

“UNDERSTANDING MAJOR ACCIDENT HAZARD MANAGEMENT – THE MORE YOU KNOW THE MORE YOU KNOW YOU DON’T KNOW”

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INTRODUCTION

Papers presented at Hazards XVII (Reference [1]) and XVIII (Reference [2]), explained the theory and practice behind the Major Accident Hazards Management System (MAHMS), developed and implemented for bp Trinidad & Tobago’s Operations. This paper completes the trilogy with a discussion of the methods used to make information available, develop understanding and change behaviors in the safety culture relating to management of major accident hazards.

Three attributes of MAHMS are particularly relevant since the system:

- Develops Major Accident Hazard Understanding
- Manages all Types of Risk as a Continuum
- Makes Major Accident Hazard Information Readily Available

All minor and major incidents, including near misses and high potential incidents, present a learning opportunity for any organization. These learning’s should ideally be retained by the company in some form of ‘Corporate Safety Memory’. It has often been said that there is no such thing as ‘Corporate Safety Memory’. Lessons learned from incidents are mainly retained by those who were involved or close to the incident at the time. When those people move on, they take the experience with them. The only way of achieving anything approaching ‘Corporate Safety Memory’ therefore is to share the learning’s from incidents within the company, with other companies and the industry as a whole, as widely as possible.

Confucius said *“I hear, I know. I see, I remember. I do, I understand.”* A fundamental objective of MAHMS has been to provide and continuously develop an understanding of major accident hazards for all levels of the organization, so that they can be managed effectively. Developing an understanding means communicating effectively. As Confucius indicated *“...tell me and I may forget”* means knowledge, *“...let me do it and I will remember”* means understanding. Figure 1 illustrates the four essential elements of an effective process for developing understanding.

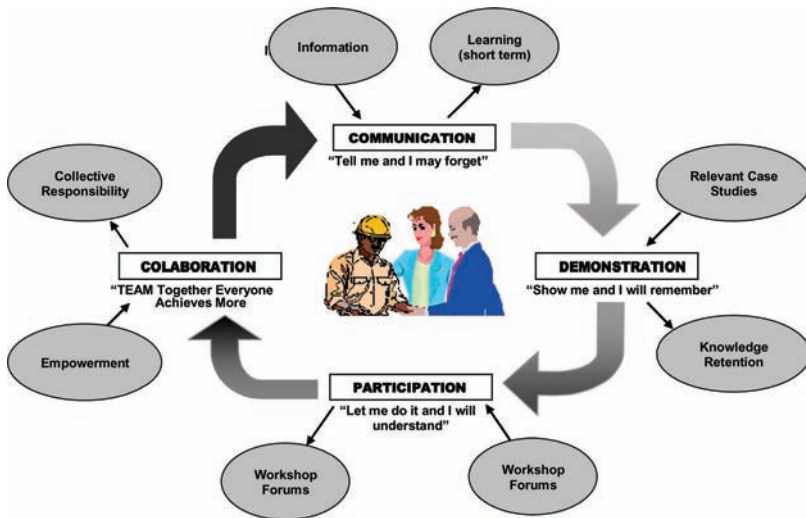


Figure 1. Elements of process for developing understanding

This 'understanding' means assimilating the characteristics of a major accident hazard event, which includes:

- **Causes** such as degradation mechanisms, mechanical damage, abuse, overload and severe environmental events.
- **Severity** which is characterized by material release rates, ignition (immediate or delayed), energy released smoke and toxic fumes generated.
- **Escalation potential** involving other material inventories, fires, explosions, structural damage and impairment of escape routes, muster points and evaluation and escape facilities.
- **Emergency Response** actions, procedures, facilities required to evacuate or escape successfully and rescue and recover survivors to a place of safety when required.
- **Consequences** for people, the environment and business interruption including reputation damage.

This paper discusses how major accident hazard information is 'tailored' to suit the requirements of typical operating levels in the organization, based on differing understanding needs. It also explains how relevant information is made readily available in clear and simple language so that it can be easily understood. Lastly, it also describes methods for extending the use of common control of work (CoW) tools beyond occupational health and safety risk into the realms of major accident risk management.

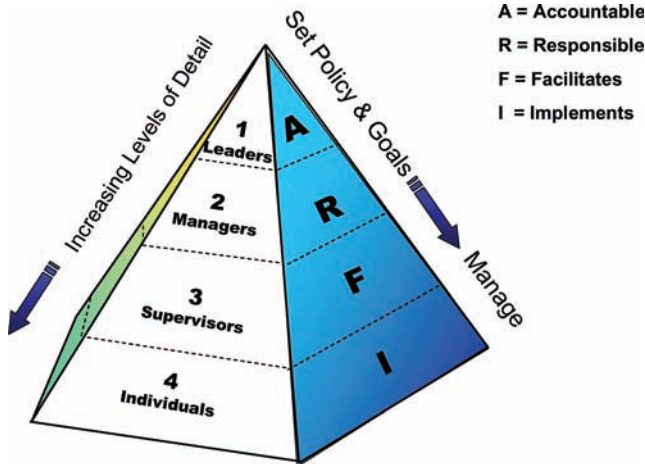


Figure 2. Typical levels in risk management

DEVELOPS MAJOR ACCIDENT HAZARD UNDERSTANDING

The first step in tailoring major accident hazard information is to identify the differing understanding needs of four typical levels in the organization. The information needs of *Leaders*, *Managers*, *Supervisors* and *Individuals* are quite different. This is because of the varying nature of the information and level of detail required for them to fully understand and perform their roles and responsibilities in the management of risk arising from major accident hazards.

Figure 2 characterises the four distinct operating levels of an organization typified by the groupings of ‘Leaders’, ‘Managers’, ‘Supervisors’ and ‘Individuals’.

LEADERS

At the top of the organization, ‘Leaders’ operate in a strategic timeframe of approximately 3–8 years. They are **accountable** to the organization for ‘company safety performance’ as part of the business.

Safety here includes the whole spectrum of occupational health and safety risk through to major accident risk management. The need to manage both occupational health and safety (OH & S) risk and major accident risk (MAR) as a continuum has been a difficult concept for leaders to grasp. OH & S incidents tend to have a high frequency but low consequences, whereas major accident events¹, where they do occur, will do so at a much lower frequency but have potentially much higher consequences.

¹ Major accident events are those with the potential for multiple fatalities, long term or widespread damage to the environment, or significant business interruption including reputation damage.



Figure 3. The safety risk continuum

There is also a significant potential for OH & S incidents to be the cause of major accident events through uncontrolled escalation. This factor is often overlooked or underestimated in initial reporting of incidents or their subsequent investigation, if this is required. Figure 3 illustrates how safety risk can be viewed as a continuum.

Occupational health and safety management is now widely understood and practiced by organizations. Effective management leads to immediate and tangible results in terms of OH & S performance measures such as first aid cases, days away from work cases and accident frequencies per thousand man-hours worked. These parameters can be easily measured and reported. The emphasis is often on minimizing the consequences of occupational health and safety accidents rather than reducing the frequency of incidents in the workplace. There seems to be a resignation that 'accidents will happen' where so much human activity is being conducted.

The management of major accident hazard risk on the other hand has to place emphasis on elimination or prevention through precluding or minimizing the likelihood of major accident hazard events, since the potential consequences are so dire. However, for major accident events performance measures are intangible, much more difficult to define and an abstract concept to appreciate. The effectiveness of measures to eliminate or prevent major accidents, may be obvious where there is an major accident free period of operation. However, this overlooks the potential for the minor incidents and near misses which have occurred, to escalate to major accident events. In other words, the underlying potential for a major accident event to occur in the operation.

It has often been stated that a numerical relationship exists between the number of OH & S incidents, minor incidents and major accidents. The relationship was first postulated by Frank E Bird in the 1960's (Reference [3]), and still holds true today. However, arguments abound about the actual ratios between the different categories of events.

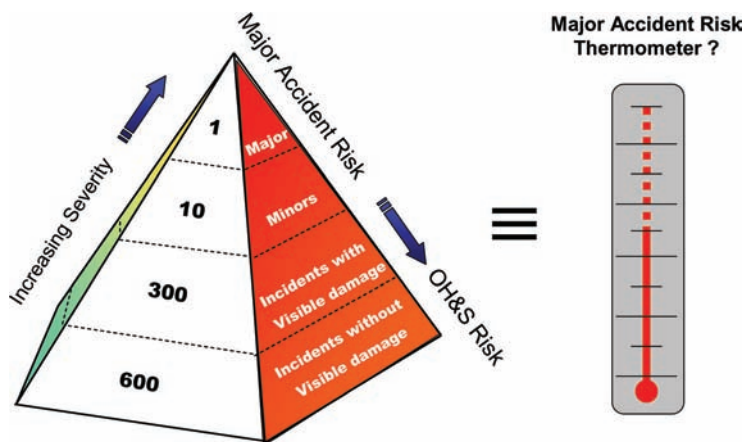


Figure 4. Incident ratios based on bird's triangle

Figure 4 shows an incident ratio based on the Bird's Triangle. The current frequency of less consequential incidents could be viewed as a thermometer of safety management performance. Leaders need to understand where the current level of safety performance places them in terms of the potential for a major accident occurring. Experience has shown that this notion has facilitated the discussion about safety risk management as a continuum.

Since it is the potential for a major accident that should be measured, and potential means likelihood, then major accident hazard management performance can be measured in terms of the current level of major accident risk (MAR). BP has recognized this and requires business unit leaders (BULs) to establish the level of MAR arising from their operation (Reference [4]). MAR is stated in terms of societal risk which takes account of public outrage increasing commensurate to the consequences of the incident. For safety risk this is evaluated in terms of potential number of fatalities. (N); against the cumulative frequency (F) of all major accident hazard events potentially causing N or more fatalities. Thus the F-N curve as shown in Figure 5 can be developed.

Note that trigger limit is set in terms of a 'reporting line'. The position of the reporting line is established as a function of 'throughput' for the business unit, which is categorised as either a medium, large or very large facility. The reporting line differentiates the level of reporting and management action required. For F-N curves above the line, BULs have to report their MAR levels to BP Group Management along with a plan to reduce MAR levels to below the reporting line within an agreed timeframe. For F-N curves below the line, BULs need to report their MAR levels to the Segment (Business Stream) Management. However in both cases there is a requirement to demonstrate

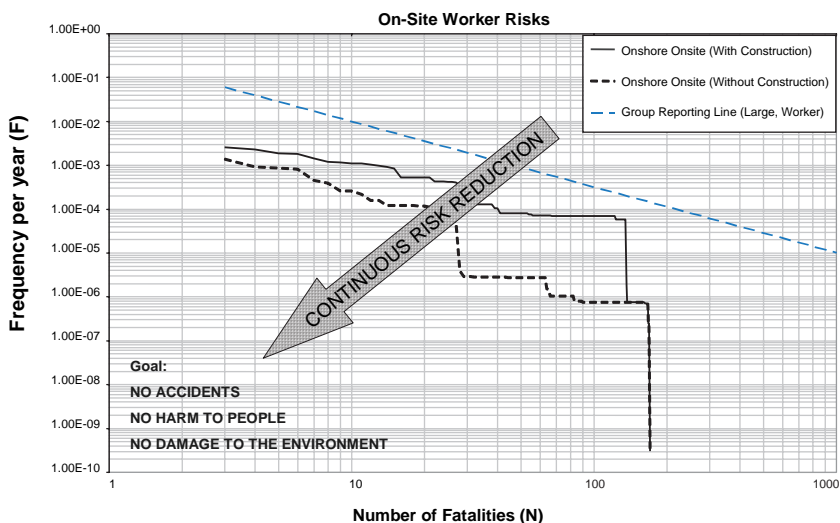


Figure 5. F-N (Societal risk) curve for a typical facility

continuous improvement over time by implementing effective major accident risk reduction measures.

There is also a similar requirement to understand, manage and report potential for environmental damage caused by major accidents. This is based on a F-Reaction curve representing the cumulative frequency of environmental events resulting in at least a given measure of public reaction or outrage.

At the leadership level, information about the extent and contributors of MAR is required so that leaders can be accountable for management of OH & S risk and MAR. This information will be generic and high level in nature so that informed strategic decisions can be made which take the potential impacts of major accident events into account. Managing risk is part of running a company since it has the potential to significantly damage the business. Any major accident has the potential to cause harm to people (both on and offsite), damage the environment and cause significant business interruption including the negative effect on company reputation.

Thus amongst leaders there is a change of behaviour taking place. 'Corporate' standards are now requiring leaders to be accountable for commercial performance and 'safety' performance as part of the business. A successful business is characterized by the degree to which it manages both these aspects effectively. Leaders need to be coached in methods used, resources required and goals set to manage risk; firstly to a level which the business deems acceptable commensurate with the benefit gained and

thereafter to strive to continuously reduce risk over a period of time. Thus leaders are dealing with strategic long term risk management objectives.

MANAGERS

Managers like leaders are managing strategically but within a shorter time frame of 1–5 years. They are *responsible* to leaders for defining and implementing plans to achieve strategic and shorter-term commercial, development and business performance goals, including safety. Managers often deal with sub-divisions or assets within the business and hence require a more detailed knowledge of which specific features of their facilities or aspects of the operation contribute to MAR. It may be that one particular asset may be contributing a disproportionate share of the overall MAR of the business unit. In this case managers need to fully understand what is driving this risk in order to make plans to eliminate the hazards or reduce the risk over time.

The trigger level for greater attention to MAR is the reporting line. This is proportional to facility, asset or business unit throughput (in terms of barrels of oil equivalent). It may be that more mature assets where production is declining also contribute an increasing proportion of MAR to the business unit, when compared to their reporting line.

Managers cannot afford to accept the ‘status quo’ in the level of MAR contributed by each facility in their asset grouping. Figure 6 illustrates how the reporting line can potentially move towards the origin as the throughput from each facility in the asset declines. Continuous risk reduction needs to at least keep pace with the downward

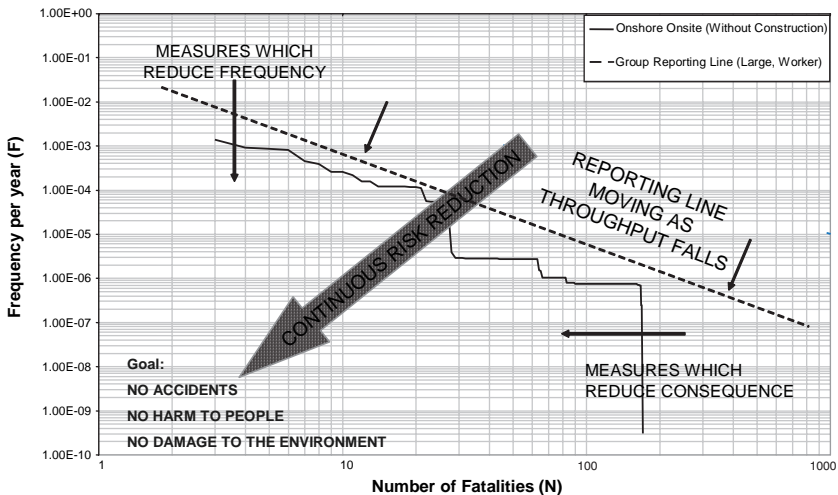


Figure 6. Remaining below the reporting line – continuous risk reduction

TOOL	REDUCED LIKLIHOOD BY	REDUCES CONSEQUENCE BY
Risk Assessment (RA)	<ul style="list-style-type: none"> ■ Identifies Hazards and Causes ■ Eliminates or Prevents Causes ■ Provides 'Understanding' 	<ul style="list-style-type: none"> ■ Implements Additional Controls ■ Implements Additional Mitigation ■ Heightens ER Preparedness ■ Reduces Nr Personnel at Risk
Job Safety Assessment (JSA)	<ul style="list-style-type: none"> ■ Adds Temporary Safeguards ■ Eliminates Work Conflicts ■ Provides 'Understanding' 	<ul style="list-style-type: none"> ■ Adds Temporary Barriers ■ Prevents/Limits Health Exposures ■ Provides 'Understanding'
Permit to Work (PtW)	<ul style="list-style-type: none"> ■ Identifies Work Site Hazards ■ Specifies Safeguards ■ Demands Conditions of Work ■ Controls Work Site & Limits ■ Eliminates Conflicting Work 	<ul style="list-style-type: none"> ■ Specifies Safeguards ■ Heightens ER Preparedness ■ Prevents Escalation
Advanced Safety Audits (ASA)	<ul style="list-style-type: none"> ■ Provides Heightened Worksite & Hazard 'Understanding' 	<ul style="list-style-type: none"> ■ Provides Heightened Worksite & Hazard 'Understanding'
Simultaneous Operations (SIMOPS)	<ul style="list-style-type: none"> ■ Identifies & Prevents Conflicting Operations ■ Clarifies Roles, Responsibilities ■ Provides Management Controls 	<ul style="list-style-type: none"> ■ Identifies and Specifies Interfaces ■ States Roles, Responsibilities ■ Interfaces ER Preparedness

Figure 7. Control of work tools – impact on MAR

trend of the production rates and hence reporting line if the facility or asset is to remain viable in terms of its contribution of major accident risk.

Some risk reduction measures will act to reduce the potential consequences by reducing the potential number of fatalities (N). Others will act to reduce the likelihood of events so that the frequency (f) of any given event expressed as an fN pair, is reduced. In both cases there will be a point beyond which further risk reduction will not be justified on cost-benefit grounds. At this stage additional options of de-commissioning or asset divestment come into play.

Identifying viable means of reducing risk may require the use of cost-benefit analysis to determine which risk reduction measures are justifiable. Here again BP's aversion to incidents involving large numbers of fatalities is encapsulated in the expression used to calculate the maximum expenditure to avoid an accident, thus:

$$X = yN^{1.5}$$

where:

- X = the maximum expenditure to avert an accident with N fatalities
- y = the expenditure to avert a single fatality
- $N^{1.5}$ = the risk averse (societal) multiplication factor for 'N' fatalities

So managers need to fully appreciate the factors affecting the MAR contributed by their assets to the overall business unit. They also need to understand whether certain risk

reduction measures are justifiable on cost-benefit grounds. If they are, then managers need to commit to a plan to implement the appropriate risk reduction measures to reduce MAR levels below the reporting line and continuous MAR reduction thereafter. These risk reduction measures may require medium to long-term 'projects' to implement. Managers need to commit and be responsible for the resources in terms of funding, access to the facility, personnel and the impact on production that implementing the risk reduction measures may require.

Managers too are being required to demonstrate changing behaviours. This is manifested through a need to consider MAR as an element of managing their asset. This means the commitment of financial and manpower resources and the consideration of risk reduction measures in production and development planning. This is particularly relevant in managing change in budgets, production targets and performance goals.

SUPERVISORS

Supervisors deal with more immediate 'operational' issues on a short timeframe of 1 day to 12 months. On a day to day basis Supervisors facilitate the safe implementation of work as part of the ongoing operation. Their sphere of influence may be narrowed to just one shift on one facility, either onshore or offshore, but the consequences of failure to manage risk arising from worksite activities is immediate and could be very serious indeed.

It is at the supervisors level where the need to understand the potential interplay between occupational health and safety risk and major accident risk is paramount. Human activity in operations and maintenance continues to be a significant cause of minor incidents, high potential incidents or major accidents to which all personnel working on a facility are exposed. Thus supervisors need access to much more detailed, facility specific and up-to-date information to manage day to day operations safely.

In particular the work planning and facilitation role of supervisory personnel requires a very detailed understanding of major accident hazards relevant to the facility. This includes an appreciation of the characteristics of a major accident hazard event (causes, severity, escalation potential, emergency response actions and consequences); so that a control of work process can be implemented that fully addresses the likelihood and consequences (= risk) of major accident events. In addition, an intimate understanding of the critical measures required to eliminate, prevent, detect and control, mitigate and provide emergency response to a major accident hazard event; is essential in order to know when control of work processes or work activities may affect, compromise or impair critical measures. In the event of this being so, then supervisors must know what additional temporary measures are necessary to ensure that operations continue safely. This may include a temporary shutdown or limitation in operations with the resultant impact on production performance.

Thus the behaviour of supervisors is changing in that they are widening their consideration of workplace risk management to encompass OH & S and MAR. There is a recognition that in some circumstances the most effective means of managing MAR arising

from planned work activity, may be to eliminate or prevent hazards through curtailing production operations. They have the support of managers in considering and implementing this as a valid means of managing MAR on their facilities.

INDIVIDUALS

Individuals are the operators, technicians and construction tradesmen making up the wider workforce, who *implement* the work. Their timeframe is very immediate spanning from the next hour to 2–3 days ahead. Individuals need accurate, up-to-date and relevant information about major accident hazards affecting their facility. This information needs to be stated in simple language not mystified by jargon or specialist terms.

The MAH understanding needs of individuals can be very detailed indeed, especially if their work affects the operation, availability or effectiveness of critical measures. They need a discrete knowledge of how their work may influence the prevention, detection and control, mitigation and emergency response facilities and arrangements. As implementers they must also be actively aware of how their mistakes could trigger a major accident hazard event, and thereafter how their role influences control of the event, prevention of escalation and successful emergency response.

The concept of risk may sometimes be difficult for individuals to grasp. Discussions about the risks affecting their facility can be a very emotive subject and need to be handled carefully. A point to stress is that whilst the consequences of a major accident event may be very serious for individuals, the likelihoods of such events are extremely low. It is the concept of likelihood or probability of events which is often the most difficult aspect to understand. We have found and used a tool which has been particularly effective in helping individuals appreciate the concept of event likelihood; that is the Paling Perspective Scale taken from a text by John D Paling (Reference [4]).

Figure 8, shows a Paling Perspective Scale drawn up to illustrate the likelihood of major accident hazard events, which may require personnel to attend muster stations at an onshore oil processing facility. It was used as part of a demonstration of the viability of the existing muster point locations, for all reasonably foreseeable major accident events.

The scale shows all the commonly used units for expressing likelihood of events against a simpler numerical scale of likelihood. The simpler (perspective) scale ranges from –6 (never going to happen) through zero (home based event likelihood) to +6 (certain to happen). A discussion ensues during which participants are asked to estimate the likelihoods of some everyday hazards that they are both familiar with; and accept the associated risk as part of their daily lives. Examples such as death occurring as a result of smoking, driving, sports activities or death through violent crime and security are good practical issues to use. The diagram is built up with an accurate estimation of the current likelihoods of fatalities from such activities. Once these levels of risk have been established, then the likelihoods of fatality due to the reasonably foreseeable major accident hazards at the workplace can be discussed and placed on the perspective scale. It soon becomes apparent that background risk is often much higher than that due to MAH at the workplace.

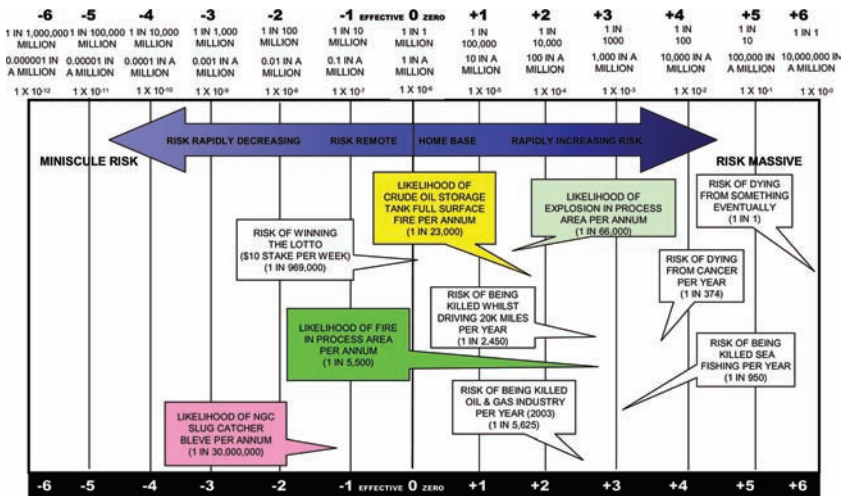


Figure 8. Communicating risk – paling perspective scale

Individual behaviours can be modified through open and honest discussion about major accident risk, its causes, consequences and likelihoods. An appreciation that individuals have their own contribution to make to the management of major accident hazards usually ensues. A wider understanding of risk can also bring about an extension of the consideration of risk in work planning and execution, into the realms of major accident risk and not solely occupational health and safety risk. This can be inculcated to such a degree that it becomes a natural way of working.

MAKES MAJOR ACCIDENT HAZARD INFORMATION READILY AVAILABLE

Traditionally, where major accident hazard information has been developed, it has been done as part of a formal safety assessment which has typically been performed to support a Safety Case. The formal safety assessment was often performed by specialist major accident risk consultants. From the operators point of view there are a few disadvantages of this:

- The safety assessment report is written in highly technical language dealing with complicated numerical QRA (quantitative risk assessment) calculations.
- The ‘understanding’ of major accident hazards often rests with the specialist risk analysts, and is rarely if at all successfully transferred to the operation.

- The Safety Case was aimed at the Regulator (ie: the HSE) as the ‘customer’ rather than the operators. Hence the safety case often serves no purpose beyond gaining a license to operate.
- The formal safety assessment is not usually kept ‘dynamic’, only being updated as a requirement to re-submit the Safety Case to the Regulator once every 3–5 years.
- Being paper documents, the Safety Case and formal safety assessments are not readily available for access by anyone who needs to consult them.

To avoid these disadvantages, MAHMS process has deliberately set out to:

- Involve the workforce by their participation in hazard identification and risk evaluation performed in workshop forums for each facility.
- Avoid the use of QRA, preferring to adopt a higher level qualitative approach to risk quantification.
- QRA has only been used where there is a distinct need for a more numerical approach; for example new facility designs in projects and understanding risk exposure to offsite personnel (public), arising from cross-country pipelines.
- Make all major accident hazard information available on-line via an intuitive and interactive website as opposed to periodically generating a paper Safety Case.
- Commit resources to keeping the website up-to-date as part of the ongoing MAR management activity.

MAHMS WEBSITE

The MAHMS website is an intranet based interactive tool for accessing major accident hazard information. The website was designed to be as intuitive as possible, requiring no specialist knowledge or training.

The website portal home page is shown in Figure 9, – with the aid of the website map given in Figure 10, some of the features of the website are explained as follows:

- **First column top:** provides interactive access to the home page, facilities (a list of platforms, terminals and pipelines), key issues (file notes describing generic issues), MAHMS Resources (links to information sources), feedback to MAHMS team and access to site administration.
- **First column bottom:** A list of contact details and profiles for members of the MAR Management Team.
- **Second column top:** A link to facility specific data, eg: offshore pipelines routing plans and pipeline details.
- **Second column bottom:** A link to MAHMS interactive primer. A six part interactive computer based training CBT tool explaining the MAHMS process.
- **Third column top:** Brief summary of the MAHMS process.
- **Third column bottom:** Links to current news items concerning major accident management issues both within the business unit and across the industry. Old news items are available in archive.

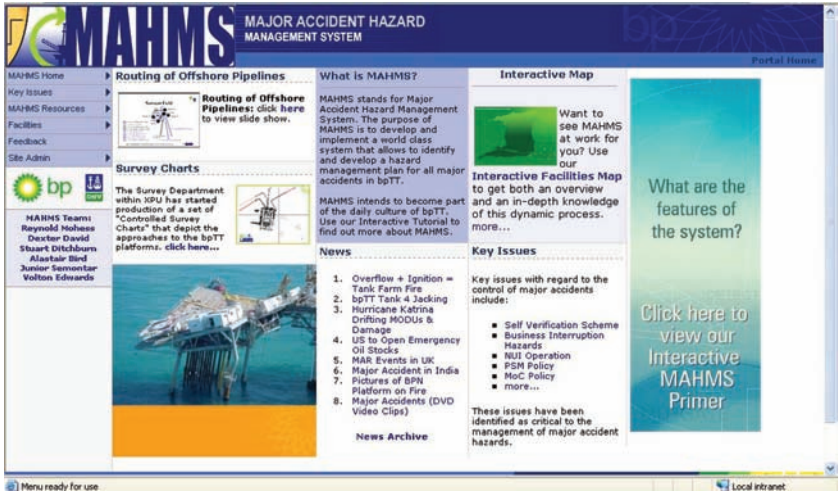


Figure 9. MAHMS website portal home page

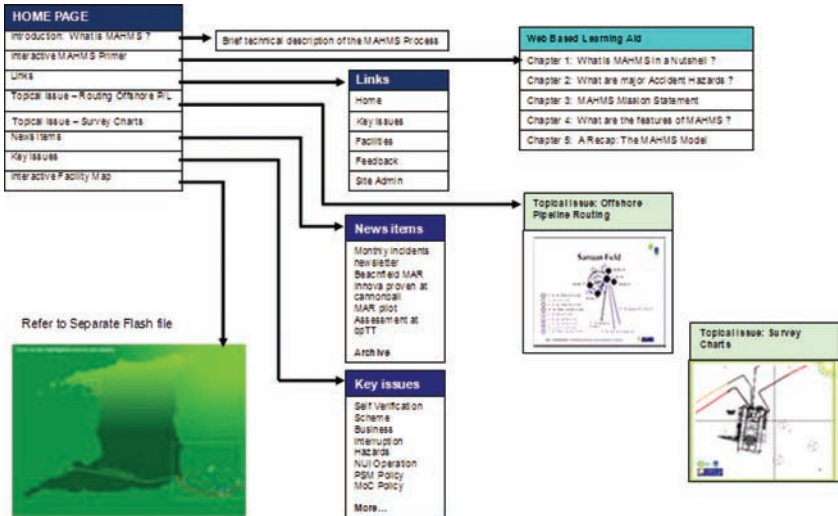


Figure 10. MAHMS website portal menu map

- **Fourth column top:** The interactive facilities map providing the gateway to more detailed information. (Refer to website map figure 10)
- **Fourth column bottom:** Link to key issue notes on topics affecting major accident hazard management.
- **Right hand column:** Link to MAHMS interactive primer CBT tool.

CONCLUSION

In conclusion attributes of MAHMS are continuing to develop understanding and change behaviors in the safety culture relating to management of major accident hazards.

The MAHMS project created a website as a repository for all the information on major accident hazard management to satisfy both the above needs. The MAHMS website portal presents information in a predominantly graphical way, making access to relevant data on any particular facility both simple and intuitive. The information is structured into layers, so that all users are presented with the highest level data first; and can then access lower layers if more detail is required. Numerous cross references, links to other websites and documentation provide a comprehensive “one stop shop” for information supporting the understanding and management of major accident hazards in the Business Unit.

At the leadership and manager levels, generic information is required so that informed strategic and commercial decisions can be made which take the potential impacts of major accident hazard management into account. Managing safety in terms of occupational health and major accident risk is part of the business affecting the whole company.

Supervisors and individuals on the other hand have more immediate concerns about managing risk. On a day to day basis they need to implement work safety as part of the ongoing operation. Their sphere of influence may be limited to just one facility, be it an offshore installation or an onshore plant. The consequences of a failure to manage the risk arising from worksite activities, is immediate and could be dire indeed.

Another important attribute of MAHMS is that it deals with all safety risk as a continuum ranging from occupational safety risk to major accident risk. This has been achieved by extending the occupational risk management tools into the realms of major accident hazard management. Control of Work is a package of tools designed to manage work safely. This typically includes Job Safety Analysis or Risk Assessment, Permit to Work and Advanced Safety Auditing. The procedures and training in the use of these tools are currently being modified to extend the thinking beyond incidents whose potential worst case consequences could be serious injury or a single fatality; to major accident hazard events where multiple fatalities and/or injuries could potentially occur.

The modified Control of Work process therefore identifies major accident events which are a reasonably foreseeable outcome of the worksite activities. This may be due to an accidental release of hydrocarbons, or one or more barriers to prevent, detect and control, mitigate or provide emergency response to major accident events being

unwittingly disabled. The modified process then identifies additional temporary safeguards required to provide at least the same level of protection as before the work was conducted. This is heavily reliant upon those involved having a detailed understanding of major accident hazards, their causes, potential severity, existing safeguards and the means to respond in an emergency situation. These and other attributes of MAHMS combine to achieve the ultimate goal:

“To have the best process and be the best in the world at preventing major accidents, harm to people and damage to the environment. This will be achieved:

- *through having a way of working where everyone will understand the dangers of major accidents and know what to do to keep us all safe*
- *by making an essential contribution to extraordinary business results, protecting reputation and facilitating growth”*

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