the LSIR Heat Map retained the information about risk from the previous version, but using the pictograms immediately brought to light the hazard source and was easier to understand than using the imbedded pie-charts of the earlier versions. It was recognised that there was also the opportunity to represent the interactions between the different platform levels. This led to the development of the final version of the Heat Map presented in Figure 11, in which the contribution to the LSIR both horizontally and vertically in the facility are shown.

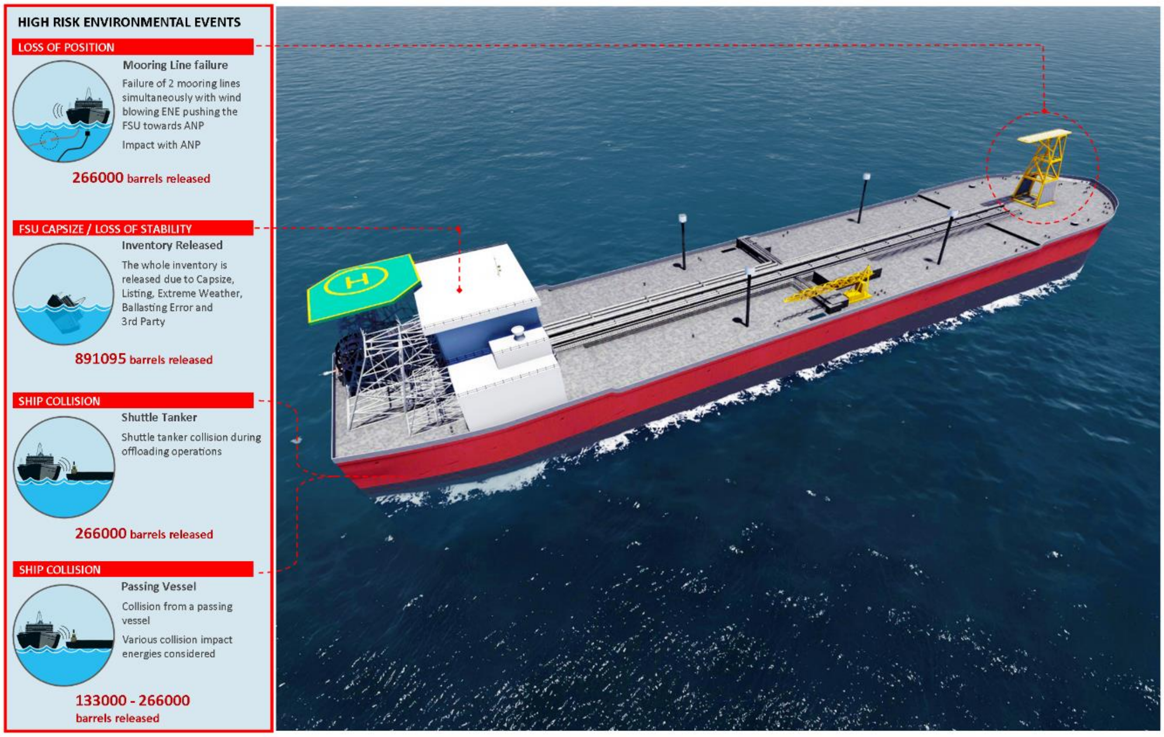
Figure 11 LSIR Heat Map for Floating Production Facility



Other applications for risk visualisation techniques

Similar techniques have also been used to provide visual representation for environmental risks. The example shown in Figure 12, gives the results of an environmental risk assessment. This highlights the key risks against the operator's environmental risk tolerability criteria. As with the infographic for the floating production facility, this is an intuitive and accessible method for conveying risk information that can be used to facilitate conversation and enable decision-making.

Figure 12 Environmental spills model visual summary



Conclusion

The development of an LSIR Heat Map for a floating production facility was an interactive and iterative process, and had to be so if there was to be a successful outcome to the project. The work has shown that infographics can be powerful tools for conveying complex technical risk information and, to be successful, required a well-organized structure and concise presentation. These tools can be used to overcome some of the cognitive biases described earlier in this paper in the following ways:

- Confirmation bias: "We only believe what we already think" – by using easily absorbed graphics, these techniques challenge the audiences assumptions with simple, convincing information.
- Groupthink: "We are wired to conform" – by providing a fresh framework to facilitate discussion, groups can disrupt the groupthink heuristic and put forward new perspectives.
- The default mode: "Our minds are built to wander" – an easy to understand and intuitive image allows the audience to absorb the required information and focus on key risks quickly, whilst the graphical representation grabs the attention and imagination much more effectively than just a numerical presentation of risk.
- Tech clash: "We don't speak the technical language" – the use of symbols and signal colour coding reduces the in-depth technical understanding required to understand the key messages and make reasoned judgements.

These techniques provide an attention grabbing and intuitive aid for presentations and conversations by highlighting key risk areas. This is a powerful tool for workforce engagement, making risk information accessible. For non-technical decision makers, the infographics facilitate more interactive conversations and enable discussion of risk tolerability and route causes. There is still a need for more detailed numerical data in many instances, however this adds another tools which can be more appropriate for certain audiences.

Information density must be considered with care; too much information can be as harmful to successful communication as too little information. By careful attention to detail, complex technical risk information can be conveyed graphically thus enabling a message to be conveyed that can be understood across diverse range of audiences.

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