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Performance indicators for the assessment of emergency preparedness in major accident hazards

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Performance indicators for the assessment of emergency preparedness in major accident hazards

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This Contract Research Report develops a framework model of emergency management and applies it to the development of performance indicators for the assessment of emergency preparedness in Major Accident Hazard industries. The research involved visiting 11 major accidents sites in the UK. Data collection consisted of detailed interviews to evaluate site preparedness for dealing with the possibility of an incident. Processes, plans, people and facilities were reviewed. At each site emergency exercises were observed and assessed. The information gathered was compiled into a database and analysed using a seven-point framework for emergency management capability. The data was used to compare the relationship between site preparedness and subsequent level of performance in emergency exercises. Six features were found to be particularly representative of quality of practical performance. These were: senior management commitment; emergency philosophy; emergency management team structure; information management system; exercise regime; and several specific features of team preparedness. The latter included: continuity in membership of emergency teams; training in command and control; competence assurance of emergency managers; and professional coaching of management teams during exercises.

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4 ACKNOWLEDGEMENTS

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- AWE
- BHPP
- BNFL (Sellafield)
- BNFL (THORP)
- BP
- ICI
- Pfizer
- Shell
- Scottish & Southern Energy
- Urenco

A database containing all the information gathered from these sites has been compiled. The data was analysed by the team and the results are presented in this report. In the interests of confidentiality, those results show trends and relationships and do not identify any site or company. Feedback has been provided to the individual companies, in confidence, and this report contains the only data that has been made available to HSE.

5 ACRONYMS

BIC	-- Best in Class
COMAH	-- Control Of Major Accident Hazards (Regulations, 1999)
COMMS	-- Communications
DEM	--Deputy Emergency Manager
ECC	--Emergency Control Centre
EMg	-- Emergency Management
EM	-- Emergency Manager
EMPIRE Evaluation	-- Emergency Management Performance Indicators and Risk
EMT -	-- Emergency Management Team
ENDEX	-- End of Exercise
ES	-- Emergency Services
ETA	-- Estimated Time of Arrival
FCP	-- Forward Control Point
LA	-- Local Authority
MAH	-- Major Accident Hazard
PA	-- Public Address System
RA	-- Risk Assessment
SIP	-- Site Incident Potential
SME	-- Small & medium Enterprises
TPRC	-- Task Performance / Resource Constraint Model.
WCS	-- Worst Case Scenario
WIC	-- Worst in Class

6 EXECUTIVE SUMMARY

This Contract Research Report develops a framework model of emergency management and applies it to the development of **performance indicators for the assessment of emergency preparedness in the Major Accident Hazard Industry.**

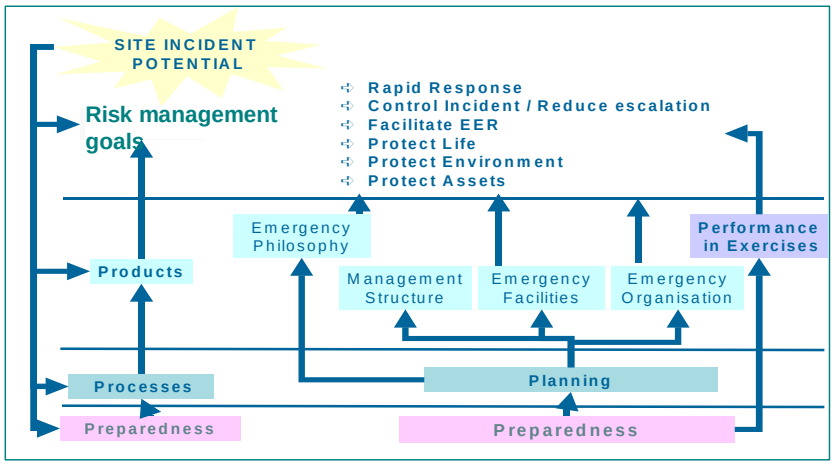
The team visited 11 Major Hazard Sites of varying sizes and complexities within the UK, and carried out detailed interviews with staff ranging from executives to operational supervisors. A detailed description of each site was built up, recounting the hazards, environment and risks, and explaining the processes, plans, people and facilities that were in place to deal with the possibility of an incident. A system of scoring, based on the experience of the researchers and the professional expertise of the industrial collaborators was applied to physical aspects and personnel of the sites. The second stage was observation and assessment of emergency exercises on each site. This enabled the research team to complete the assessment of site emergency preparedness and to relate the levels of risk posed by the site to the actions taken to mitigate and prepare for an incident.

The information gathered was compiled in a database, and was then exported to the Emergency Management Performance Indicator and Risk Evaluation framework (EMPIRE). The framework allowed weightings to be placed on the Risk Management Goals, according to their relative importance on those specific sites. Performance of the sites was compared against each other, compared in terms of their performance relative to the risks posed, and relationships between features of the site preparedness and their subsequent level of performance in exercises were recorded.

The scores were then verified with each of the participating sites. The feedback resulted in some minor refinement to the scoring and assessment system, but there was a general concurring view of the ultimate conclusions. Each site then verified its own EMPIRE scores as representative of its current performance.

The EMPIRE model follows the structure below.

Figure 1.



It assesses seven perspectives on emergency preparedness and relates them together to an overall picture of emergency management capability. From there, various

assessments can be performed of how well site goals are satisfied or how effective are the emergency arrangements in the context of site risks.

The results show that a document review alone is a misleading indicator of emergency preparedness and must be backed up by site inspection. At this stage, there are several important indicators of emergency management performance. Observing an emergency exercise is not a sufficient indicator to be used in isolation, as it only provides a snapshot of one particular team's performance. The exercise must be considered alongside the overall emergency preparedness of the site. Six features were found to be particularly representative of overall emergency capability and quality of practical performance. These were: senior management commitment; emergency philosophy; emergency management team structure; information management system; exercise regime; and several specific features of team preparedness.

The level of senior management commitment, in terms of involvement, leadership and financial support for emergency preparedness training and exercising was strongly reflected in team performance. A realistic and risk-based site emergency response philosophy was indicative of strength in depth across the site emergency arrangements as a whole. Given effective resources, a team with defined roles and mandates, in a structure that promotes fluid information management and a reliable leadership structure, can be expected to demonstrate a robust chance of managing a site emergency successfully. The process of handling information and presenting it as a basis for decision-making was shown to be a key differentiating factor in emergency team performance. The frequency, realism and detail of emergency exercises have also been shown to impact on performance. A defined structure of frequent small scale drills with less frequent large-scale simulations based on the site safety case or actual incidents is shown as good practice. Well-planned exercises which take the team beyond the regular procedures will provide a 'close-to-reality' environment and test to a greater extent the plans and capability and competence of the team and facilities. Finally, a detailed study of team preparedness highlighted those factors which most influenced quality of performance. These were: training in command and control techniques; competence assurance of emergency managers; professional coaching of emergency management teams during exercises; and continuity in membership of emergency teams.

7 INTRODUCTION

7.1 REMIT

This report covers work carried out for Health & Safety Executive (HSE) under contract 3939/R68.044. Under this contract, the HSE commissioned OCTO and Cranfield University Reliability Engineering and Risk Management Group to carry out a research project with the following aim:

"To develop performance indicators for the assessment of emergency preparedness in the Major Accident Hazard Industry."

The objectives of the project were to:

- **List the critical success factors of sound emergency management**
- **Define acceptable standards for emergency management training and competence demonstration**
- **Prepare a standardised methodology for use in the evaluation of both emergency exercises and emergency management training programmes.**

8 METHODOLOGY

Three techniques were employed by the research team to measure emergency management performance. These techniques enabled the team to observe, record, analyse and compare the capability of MAH sites in dealing with simulated emergency situations. The significant limitation of this project is that the simulation environment is not identical to an actual emergency incident environment. The simulation environment is, however a reasonable gauge of performance in crisis reality and for the purposes of developing performance indicators of emergency preparedness, is the most realistic experimental method available. The techniques used were:

- The most comprehensive technique used, is Emergency Management Performance Indicator and Risk Evaluation (EMPIRE) benchmarking model. Cranfield University and OCTO Ltd. developed the model for this project, and it is described below. Further detail and explanation of the model is provided in appendix 1.
- The second is a specialist tool for assessing performance in emergency exercises – the Task Performance / Resource Constraint model (TPRC), developed at Cranfield University. Based on the concept that, in a time-driven situation, good performance can be judged against achieving performance targets on time, this technique seeks to quantify success in emergency exercises. Its development and utility are described in this section, with a more detailed description and the results from its application to this project, presented in appendix 2.
- Finally, the data collection for this project gave the research team a unique insight into the observation of MAH site emergency exercises. Resulting from this, OCTO Ltd. has drawn up a framework for the assessment of exercise performance which is presented as part of Section 10.3.

8.1 THE EMPIRE BENCHMARKING FRAMEWORK

The preliminary list of the key elements of successful emergency management was generated and developed as a questionnaire and used by the research team in interviews with appropriate managers on MAH sites, to gather data and confirm the validity of the indicators. The actual questionnaire and interview scripts remain confidential, and do not appear in this report. As a result of these interviews, a number of new perspectives were revealed and the model was enhanced further. By applying the performance indicators to a number of different COMAH sites, benchmarks that compare companies and identify “best in class” and “worst in class” have been generated. Further benefits can be obtained by grouping the performance indicators across a hierarchy of perspectives. This provides a means of visualising and quantifying a company’s emergency management strategy. From this, strategic strength and weakness can be identified.

Figure (1) **The EMPIRE benchmarking process**

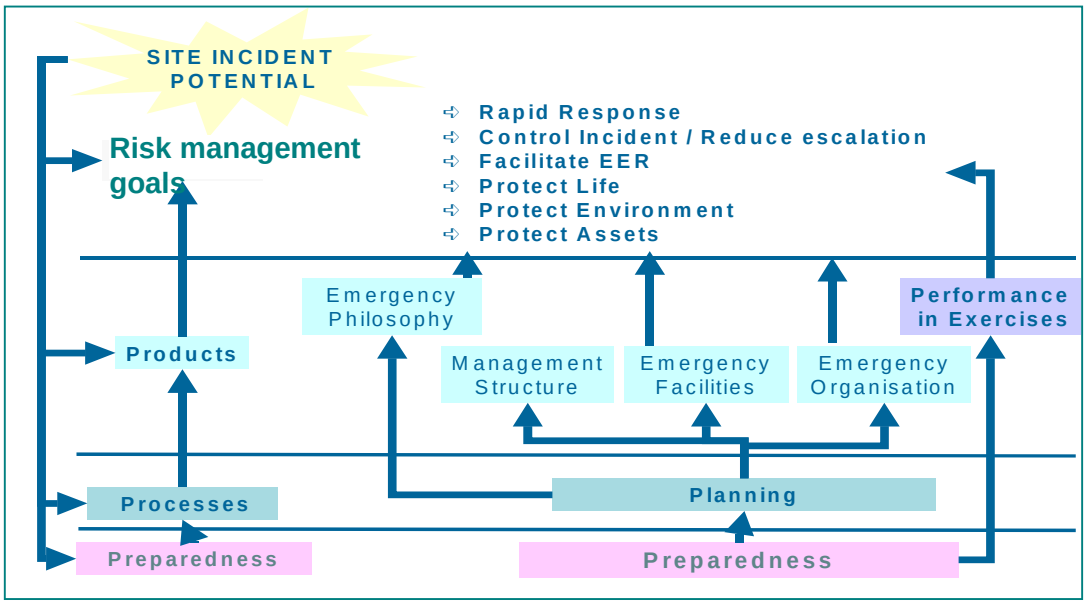


Figure 1 shows the structure of the EMPIRE system, and how the effectiveness of emergency management can be measured by examining the Risk Management Goals. These goals address the site hazards and the potential for major accidents at an installation and the company's strategy for dealing with emergencies arising from such events.

The achievement of the **risk management goals** is dependent upon certain key products of management:

- ***emergency management philosophy***
- ***emergency management structure – the team composition***
- ***emergency facilities – equipment and site provisions***
- ***emergency management organisation***
- ***performance in exercises – how the interfaces work in a simulation***

These products depend upon the organisation's management capability in;

- ***planning processes*** (ability to plan for emergencies) and
- ***preparedness*** (readiness for emergencies).

An evaluation of these perspectives can then be compared against the site environment and hazard characteristics, expressed as:

- ***The Site Incident Potential (SIP).***

The EMPIRE framework was inspired and guided by several different research fields and concepts. These include the Balanced Score Card Approach (Kaplan, RS 1996), the Competence Maturity Method (CMM) (Carnegie Mellon, 2000) and to a lesser extent Business Process Analysis (BPA), and Quality Function Deployment (QFD). Some of this background research was already available at Cranfield University, through a parallel project on Design Safety Performance Indicator also funded by HSE (HSE / 8890 / 3680).

In developing the framework, the knowledge and experience of the research team has been combined with the expertise of industrial emergency managers, elicited during interviews with collaborating organisations. The companies involved represent a cross section of industry, from large, complex sites to smaller companies on less developed sites. A benchmarking approach was selected as the preferred method of evaluating emergency preparedness for the following reasons:

1. Benchmarking ensured a structured and focussed assessment;
2. It enabled a stand-alone assessment of emergency performance and also assessment relative to on-site risks;
3. Benchmarking absorbs the range of performance across major hazard industry – incorporating the leaders in the field as well as some smaller or less developed sites.

EMPIRE's measurement of emergency management effectiveness through a set of key performance indicators ensures a repeatable, numerical measure of a company's ability to manage MAH emergencies. The 'key emergency-management performance indicators' which are an output of this project, were designed with several specific aims. They were to reflect company strategy for the protection of the workforce, the public, the environment and the physical assets, reflect practical knowledge and experience of the major hazards industry and could be scored as part of an auditing process by the company itself, a regulator or an independent verifier.

From the original list of indicators, a framework was developed, with some high level indicators of performance. These "headline" measures are referred to as '***perspectives'*** throughout this report and form the basis of the Benchmarking system, and are listed below. A detailed description of the seven perspectives and their indicators can be found in appendix 1.

Table (1) Perspectives – the basis of EMPIRE

Site Incident Potential	The ***Site incident potential*** (SIP) is a perspective which relates the level of difficulty in emergency management to the potential for on-site and off-site hazards.
Emergency Management Strategy	The emergency Management Strategy is implemented to manage the site incidents. It is built up from the following general EM Perspectives: • Overall Emergency Management ***Philosophy*** • Emergency Management ***Structure*** • Emergency Management ***Facilities*** • Emergency ***Planning*** • Emergency ***Preparedness***
Performance in exercises	Performance in exercises is the most effective way of demonstrating emergency preparedness. In EMPIRE it is measured and recorded in two ways:- • Qualitative ***Performance in Exercises*** perspective • Quantitative measure using the Task Performance Resource Constraint Model – ***TPRC (section 8.2)***

Within each ***Perspective*** there exists a set of emergency management performance indicators (EMPIs). Each indicator within a given perspective can be scored and combined to generate a headline score for each perspective. These are described in appendix 1. (*EMT* is the Emergency Management Team, and *EMg* is short for Emergency Management)

For example, in assessing the emergency management philosophy of a company, the indicators listed below in figure (2) were used:

Figure (2) Emergency philosophy indicators

		M	Q	A	Tot
1	Muster shelter and evacuation of personnel	1	3	4	88
2	Emergency Alerting systems	1	4	4	100
3	Relation with emergency services	1	2	2	50
4	Size and structure of EMT as yr. round cover	1	4	4	100
5	On site medical treatment capability	1	3	2	63
6	On-site Fire fighting capability	1	3	4	88
7	Out of hours response from EMT	1	3	4	88
				Rating	**82**

Scoring is based on the concept of good practice dictating that each of measures (indicators) should be addressed (M). They should be aligned to the company or legislative requirement (A) and they should be of good quality (Q). The 'A' and 'Q' ratings measures have a range 1 to 4. If the measure (M) exists it is given a rating of 1 and if it is absent it is given a rating of 0. The ratings are then accumulated as an arithmetic mean. Thus, for example:

Rating for indicator (i)	$S_i = M_i \times (Q_i + A_i) / (Q_{imax} + A_{imax})$
Rating for muster (i=1)	$S_1 = 1x\ (3+4) / (4+4)$
	$S_1 = 88\%$ after rounding
Overall rating for indicators	$S_0 = \text{Sum}\ (S_i) / N_i$

where $N_i = 7$ is the number of indicators in the ***EMg Philosophy*** perspective.

Hence: The Overall Philosophy rating = [88+100+50+100+63+88+88] / 7

= 82% after rounding

The use of the product between M and (A+Q) ensures that if a good practice measure is missing, a zero score will be returned for that measure.

The perspectives, their associated indicators, the rating rationale and actual indicator ratings for each company, together with supporting evidence, justification and comments have been developed into a formal database for ease of data entry, storage and manipulation. The rating rationale was developed from OCTO's specialist knowledge on Emergency Management good practice, enhanced and clarified by the experience of visiting the MAH (Major Accident Hazard) sites and conducting the data collection. The scoring / rating was carried out with an experiential learning intent, by OCTO consultants, along with Cranfield University researchers who were present at the site visits. This dual observation and logging strategy contributed to the continuous development of transparency and accountability within the rating structure throughout the project.

Examples given below illustrate how the scores were defined and calibrated for the Site Incident Potential part of the EMPIRE Benchmark assessment. Each table shows the extremes of the score bracket, and an example of the site conditions that would be awarded such a score.

8.1.1 Site Incident Potential – scoring criteria examples

8.1.1.1 Inventory of materials in major hazard scenario

Table (2) Inventory of materials in major hazard scenario

Criteria		How challenging is the site inventory in terms of emergency management?
High	4	Main toxic scenario, rupture of 40te liquefied toxic gas, fire of 20te flammables. Explosion from single point release. Storage of 1800 te liquefied toxic gas; 3500 and 2500 te flammable.
Low	1	2te propane storage, 5Te condensate; pipeline inventories of high pressure flammable gas; pipeline inventory of oil.

8.1.1.2 Complexity of technology – in response to major hazard emergency

Table (3) Complexity of technology

Criteria		How challenging is the technical complexity of the emergency response?
High	4	Some highly technical plants on site, with complex safety shutdown, control and mitigation systems.
Low	1	Relatively simple response to emergency on plant – no complex shutdown routines.

8.1.1.3 Site population density – worst case

Table (4) Site population density

Criteria		How challenging is the density and distribution of people in terms of emergency response?
High	4	High. Over 5000 staff on site during day. A few hundred on nights. Some significant scenarios would affect a good proportion of people on site.
Low	1	In day, 60 persons on site – mainly in office 200-300m away. 5 persons on plant. At night, 15-20 persons on-site.

8.1.1.4 Diversity of hazards under emergency management team

Table (5) Diversity of hazards

Criteria		How challenging is the diversity of hazards on site - in terms of emergency management?
High	4	Many different facilities and technologies on-site – site shift manager and emergency response teams need a good grasp of the basics on all of them. Potential interactions between facilities in emergency situations.
Low	1	Only one major hazard chemical, used in several ways around the site.

8.1.1.5 Rate of escalation and associated demand on emergency management team

Table (6) Rate of escalation

Criteria		How challenging is the rate of incident escalation – considering some worst credible scenarios?
High	4	Catastrophic scenarios e.g. rupture of pipeline has an immediate effect, although little further scope for escalation. Escalation potential incidents based on fire and environmental incidents are more realistic.
Low	2	Plant well dispersed. High quality of shut-down system of proven reliability. Effective inventory sub-division. Fire escalation between float tanks is possible. Single emergency plan.

8.1.1.6 Level of off-site risk

Table (7) Level of off-site risk

Criteria		How challenging is the off-site risk in terms of emergency management?
High	4	Worst case is (highly toxic gas) going off-site and impinging on highly populated area.
Low	1	Close proximity of housing but incidents involving off-site gas are of short duration – with limited involvement of emergency services.

Two other possible categories – 'Complexity of off-site interfaces' and 'maximum numbers for potential evacuation / personnel movement' were considered, but rejected during the course of developing the scoring protocol on the grounds that they did not contribute a discrete perspective but overlapped with existing SIPs.

8.1.2 The Application of the EMPIRE Framework

Through a series of interviews with key managers in the collaborating companies, each company's emergency management system has been scored in accordance with the methodology outlined above. The information was recorded in the questionnaire format and subsequently transferred to a database. The indicator scores for each company in the database have been collated in the indicator framework. This has generated a set of headline scores for each company. The accumulation of scores to generate the headline results and benchmarks is currently implemented through Microsoft Excel as a set of spreadsheets. However, future development of the framework could integrate the database and spreadsheet functions.

8.1.3 Generation of Benchmarks

The final stage of the analysis is to combine all the various "headline " scores to generate benchmarks, which can be used to compare different sites, identify worst in

class (WIC) and best in class (BIC). For example figure (3) shows the headline figures for site incident potential and overall EM capability for 10 organisations.

Figure (3) **EM & SIP Benchmarks**

E-M SIP Benchmark

	Company A	Company B	Company C	Company D	Highest	Lowest	Improvement potential of company D wrt BIC	Improvement potential of company D wrt BIC
Site Incident Potential %	67	50	88	83	92	50		
Overall E M Capability %	82	66	81	84	92	44	0.1	0.2

The improvement potentials with respect to best in class or maximum value (100) are defined as

Improvement Potential wrt BIC = (best – score) / score

Or Improvement Potential wrt max = 100 -score / score

The improvement potential varies therefore from 0 (score = best or score = max) to infinity when the score is zero.

Benchmarks can be generated for all the variables in the empire model. The full range is shown in Section 9.1.

Figure (4) **Overall benchmark for emergency management philosophy**

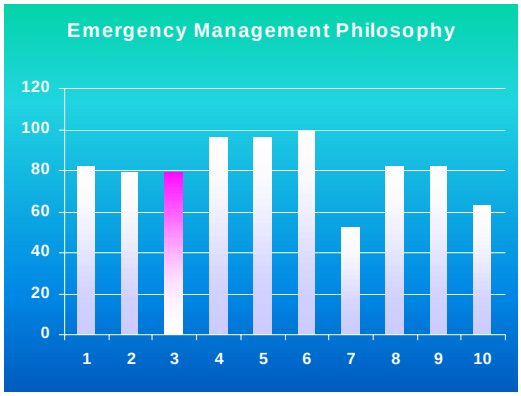


Figure (5) **Detailed benchmarks for emergency philosophy**

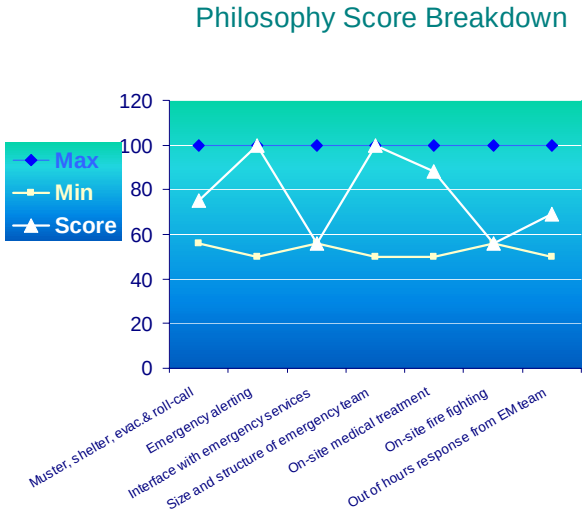
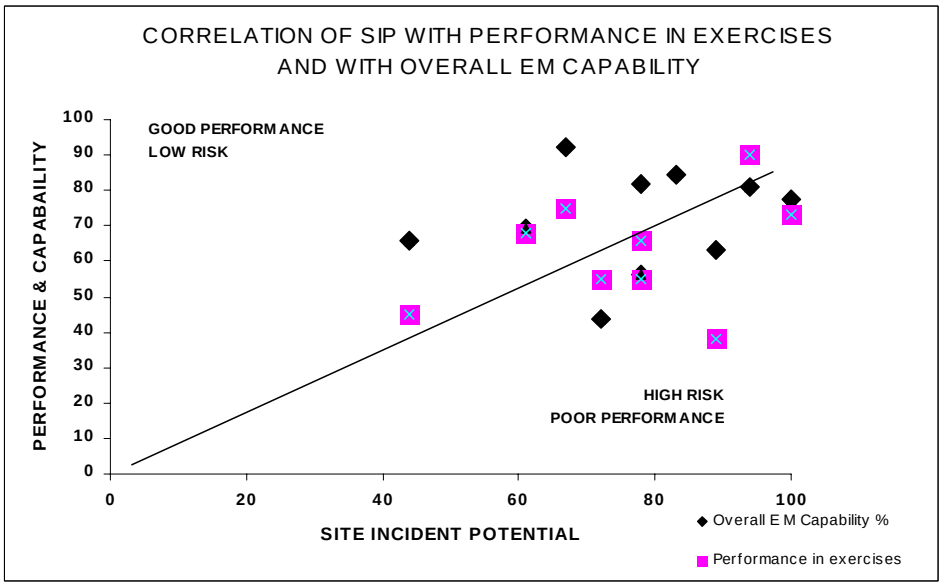


Figure (6) **Relationship between (i) Performance in exercises and Site Incident potential (ii) E-M capability and site Incident potential.**



Using the benchmark framework it is possible to investigate the relationships between different parameters. For example figure (6) shows the relationship between the site

incident potential and two different parameters; performance in exercises and emergency management capability score. Scores to the right of the line represent under performance and higher risk whereas scores to the left of the line represent excellent performance i.e. better than required.

Further relationships are discussed in section 9, the results section of the report.

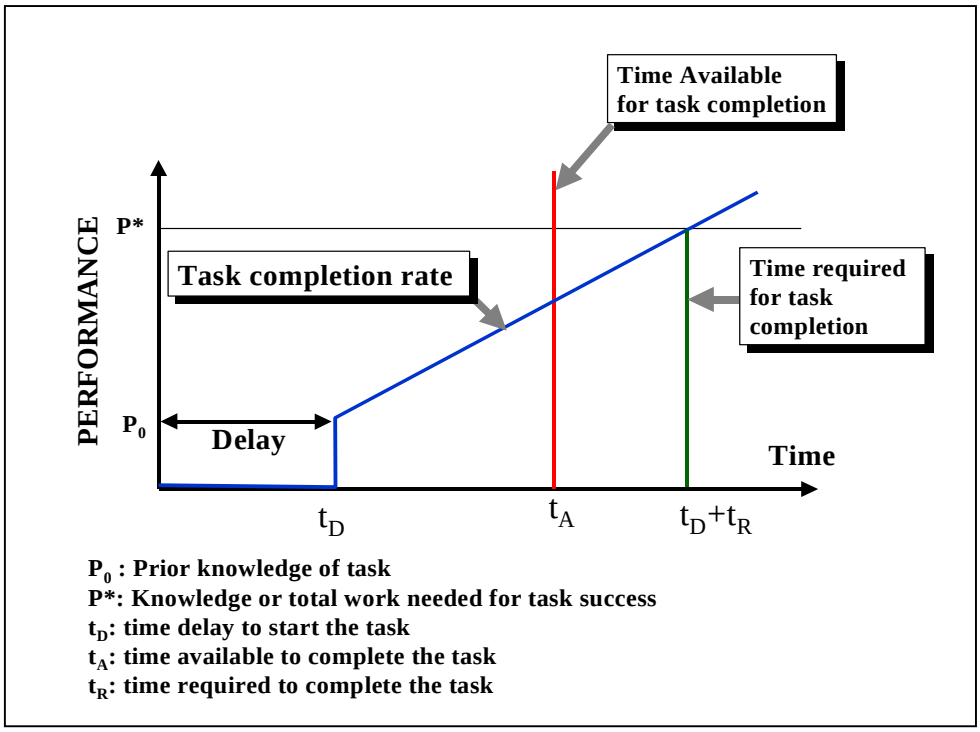
8.2 TASK PERFORMANCE RESOURCE CONSTRAINT MODEL

The Task Performance Resource Constraint or TPRC model is an alternative method of assessing performance in exercises. A deterministic model, described in Section 8.2.1, below has been developed. A probabilistic model (Strutt, J.E et al, 1998) has also been developed in previous research funded by EPSRC and OCTO but is considered too detailed for application in this study. The deterministic model is simpler to apply and has been used to assess three of the emergency management exercises viewed as part of the project. The detailed methodology and the results are described in Appendix 2.

8.2.1 Description of TPRC Model

Emergency management can be viewed as a set of time and resource limited tasks performed by the team in managing an emergency incident. Each task has a goal or objective, a start, duration and end, plus one or more resources (including time itself) to support the task. The nature and amount of work to be carried out, the work rate, and the time and resources available and their rate of consumption are key factors. These can be related to the overall performance.

Figure (7) Concept of the Task Performance Resource Constraint Model (TPRC)



In the model, a distinction is drawn between the ***time required*** to complete a task, given the particular conditions (related to the nature of the task), and the ***time available*** to complete a task. The marshalling and application of resources and associated logistics will in general govern the latter. These points are explained below and illustrated in figure (7) for the simple case of a single task.

8.2.1.1 Time Required

The nature of the task determines the amount of work necessary to complete the task. The required task duration depends both on the total amount of work required to achieve the task objective and the work rate or the rate of progress towards successful task completion. Take a simple routine task, with well-defined procedures, in which there is little or no special learning required, e.g. a person moving from position A to position B to muster. There will be little uncertainty in the time needed to undertake such a task. In this simple case P* is the distance to be travelled and the task completion rate is the speed of the person's movement. All this should be well-defined in emergency management plans

At the other extreme, a problem-solving task may be very complex, poorly defined, with no procedures or prior experience and demand a significant learning process to achieve the task objective. In this case there is likely to be a great deal of uncertainty both on how much work is required to achieve the objectives and on the rate of progress. Ultimately, full success in the task must be achievable.

Examples of tasks in this category are emergency management tasks that involve diagnosis of a complex problem. The task requirement, P*, in problem solving tasks can be equated to the level of information required, and the task completion rate to information gathering and knowledge accumulation rate.

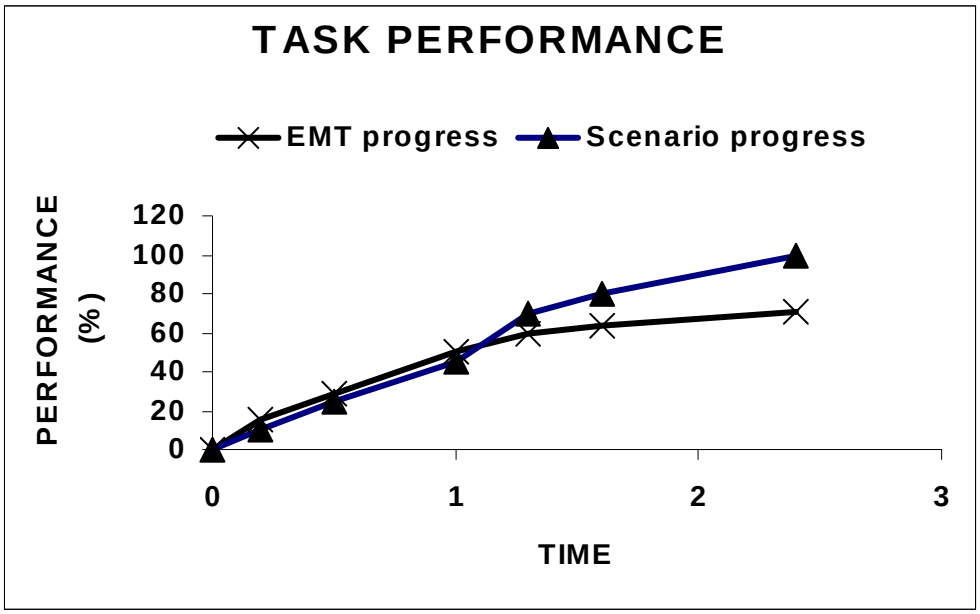
8.2.1.2 Time Available

The speed of developments or rate of escalation will dominate the time available to complete emergency management tasks. If the task completion rate is insufficient, i.e. time required is greater than time available, then there will either be a short fall in the required performance or late completion of the task. These two modes of failure may result in very different consequences depending on the context.

A delay in the initiation of a task has a significant effect on the likelihood of successfully completing a task within the time available. The greater the delay, the greater the risk of a shortfall in performance or late completion. Hence the importance of a timely response.

An example plot using the data in Fig (57) appendix 2.

Figure (8) TPRC Output plot .



8.2.2 Data gathering and the scenario

The scenario chosen for a TPRC analysis should be based on an emergency scenario identified in the safety case and for which technical information is available. The scenario could include management of:

- technical systems, eg. shut-down systems, leak / release of hazardous materials possibly leading to fire
- personnel, eg. mustering personnel, search and rescue of casualties
- external people, eg. involving external assistance from emergency services,
- communications, eg. informing personnel and public (if necessary) of incident and emergency management progress

The scenario should include a number of features that are “manageable” to test the skill of the emergency manager. Those emergencies which are so unmanageable that the only actions to be taken involve evacuation should be avoided as scenario examples. The business continuity and corporate tasks arising from a MAH incident have not been addressed in this study, but if measured in a time and success dependant manner, could be assessed by TPRC.

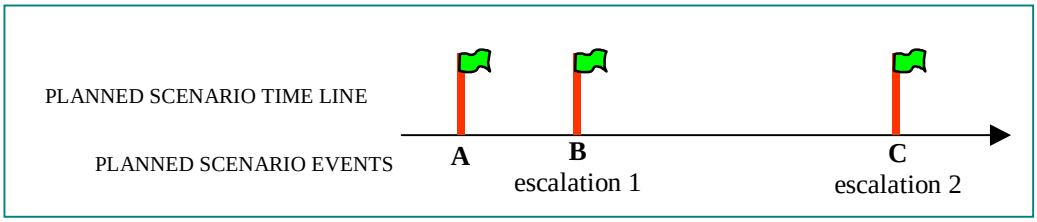
There should be a minimum of 2 escalation points within the scenario to show management of changing circumstances. The emergency manager should not know which emergency scenario has been selected for the exercise.

8.2.2.1 Preliminary data collection

Establish the objectives of the exercise and the extent to which it includes elements of training and elements of assessment.

A copy of the emergency scenario should yield the following information: the planned timings, the key inputs and the fixed escalation points.

It is then possible to develop a simple time-line for the scenario:



Against this time-line we then prepare expected or typical responses from the emergency manager and emergency management team at various points in the exercise. This is in order to help track the progress of the event during exercise observation. See table (8) on page 38 for guidance.

Finally we monitor both the timing of the scenario and the timing of the emergency team responses throughout the exercise. Accurate time recording to a suitable accuracy can take place by writing a time log based on direct observation, but is facilitated by use of a video camera.

At each defined escalation point we apply the TPRC model – collecting measurements as defined in Figure (7) and described in detail in Appendix 2.

8.3 ASSESSING EXERCISES

8.3.1 Inherent Limitations

- An emergency exercise usually tests only one scenario at a time.
- It is only a snap-shot of the performance of one team on a site.
- The time / event relationship is often compressed unrealistically (not necessarily a bad thing).
- Many of the mundane things that create serious difficulties in reality, e.g. the movement of people and resources, omitted actions and their real consequences, and all the associated communications and information intricacies, are difficult to simulate in exercises.
- It is not feasible, nor indeed generally helpful nor even safe, to attempt to reproduce the stress aspects of a serious emergency in an exercise (even if cautious

insights may be gained from the different stress induced by the 'needle' of the occasion).

- Scenario writers tend to carry matters outside the procedural envelope in a misleading way, often as a consequence of their own inexperience; and
- Consciously or unconsciously, exercises can become the victims of stage management and wishful thinking.

It is important to approach these limitations in a constructive way. There are clear examples of exercise parameters which - with the most admirable of intentions - have over a period reduced series of exercise demonstration to a predictable ritual dance that is far removed from the reality of a serious emergency. It is important therefore always to analyse any exercise in the context of the site risk potential and the observed and needed emergency arrangements as a whole. Pre-study of this context together with an understanding of the prevailing background agenda should enable the exercise assessors to learn from what they witness through sensible filters and using a sound balance of indicators, and to make realistic and useful judgements thereby.

8.3.1.1 Purpose of assessment

Before assessing an emergency exercise consider the purpose of the assessment. From a regulatory perspective, the purpose is to demonstrate that the emergency management team and arrangements are capable of managing a site emergency. The list below suggests some options.

- Resolve uncertainties in the preliminary assessment. For example: operation of the emergency control centre; competence of the management team.
- Set up to test areas of weakness in the emergency plan / emergency arrangements.
- Informed by the range of factors listed in Section (8.3.1) above, determine the context of the exercise and anticipate constructively the deviations away from a purist agenda that may occur.

8.3.2 Type of exercise

Different types of exercise offer different assessment opportunities – these are detailed in in the results sections. The features and observations during an exercise observation were made using the outline given below. Upon studying the site documentation and procedures, along with the scenario script and exercise plan, specific features of the emergency response can be noted in column three, and the observer can pay particular attention to logging these details.

8.3.3 Exercise objectives

An emergency exercise should have a small number of clearly articulated objectives – in emergency management terms these can contain elements of training as well as assessment.

For each expected action, there should be performance criteria including a time target.

9 RESULTS

The results of the research are presented under the same sections as in the methodology. There are results from the EMPIRE model, results from the TPRC analysis and results from the direct exercise observation. The EMPIRE and exercise observation results are shown here, while the TPRC results appear in appendix 2.

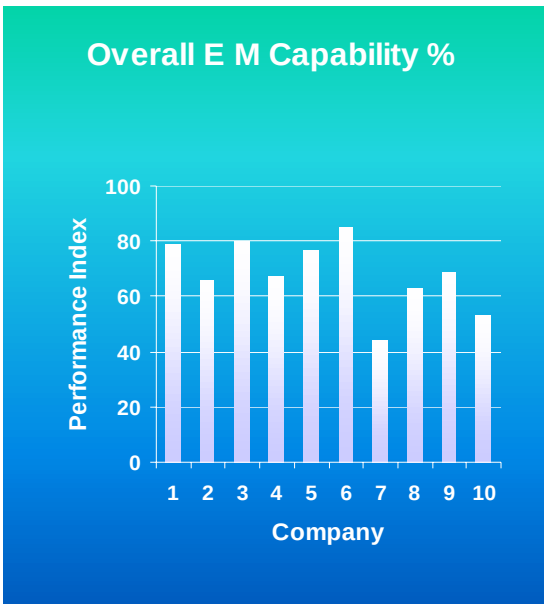
9.1 RESULTS FROM THE EMPIRE BENCHMARKING MODEL

9.1.1 Trends in emergency management practice

This summarised material presents some of the interesting features of the benchmarking study. It is not construed as an exhaustive statistical review, and any relationships implied are visual interpretations of the data, not statistical conclusions. Statistical analysis of the data was not part of the remit for this research, and has not been carried out.

9.1.1.1 Benchmarks of Site incident potential; emergency capability and performance in exercises

Figure (9) **(a) Overall Capability** **(b) Site Incident Potential**



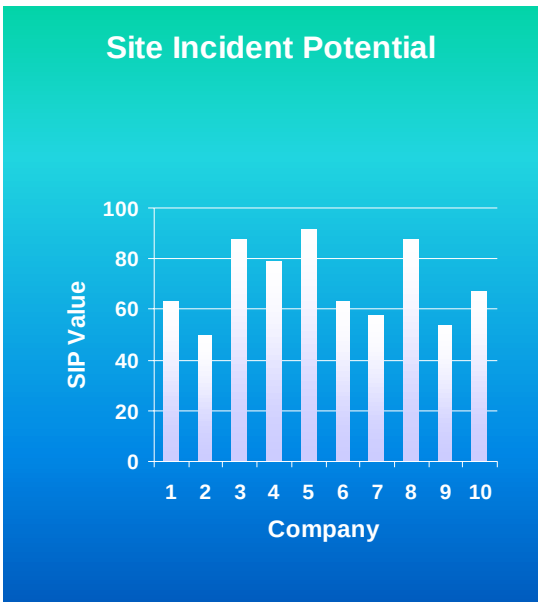
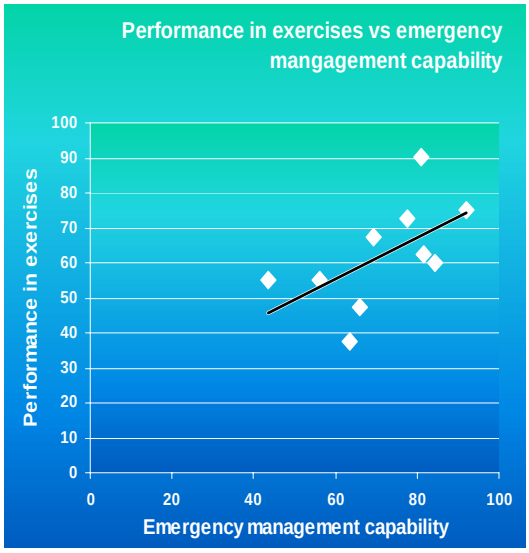


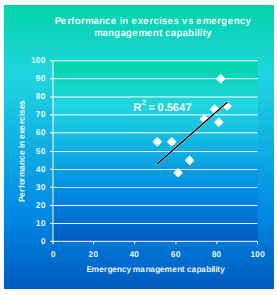
Figure (10) Performance in exercises

9.1.1.2 Performance in Exercises vs Overall Capability

Figure (11) Performance in exercises vs overall capability



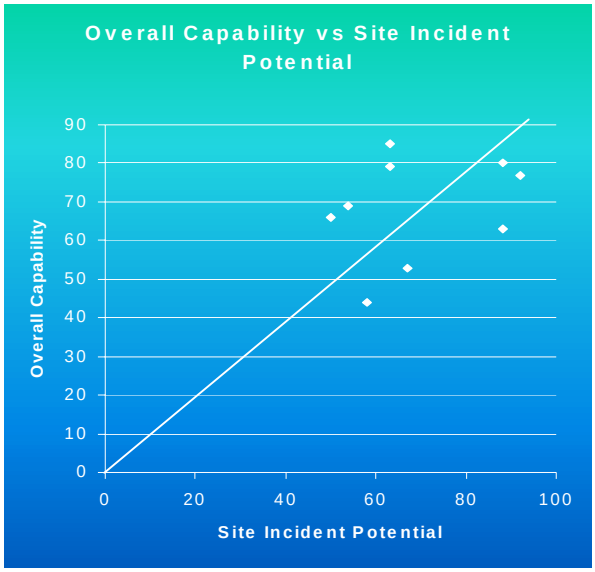
Our observations would support the deduction that emergency management capability (emergency management structure; emergency organisation and infrastructure; emergency management facilities; team preparedness) leads to better performance in exercises. For this graph two data points have been removed as atypical. Performance in the two exercises concerned (a table-top and a generic exercise) returned scores that were judged artificially low due to the exercise media selected. The graph with the complete data is offered at right for comparison.



The outlying point on the graph scoring 90% performance in exercises represent a team who had just emerged from intensive training in preparation for a major exercise.

9.1.1.3 Overall Capability vs Site Incident Potential

Figure (12) Overall Capability vs Site Incident Potential



This plot shows that, in the context of emergency management, there is little relationship between the degree of challenge posed by the site and emergency management capability. The results of the benchmarking and the experience of collecting the data allow us to make several points regarding this result:

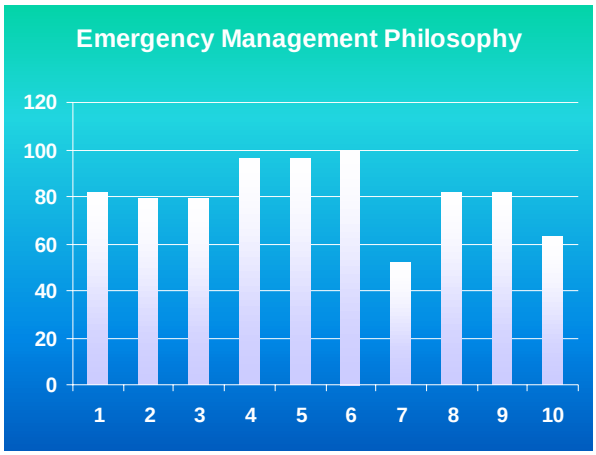
- None of the most demanding sites quite meet the standard set by the Site Incident Potential. All emergency arrangements demonstrate some areas of weakness, which could be improved upon. The improvements could, in all cases, raise their capability above the line.

- It is obviously easier for the less demanding sites to achieve an acceptable level of capability.

- Some sites set very high standards. Others are significantly under-prepared.

9.1.2 Scores in each topic across the range of companies studied.

Figure (13) **(a) Emergency management philosophy (b) emergency management structure**



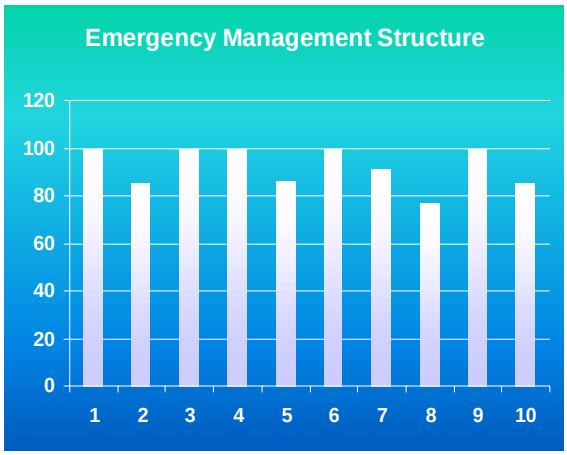
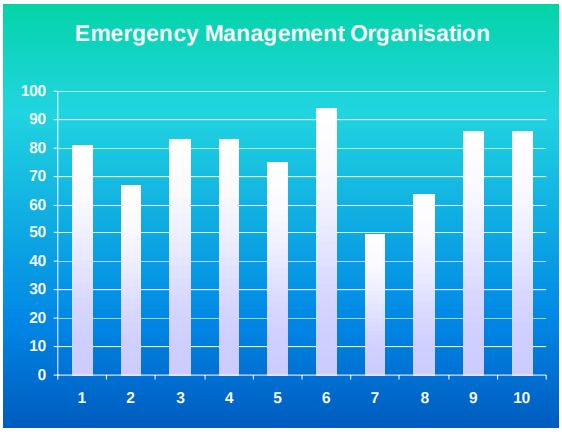


Figure (14) **(a) Emergency management organisation (b) emergency management facilities**



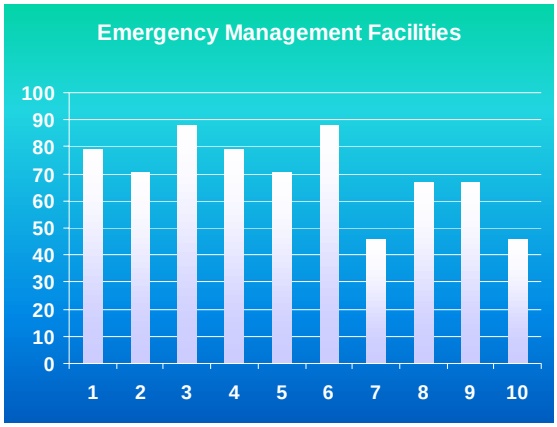
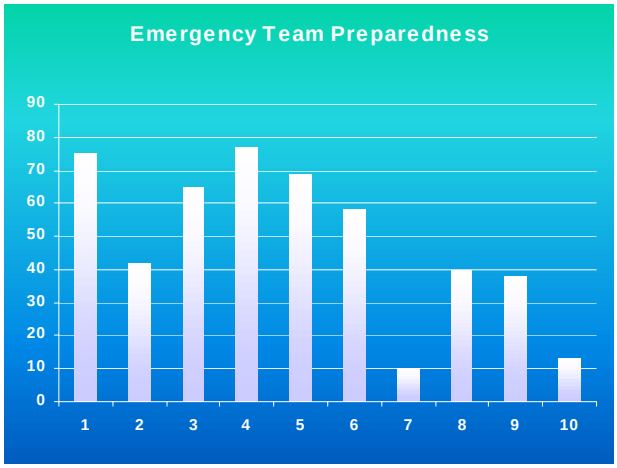


Figure (15) EMT preparedness



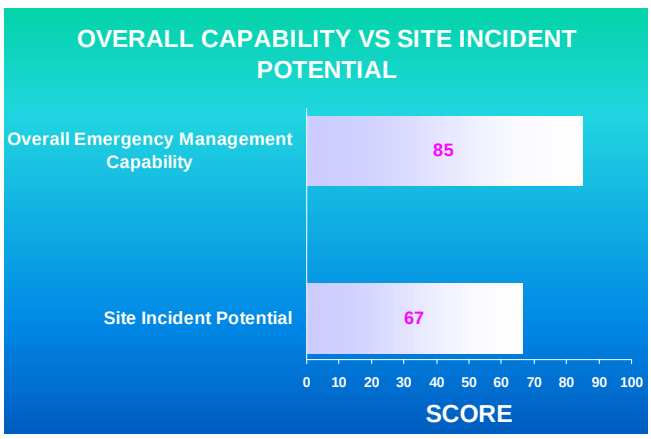
9.1.3 Benchmarking Profile for a single company

This section illustrates how the benchmarking system assesses the emergency capability of a single company. The following perspectives are examined:

1. Overall performance – a broad overview.
2. Incident risk management – how good does the site need to be?
3. Competence correlation – how does emergency capability rank against site requirements?
4. Strategy - how is emergency management effort divided between objectives?
5. Performance in exercises – an indicator of performance in an incident.
6. To preserve anonymity, data is used across a number of companies.

9.1.3.1 Overall performance

Figure (16) Overall capability vs Site Incident Potential



This graph gives a first impression of how the level of preparedness for emergency management compares with site requirements. The interpretation of this graph is a complex matter. The Emergency Management Capability (EM) score is derived using professional judgement to score many features against consistent score criteria. The Site

Incident Potential (SIP) is scored independently, again based on professional judgement.

A natural normalisation process has taken place in the following respects:

- All capability-related scores are on a scale of 1 to 4. Although discrete score criteria have been developed for each item, each follows the pattern of: 1 = poor; 2 = sub-standard; 3 = adequate; 4 = very good. A judgement must be made in each case if the subject meets a standard of adequacy or not – there is no middle score.

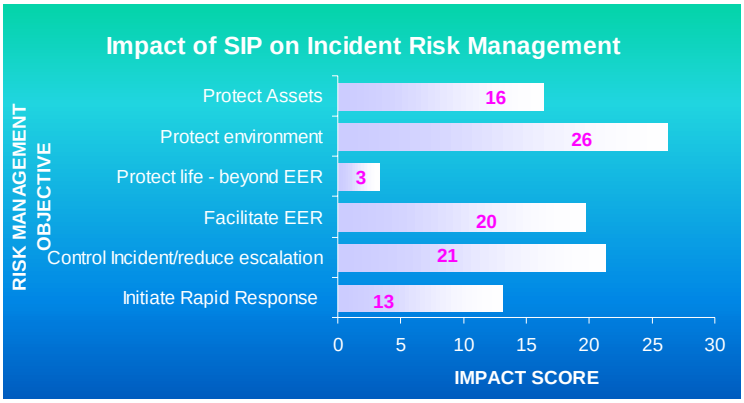
- SIP is scored on a scale of 1 to 4. Implicit in the scoring structure is the level of emergency preparedness that must be achieved in order to meet the site emergency requirements – to the same scale as above.

See Appendix 1 for detailed description of the methodology. Also see the Methodology, Section 8.1.1 for examples of SIP results from the research.

The SIP scores were checked and verified in two ways. Firstly, OCTO assessors ranked the sites subjectively according to perceived level of difficulty in emergency management. The judgement of the two assessors agreed closely and correlated very closely with the ranking produced by the SIP scoring protocol. The second verification was from the Emergency Managers and Planners on the sites themselves, who agreed that their individual SIP scores were realistic.

9.1.3.2 Incident risk management requirement.

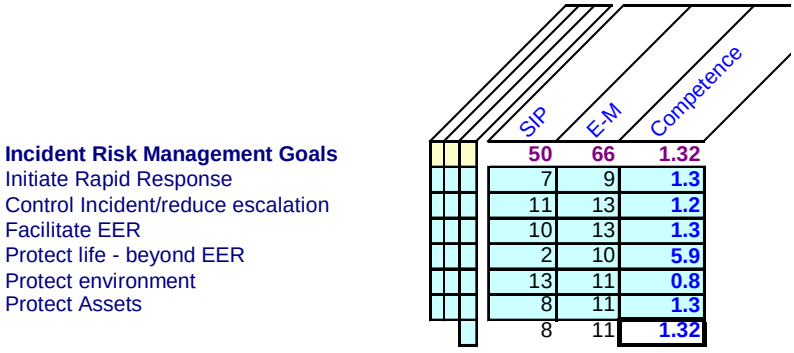
Figure (17) Impact of Site Incident Potential on Incident Risk Management



This graph shows the proportional demand that the SIP places on the management of each risk management objective. For instance, the graphic shows that the site has a high environmental sensitivity and a relatively small off-site risk to persons. This means that emergency preparedness needs to focus effort in areas which will promote an effective response to an environmental emergency, whilst also satisfying the requirements to Protect Assets, Facilitate EER and Control Incident. The low ranking of Initiate Rapid Response is because here we are assessing only the response of the site management team, not the plant facility team. The site management teams have a much lower impact on initial response than do the facility team. The rest of the requirements are distributed appropriately.

9.1.4 Relationship between Emergency Management Capability and Site Incident Potential

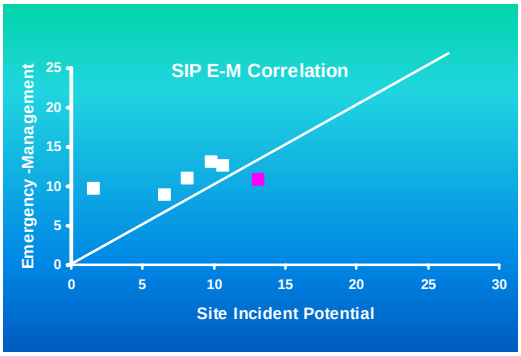
Figure (18) **Relating Emergency Management Capability to Site Incident Potential**

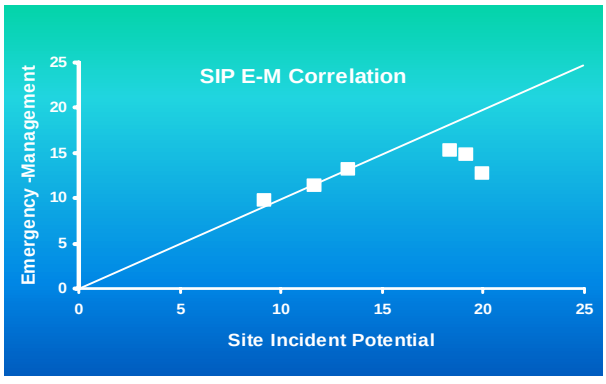


Having assessed how well prepared the site team needs to be in order to meet the site emergency response requirements, we can now relate the two through the E Matrix. In this graphic taken from the benchmarking spreadsheet we see, in the 1st column, our emergency response goals – or Incident Risk Management Goals - The 2nd column has normalised the proportions in the graphic to the actual SIP value of 50%. The Emergency Capability overall score is 66%. This is distributed amongst the Incident Risk Management Goals in the proportions shown in the 3rd column. The values are normalised to the overall Emergency Capability score of 66%. Thus we can compare how well the site emergency management team is prepared to meet its strategic objectives.

9.1.5 Competence Relationship

Figure (19) **Emergency Management Capability compared with Site Incident Potential – two graphics**





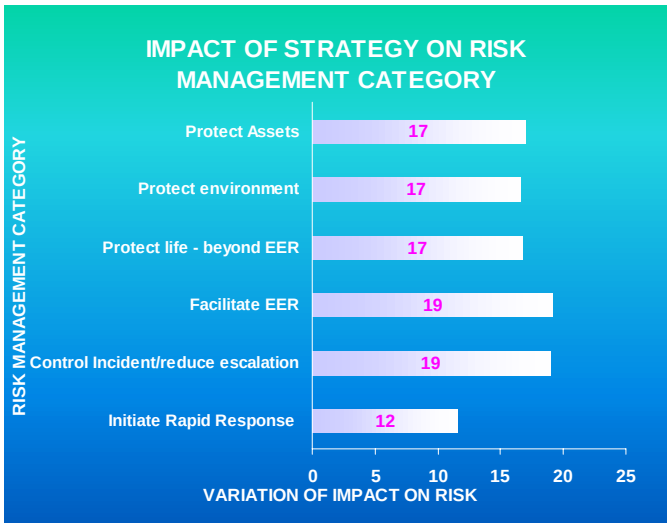
Plotting the 3rd column against the 2nd we can see that the emergency management team is well prepared in all areas but one – the most demanding requirement of Protect Environment. In this area, some improvements in capability are needed. By contrast, in Protect Life (on-site and off-site) they are particularly well-prepared.

A detailed examination of the balanced score card can then assess the validity of this result and suggest areas where improvements could be made to best effect.

By contrast, the graph on the left is for a company with a high SIP. Although the company has a good emergency capability score, it only just meets three requirements and they fail in three. These are Control Incident; Facilitating EER and Protect

Environment. The balanced score card again reveals a number of elements in which improvement would raise these three scores. These are: adding an extra person to the site emergency management team and adjusting the roles of individuals within the team; a few small but significant improvements in the emergency management facilities and further development of the existing, broadly good, training programme. How emergency management effort is divided between objectives

Figure (20) Impact of strategy on risk management category

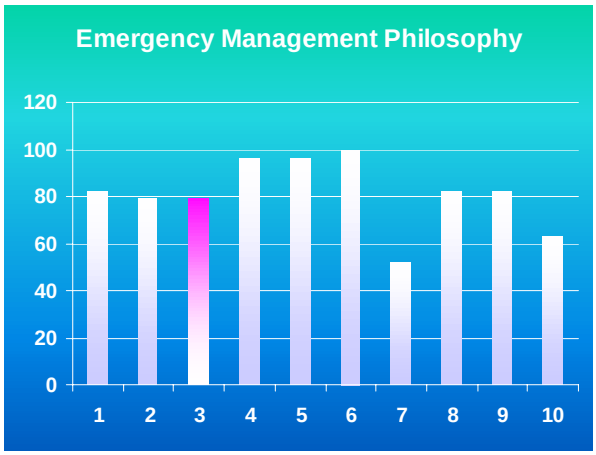


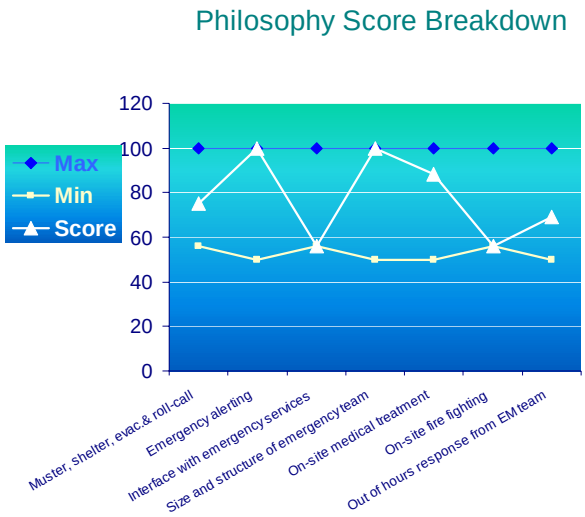
A final overview graph denotes how the effort put into emergency management preparedness is divided up between the six risk categories. The total of the scores is 100%. This graphic is for a third site.

9.1.6 Detailed benchmark on each topic

For each topic, the company can see where it stands within its peer group in absolute performance. Alongside this is a detailed breakdown of each constituent element and how this compares against best and worst in peer group. The data relating to emergency management philosophy are illustrated in Figure (21).

Figure (21) Benchmark on Emergency Management Philosophy





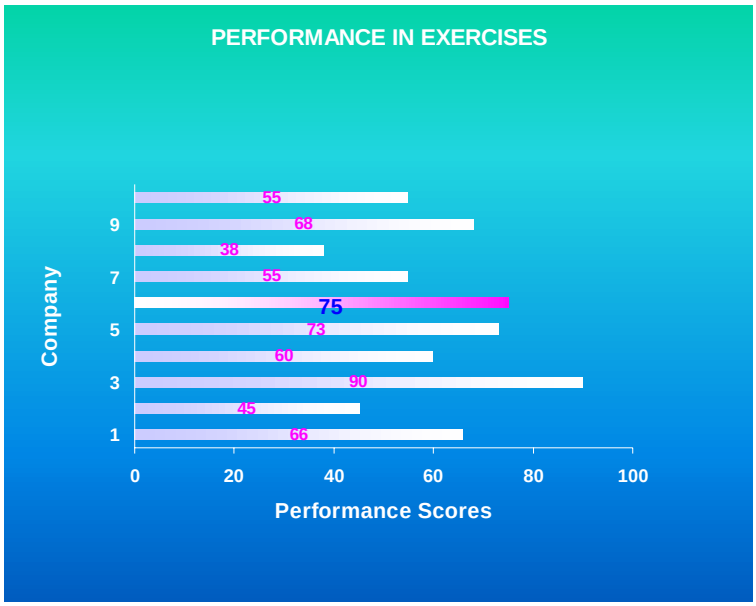
Similar plots could be constructed from the data regarding:

- Management structure
- Emergency management organisation
- Emergency management facilities
- Emergency team preparedness
- Emergency planning (only review and testing of the plan is within the scope of this project, other features could however be developed).

9.1.7 Performance in exercises – an indication of team performance in an incident

Performance of an EMT in an exercise can then be weighed alongside overall emergency capability and the competence correlation to gain a detailed picture of the strengths and weaknesses of emergency management practice. The highlighted number in figure (22), for example, shows how company number 6 has performed in relation to other companies. The detailed scores from the balanced scorecard can offer greater insight into areas of particular attention.

Figure (22) Performance in exercises benchmark



9.2 EXERCISE RESULTS FROM EMPIRE

From the benchmarking project, the number and type of exercises chosen to demonstrate emergency management capability were as shown in table 8.

The scores show that, from the point of view of emergency management (as distinct from detailed practical plans), as much value could be gained from a telephone simulation exercise as from a full site simulation. The low scores for exercises Types 1 and 2 are indicative of the true performance of the team. Two facets out of ten could not be assessed fully, owing to the nature of the exercise: effectiveness beyond the procedural envelope and use of resources. Full scores for emergency management capability were theoretically achievable for exercise Types 3 to 5.

Table (8) Merits of the various types of exercise studied.

Exercise Type	Number undertaken in study	Comment	Score (%)
1. Table-top exercise, in slow time	1	• Useful training medium for procedures and familiarisation with site emergency issues; • exposed some weaknesses in the emergency management team; but • did not offer scope to assess fully emergency management capability – missed effectiveness beyond procedural envelope and realistic use of resources.	**38**
2. Full telephone, role-play simulation exercise for emergency management team using non site-specific scenarios – primarily a training exercise	1	• Useful training medium for developing emergency management principles; optimising team structure; but • did not test emergency management of site scenarios – also missed effectiveness beyond procedural envelope and use of resources.	**45**
3. Full telephone role-play simulation exercise for emergency management team using site-specific scenarios.	2	• Most flexible training medium for developing emergency management skills; • can easily perform 3 exercises in a day, with full debrief; maximum training opportunity; • most key interfaces tested; but • did not test communications realistically	**75; 55**
4. Partial simulation of site incident response teams in support of full simulation of emergency management team	2	• Useful training medium – not as flexible as (3) and more difficult to adhere to a realistic time-line; • embraces more people in training; • most key interfaces tested; and • quite realistic test of communications	**73; 55**

Exercise Type	Number undertaken in study	Comment	Score (%)
5. Full simulation of site incident response teams, mustering staff and emergency management team. Some telephone simulation filling in for external agencies.	3	• Useful training medium for developing emergency management skills – scenarios are less flexible than in 3; • heavily resource-intensive, can only perform one exercise in a day, restricting training opportunity; • tested all key interfaces; • realistic test of communications; but • unless very skilfully designed will not put realistic pressure on site emergency management team.	**65; 90; 68**

This section shows each perspective and then each element of each perspective in turn. It presents best practice and worst practice from the results of the study. It then distils from the whole database the key assessment points for HSE. All advice reflects the current practice on the range of sites assessed for this project, and can be considered indicative of UK Major Accident Hazard Industry contemporary practice.

9.2.1 Management structure

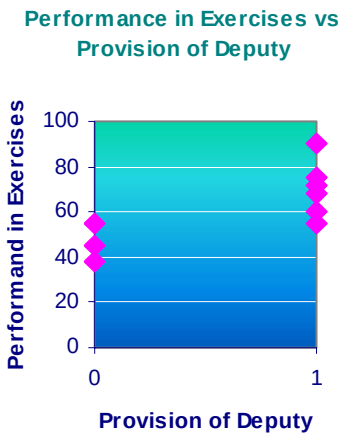
Table (9) Management structure

Role	Comment
Emergency controller	Generally drawn from senior management team – engineers or operating managers. Up to 10 managers on some emergency controller rotas – likely to be a challenge to maintain them all at a good competence level. One site selects emergency managers from a general management background; has them rostered for a week on duty. During this time they are supposed to be relieved of their routine work and able to devote their time to familiarising themselves with the site and working on emergency preparedness with the various facilities - this proves difficult to achieve in practice. Some emergency controllers at facility level were senior shift managers.
Deputy emergency controller	3/10 companies had no provision for a deputy in support of the emergency controller. In these cases, the exercises demonstrated that the emergency controller was liable to be drawn excessively into detail 4/10 companies had a formal deputy role; 1 recognised the benefit in difficult circumstances and made provision to call one in; 2/10 companies had a person fulfilling more of an assistant role than a fully-fledged deputy. In some cases the deputy emergency controller is formally trained and certified as competent, to a level just below the emergency controller.

Role	Comment
Information manager	3/10 companies had no provision for person/s dedicated to managing information. 6/10 companies had provision for one or more specialist information managers – these were experienced staff who understood the technical information they were handling – not to be confused with a logger. 1/10 had a situation unit – not tested at time of writing.
On-scene liaison	10/10 had this role. In all but one case it was an experienced plant person. The remaining company used a very experienced shift desk/radio operator to liaise on all issues except technical issues which were routed to the emergency controller or deputy. The team was stronger when issues were routed via the deputy.
External communications	10/10 had someone in this role
Personnel accounting	9/10 had this role. One site had recognised the shortcoming but had not yet established the role. Several sites operate an electronic swipe card system, administered from a central control room and feeding into a central office. One site co-ordinates personnel accounting for the whole site at the forward control point. This system may be fragile in a complex personnel movement situation. Other sites conduct local plant roll-call from muster stations and feed results though to a small personnel administration team.
PR Liaison	Present in 9/10 teams studied.
Communications officer	Present in 6/10 teams studied. Four sites had a dedicated communications centre, within or adjacent to the emergency control centre, staffed by full-time shift communications experts. One site had a communications specialist operating on hands-free radio and boom microphone, in almost constant touch with the site, updating wall-boards simultaneously. Other sites provide a communications officer within the team, to take some of the routine communications load.
Logger	7/10 teams had a dedicated logger. One team has removed the logger, having found that their new information management system left it redundant.
On-scene incident controller	10/10 - a necessity for everyone. In several cases, the on-scene command role is split between the plant specialist and the fire team leader, each taking priority in their specialist field. Others place a more senior manager in control of the forward control point.
Fire team leader	10/10 – a necessity for everyone. A specialist subject, particularly on chemical plants.
Medical officer	6/10 sites have on-site medical assistance immediately available in an emergency – beyond the provision of 1st-aiders.
Other in on-scene team	6/10 sites have a gas monitoring team. 4 did not mention gas monitoring at all.
Technical specialists	10/10 sites had access to varying degrees of specialist advice. All had such provision within their emergency plan.

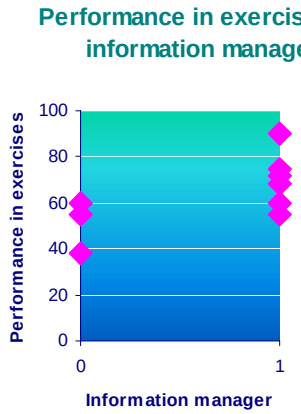
Key indicators:

Figure (23) Performance in exercises vs provision of deputy emergency controller



- Emergency controller should be a senior line manager
- The position of the emergency controller is much strengthened by the addition of a deputy. The exercise performance scores are consistent with this advice. The reason for this could be that the more capable emergency teams have recognised the need to distance the emergency controller from the detail, and have instituted a deputy role to facilitate this.

Figure (24) Performance in exercises vs information manager



- The provision of a person to manage information on behalf of the emergency controller was of demonstrable benefit in some exercises. The exercise scores are consistent with this.

- The role of on-scene commander is particularly important in establishing control and mitigating the effects of the incident. Attention should focus on the training, experience and overall capability of this individual.

9.3 EMERGENCY MANAGEMENT ORGANISATION

9.3.1 Emergency procedures – content presentation and layout

The full content of the emergency plan lay outside the scope of this project. Comments here focus on the procedures used during the incident – taking general points on content, presentation and ease of use.

Table (10) Emergency procedures – content presentation and layout

		Emergency procedures – content presentation and layout	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Very succinct and to purpose. No more than two pages per person. Includes: location of individual; means of identification; main duties; equipment and information provided/needed; aide memoir of key prompts	• Do they devolve accurately from the mandate? • Ensure check-lists separated into different subject-matter – for instance: main duties; initial response aide-memoir; aide-memoir of subsidiary guidelines; equipment lists. Mixing them up is confusing under pressure. • Can you read and assimilate key elements in about 1 minute?
Low score	**1**	Emergency procedures out of date and inaccurate. Rambling overlapping catalogues of information, duties and check-off lists of minutiae. Major re-write in progress.	
Others		Easy-carry A5 booklets; laminated grab-cards.	

9.3.2 Call-out arrangements

Table (11) Call-out arrangements

		Call-out arrangements	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Use pre-established bureau system to bleep or telephone many people at once in response to one phone message. All personnel carrying bleepers. Nominated principals and deputies; no rota. Tested regularly against performance standards.	• When system needs to call up a large number of people – say more than 5 quickly use automated call-out system to save limited resources on-site early in incident. • Rotas and/or nominated deputies are more reliable than just going down a list and hoping for the best. • Balance requirements against the speed of incident development and level of capability within the on-site team. • Culture of all managers ensuring best practicable contactability when off site.
Low score	**2**	Call-in by telephoning down a list of likely managers in priority order. No rota. Managers carry bleepers.	
Others		As score 4 – but with rostered personnel on call.	

9.3.3 Emergency management organisation resources

Table (12) Emergency management resources

		Emergency management resources	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Size and structure established against worst credible scenario in safety case. Policy of over-reaction and then man-down.	• Establish quickly maximum resources against safety-case scenarios • Ensure emergency controller can stand back and THINK – he/she should not be drawn into routine work in the emergency control room • Ensure back-up arrangements are organised and realistic
		All identified emergency teams are adequately resourced, with back-up staff available both for relief teams and also to establish satellite support teams.	
Low score	**2**	Emergency controller is under a lot of pressure by the system – he is a one-man band effectively. Team roles are well-defined.	
Others		Considering adding an extra person to the emergency management team – to take weight from the emergency controller and allow him/her to stand above a deluge of immediate issues.	

9.3.4 Mandates for decision-making within emergency management team

Table (13) Mandates within emergency management team

		Mandates within emergency management team	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Mandates clear, concise and unambiguous – define decision-making envelope	• Mandates should define the over-arching accountability for the emergency controller in inescapable terms – should not be littered with words like liaise; communicate; co-ordinate. • Back-up a simple statement of authority with a list of key responsibilities. • Ensure managers talk through and understand the nuance and interpretation inherent in their mandates – do this through what-ifs.
		Mandates bestow clearly overall command; ensure safety of public and personnel; empowered to act on own judgement. Back-up check-list a sensible headline aide-memoir.	
Low score	**1**	Written mandates diffuse and bereft of executive aim and delegation; words like co-ordinate and liaise used liberally instead. Also unclear in minds of key players. Additionally, names of command centres recently changed, increasing confusion.	
Others		Grab boxes contain mandate sheets for key players in the emergency control room.	

9.3.5 Relationships between emergency team members

Table (14) Team relationships and team dynamic

		Team relationships and team dynamic	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Roles clearly defined. All individuals practised in their roles and efforts made on site to keep teams together.	• Emergency controller should not be engaged in routine communications or detailed work – this should all be delegated, allowing him to stand back and control direction, leaving minutiae to others. • The role of a deputy emergency controller has proved particularly useful in achieving this. • Emergency teams which are able to maintain continuity of personnel – such as shift teams – reached higher standards in exercises. See Figure (25) • Team roles need clear definition – but it should be recognised that team structure is not static, and will often need to be adapted subtly to the needs of the specific emergency.
Low score	**2**	Roles of emergency team members are defined. However, heavy reliance on emergency controller as principal conduit for information and universal problem-solver hampers other team members in playing a full, empowered role.	
Others		Role of deputy developing, not yet fully established. Assistant emergency controller performs role of deputy – worked well in exercise – but system fragile.	

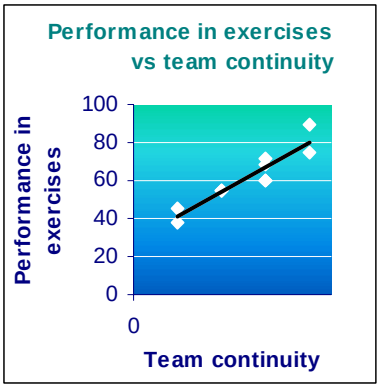


Figure (25) Performance in exercises vs team continuity

Team continuity was not the only variable in play here. The teams, which had maximum continuity had also practised the most vigorously and were on the whole trained to a higher standard.

9.3.6 Contingency arrangements if key personnel unavailable

Table (15) Contingency arrangements

		Contingency arrangements	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Quality of team training allows flexibility to assume various emergency team roles.	• Policy of calling in more than required – until full extent of emergency can be gauged. • Broad understanding of peer roles, and a practised preparedness to take responsibility on behalf of others in their absence. • A thorough understanding of mutual rolls by associated emergency centres, enabling mutual support. • Ensure arrangements tested. • Consider hazards to persons called in – are they given clear safety instructions?
Low score	**1**	Arrangements ad-hoc and untested.	
Others		Policy always to call in more people than required. Alternates assigned for each role – to be called when primary contact unavailable.	

9.3.7 Mandates for decision-making at on-scene command

Table (16) Mandates at on-scene command

		Mandates at on-scene command	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Clear mandates delineate authority to act, including safety of personnel and preservation of life at the scene; control of on-scene response; provision of information to emergency controller. Backed up by short and apposite check-list of general duties.	• Apart from the requirements of clarity and brevity, the on-scene command contains some specific issues of command structure: Eg. • How is an effective fire-fighting strategy developed • What is relationship with site emergency control?
Low score	**2**	Individual site facilities are not yet prepared for emergencies to the same level as the site organisation.	
Others		Fire team leader and on-scene commander are deliberately co-equal. Each leads in their own area of expertise. System appears to be well-proven and command confidence – requires frequent and high-quality exercising to work well.	

9.3.8 Mandates for muster-checkers

Table (17) Mandates for muster-checkers

		Mandates for muster-checkers	
	Score (/4)	**Comment**	**Indicators of adequacy – in priority order**
High score	**4**	Muster checkers demonstrate excellent grasp – rapid evaluation of muster/roll-call in small units across site – coupled with simultaneous assessment of possible casualties. Both factors fed forward for central, timely evaluation.	• Assessment here needs to consider site risks and the level of difficulty of mustering and evacuation on site. The very best practices may not be appropriate for smaller sites • Muster points should assess potential casualties (not necessarily confirmed casualties) and feed this information as soon as known to the centre – as well as factual information on roll-call, • Where site emergency conditions demand, those nominated in charge of the muster point must take responsibility for moving persons (safely?) to an alternative point of shelter. Emergency arrangements need to support this as a credible option.
		Duty defined: ensure that all personnel accounted for at the muster point and identify missing persons; activate safe evacuation if required; provide back-up personnel on request.	
Low score	**1**	Mustering system inadequate and personnel untrained.	
Others		Mandate does not cover contingency of needing to move personnel from muster point.	

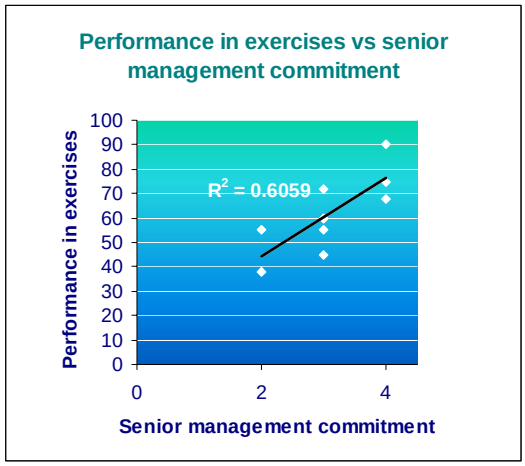
9.3.9 Evidence of senior management commitment

Table (18) Senior management commitment

		Senior management commitment	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Head of Site has provided clear direction and strong personal leadership in the recent improvement of site emergency management effectiveness. A capable practitioner – leads from the front.	• Like safety is not the responsibility of safety department – emergency management is not the responsibility of the emergency preparedness engineer. Emergency management is a line-management responsibility. It thrives with active, demonstrable top management support. This can be manifested in several ways: • Site manager is a trained and expert practitioner, leading from the front; • Senior managers make time to lead in realistic training regimes; they make a point of opening senior training events and look in on training sessions and take an informed interest. • Selection criteria for senior operational positions include emergency management skills, which are seen a s significant component of the competence inventory; • Performance in emergency exercises is included in career appraisals • Adequate resources – money and time are made available to emergency training and exercising.
		Senior managers have shown strong and consistent leadership over a number of years. Policy of being world-class is more than a mantra – and even within reach.	
Low score	**2**	Institutional weakness as emergency controllers – top management representative are the principal weak link in the system.	
Others		Top managers proclaim vigorous support for emergency management but are always too busy to put in an appearance.	

Figure (26) Senior management commitment

Senior management commitment is demonstrated to be a strong influence on emergency performance.



9.4 EMERGENCY MANAGEMENT FACILITIES

9.4.1 Setting up

Table (19) Setting up

		Setting up	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Permanent installation; all reference information available; telephones; faxes; T.V.'s etc. in permanent readiness; Clocks display correct time.	• Does a reputable individual have "ownership" of facility as a whole? • Is facility neat and orderly? Are associated convenient stowages correctly provisioned against a contents list, neatly ordered and protected by a seal on the lock or catch? • Are communications facilities and information management systems tested regularly and realistically? • Most non-permanent facilities – if adequately provided with telephones, fax machines and PCs - can set up very quickly, provided clear instructions given, all equipment stored in an orderly way and on-site people trained to deploy efficiently.
Low score	**2**	Emergency centre not yet built; a manager's office used meanwhile. Inadequate guidance for setting up temporary arrangements, extemporised communications, insufficient space for information management wall-boards, clocks randomly inaccurate, marker pens worn out.	
Others		Emergency managers provided with small bag – telephone; key information; contact lists; emergency procedures.	

9.4.2 Layout of emergency control centre

Table (20) Layout of emergency control centre

		Layout of emergency control centre	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Newly upgraded emergency control enclave has good positioning of key personnel; common processed information display. Line of sight contact between key players. Access to communications and subsidiary teams is satisfactory.	• A specialist topic. A few pointers are listed below: • Can emergency team share a common information display? • Is there line of sight between key players? • Ready access to communications? • Key members readily identifiable?
Low score	**2**	Very simple rectangular room with wall-mounted white-boards and a central table. Communications are in adjacent room. Team wear ID tabards. Virtue of simplicity. Increase in practical support for emergency manager could yield a high upgrade in capability.	
		Emergency control centre is too small to accommodate the emergency management team and the external services representatives around the same table. Concern over the level of noise and disruption that would be generated.	

9.4.3 Back-up emergency control centre

Table (21) Back-up emergency control centre

		Back-up emergency control centre	
	Score (/4)	**Comment**	**Indicators**
High score	**3**	Stand-by emergency control centre is satisfactory and amply provided with accommodation for all players. Central enclave is small and cramped and common processed information presentation is achieved with some difficulty. Unexpected transfer from primary centre exercised successfully.	• An alternative emergency control centre should be available if the main one can credibly be incapacitated during an emergency. • Equivalent essential information should be provided. • Adequate communications • Means of moving from one to another needs to be established. • The transfer evolution must be practised realistically.
Low score	**0**	None in place	
Others		Two available sites – equipped to skeletal level only – master maps and grab boxes are available.	
		The major failing of the back-up centre is that it is off-site, some miles away and is not equipped with similar information aides.	

9.4.4 Information management and display system in emergency control centre

Table (22) Information management in emergency control centre

		Information management in emergency control centre	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	History, situation and forward plan shared in real time between all key players. All essential technical information in place: safety case; gas dispersion etc.	Emergency manager and team need to be able to share a common picture of the emergency. This should include: • What has happened – key events • What is going on – the current situation • A forward plan to show the team what to do.
Low score	**1**	Information management system is basically a log. There are no forward looking elements. Essential reference information in place.	
Others		Two formatted cards structure information transfer between scene of incident and emergency command centre.	

9.4.5 Information management and display system at-scene

Table (23) Information management and display at-scene

		Information management and display at-scene	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	For a small, single plant site – the forward control point is run effectively from the plant control-room – with full information management support.	The rate of action at on-scene command limits what information can be shared. However, much detailed planning often needs to take place, and resources must be made available. For instance: • BA boards give a forward plan of fire team deployment and air-use. • Also need to keep track of other essential resources – people; equipment. • May need information to assist with dynamic risk assessment – hazard data sheets – or preferably a ready-reference sheet devised for use in an emergency.
Low score	**0**	None present.	
	1	On-scene commander has a few simple check-lists.	

9.4.6 Range, redundancy and security of communications

Table (24) Communications

Criteria		Communications?	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Hard-wired and exchange telephone lines into emergency control centre. Two site telephone exchanges with UPS etc.; separate radio network for police and fire-brigade use; site radios. No channel-hopping or other security device.	• Look for more than 1 telephone technology, plus back-up systems for power failure. • Radio systems must not be overwhelmed – likely to need several active frequencies in an emergency. • Cannot rely on radios – they fail too often and are not reliable in high noise areas; also they are readily monitored off-site.
Low score	**2**	A small number of communication technologies. – Telephone. No radio back-up in emergency control room.	
Others		No known radio black spots. Good use of hands-free and helmet headsets.	

9.5 PERFORMANCE IN EXERCISES

9.5.1 Performance of emergency manager

Table (25) Performance of emergency manager

		Performance of emergency manager	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Powerful, balanced demeanour, showing sensitivity to team. Forward looking, clear objectives; coherent strategy and tactics. Well-organised overall. In sum, effective leadership.	A specialist area. Look for: • Effective leadership presence and performance • Demonstrating understanding of the situation • Assessment of command ability; leadership; stress management, demeanour, team management is a specialist topic which we would not suggest a non-specialist should attempt.
Low score	**2**	Veneer of sharpness and authority – degraded progressively under pressure of events. Lack of grasp of principles of emergency management.	
		Attempted a strategic view, looked ahead and sought a clear focus on the priorities. Confident demeanour inspired confidence in team. Good briefs to team. Excellent potential. However, lost track of key time-lines and failed to achieve a satisfactory outcome to the emergency. Mainly due to lack of quality information, not the individual - however end result did not deliver.	
Others		Good examples of taking control and making good decisions under pressure. Some instances of reluctance to delegate.	

9.5.2 Performance of deputy emergency manager – if present

Table (26) Performance of deputy

		Performance of deputy	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Well-integrated with emergency manager and complementary to him. Managed team with depth and polish. Effective control of information management. Manager and Deputy were teamed and very used to working together.	An effective deputy role takes the weight of all routine activity off the emergency manager. Often the need for a deputy is indicated by the emergency manager being very active in directing the team minute by minute, being over-involved in detail and back-seat driving a secondary control centre – and hence missing the wider strategic picture and, at worst, creating confusion.
		Highly effective performance. An inexperienced emergency manager was supported and protected. The information management systems were used well, with the exception of forward planning.	
Low score	**2**	One role of the deputy was to ensure that the information management system worked. This was not achieved.	
Others		In practice, deputy more of an assistant ('gofor'). Emergency manager could be better supported.	

9.5.3 Information management – during exercise

Table (27) Information management during exercise

		Information management during exercise	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Whilst not perfect, all essential features were functional and managed intelligently. Clear picture presented of a complex situation; moreover transferred effectively to secondary control centre without significant disruption to picture. Essential features comprised: plant and emergency situation; implications for site and off-site; strategic direction for emergency management; comprehensive and accurate action plan.	• This is a specialist topic – whilst it is easy to identify what does not work, it is a specialist job to identify solutions. • Look to see if emergency team members use the information aides on the wall – if they don't then they are probably not of much value. • Ensure that the main decision-maker(s) are not main conduits of information. • The team should be able at all times to know what is happening in the incident - what they are trying to achieve and how. If this is not clear to the observer, the team is probably confused too.
Low score	**1**	The simple log as only used by one team member, and not the emergency manager or other key players. The logger reported being unsure of what was going on most of the time. The team did not share a common forward plan. The emergency controller was often the main conduit for information in and out of the control centre.	

9.5.4 Team performance

Table (28) Team performance

		Team performance	
	Score (/4)	**Comment**	**Indicators**
High score	**3**	Team competent, not polished – performing effectively under strong leadership. Core team needs further practise in linking with satellite specialist teams.	Assessment of team activities in support of emergency manager is a specialist skill. Points to look out for: • Team should be busy – emergency manager much less so. • Team should be handling communications – not emergency manager. • Room should have a purposeful hum, look busy but well-ordered. High noise level is a reliable bad sign. • Team members should demonstrably share essential information.
		Team members were generally competent at their tasks. The team as a whole was overly dependent on the emergency controller, thus not realising its full potential to support him.	
Low score	**2**	Team members of variable quality and experience – not used to working together	
		Team members well-practised and committed. All were sound. Team dynamic weak, in that all activity focussed around emergency manager – too much watching and too little doing. Team spent much time seriously behind the power curve.	
Others		Very small team of 3 shows compactness and has virtues. However, such a small team structure heavily reliant on competence of emergency manager and communications officer. Small team brittle by nature.	

9.5.5 Effectiveness of mandates

Table (29) Effectiveness of mandates

		Effectiveness of mandates	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Relationships between forward control and site response team were clear and well managed.	A specialist subject. It is more easy to identify if command and control structures are wrong than it is to identify solutions. Look out for: • Micro-management of the incident from on-high • Too many, and low level decisions being passed up the line
Low score	**2**	Emergency manager failed to discharge his mandate to full effect. Did not take control of the site – instead micro-managed the incident.	
Others		The high-quality mandate is still the exception; most are weak in distinguishing essentials from detail.	

9.5.6 Quality of scenario

Table (30) Quality of scenario

		Quality of scenario	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	Realistic, demanding scenario – moved outside procedural envelope. Well executed – good role play via realistic media – telephones, radios, fax. etc.	There is no substitute for reality! Emergency exercises used as a demonstration should simulate so far as possible a real emergency. This means: • Use a safety-case scenario – and move through the full range over time • keep to a realistic time-line; • ensure mechanism for following up actions • use the 'for real' communication media – telephones, radios, certainly sufficiently realistically to discover the problems. • Same location also ideal; however, if relevant features like information aides and relative spatial positions around the table are maintained, can get good results in a simulator. • The scenario should respond to the emergency team, not lead them. • A really testing scenario should move beyond the procedural envelope • Role-play – where used - should be realistic
Low score	**2**	Realistic, relevant scenario – well thought through. Run with flair and enthusiasm. Table-top, discussion event – not a full analogue of a realistic emergency situation. Information flows not realistic.	
Others			

9.5.7 Operating beyond the procedural envelope

Table (31) Operating beyond the procedural envelope

		Operating beyond the procedural envelope	
	Score (/4)	**Comment**	**Indicators**
High score	**3**	The scenario presented a time dependent need to shift to the secondary emergency control centre. The nettle was grasped, the shift achieved effectively and control exercised from the secondary centre for about the last hour of the exercise. This result was achieved through correct analysis, sound planning and good leadership.	Any emergency worthy of the title will move outside pre-planned procedures and require independent management action in order to gain control. • Assess the scenario plan, and determine those points where the emergency starts to deviate from routine procedure. • Assess if control is achieved and sustained. • This assessment required practice and experience
Low score	**0**	Scenario did not move beyond procedural envelope- therefore team not tested sufficiently.	
Others	**2**	It was when the emergency moved beyond the procedural envelope that the team fell seriously behind the power curve.	
		Practical communications and procedure problems, aggravated by back-seat driving and disfunction of action management, put the team behind the power curve.	

9.5.8 Review and learning process

Table (32) Review and learning process

		Review and learning process	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	The review was facilitated by the site emergency planning manager – all key learning points identified, with just a little assistance from external advisor.	Reviews conventionally identify a lot of logistical and circumstantial detail – which is valuable and should be captured. They should also address key strategic issues like: (a) did the team actually bring the emergency under control / save life / generally meet their bottom line? If not – why not? (b) emergency team performance; team relationships; leadership; command and control. These are specialist topics; it often requires external facilitation to bring out the learning points.
Low score	**3**	The team was not sufficiently trained to contribute to a coherent, in-depth analysis. Some useful points emerged, prompted by the emergency planning manager and attending fire-brigade representative.	
Others		Assisted by external advisors, the team conducted a searching review and was perceptive, objective and responsive to feedback. All major points identified.	

9.5.9 Adequacy and effective use of resources

Table (33) Adequacy and effective use of resources

		Adequacy and effective use of resources	
	Score (/4)	**Comment**	**Indicators**
High score	**4**	No shortcomings in the identification, bringing forward and deployment of resources was detected	See Section 6 of main report and Appendix 2 - TPRC • In assessing the exercise, have a view of what resources will be required in response to what eventuality. • Check that key resources are mobilised and delivered on time.
Low score	**0**	Exercise did not test this feature	
	2	The facility team failed to mobilise in time to rescue casualties. This was not sorted out by the central emergency response team. Resources for casualty handling and incident control were brought forward in good time.	
Others		Resource shortfalls occurred in provision of breathing apparatus and advice and deployment of external agencies in response to off-site risks.	

9.5.10 Adequacy and effective use of facilities

Only a narrow assessment of this feature was made within the scope of this project – which excluded the detailed emergency plan. An overall assessment of facilities is difficult without a detailed assessment of the plan. Facilities in this case were confined to emergency management facilities.

Table (34) Emergency management facilities

Criteria		**Emergency management facilities**	
	Score (/4)	**Comment**	**Indicators**
High score	**3**	Emergency facilities of high quality and well thought through. Information management facilities not used to full effect.	A specialist topic. Consider: • what facilities are actually used compared with those provided; was provision brought forward against 'worst case'?. • does their use appear to help or hinder? Is anybody engaged in an apparently pointless activity? Is space available sufficient? • is equipment sufficient, readily available and easy to deploy to best effect?
Low score	**2**	The new site emergency response room is very small and likely to be heavily encumbered with the presence of external agencies.	

9.6 EMERGENCY RESPONSE PHILOSOPHY

9.6.1 Muster, shelter, evacuation and roll-call

Table (35) Muster, shelter, evacuation and roll-call

		Muster, shelter, evacuation and roll-call	
	Score (%)	**Comment**	**Indicators**
High score	**100**	Personnel accounting system for large plant based on electronic swipe-card system with a degree of zoning within the facility. People muster in building or outside shelter areas depending on alarm. Proved in exercises to meet performance standards – rapid muster count delivered.	• Consider strategy for mustering out-of-doors and moving rapidly in case of gas escape vs. sheltering indoors with possible danger of being trapped. Assessment highly dependent on site characteristics – no single solution. • Given that any strategy adopted is unlikely, except on most straightforward sites, to cope with all emergency scenarios – need a contingency plan for evacuating / rescuing sheltering personnel or sheltering mustered personnel. • Expect casualty identification system to operate much more quickly than roll-call arrangements on a big site. • For very large sites, order 4000-5000 people, electronic mustering is only viable option presented in this study – IF a site roll-call is indeed necessary • Personnel management/control/ movement problems on large sites are awesome. Does emergency management system comprehend and have a system for controlling and moving large number of people around and off site in hazardous conditions?
Low score	**56**	Manual personnel accounting system for 4000 + people. Difficulty in deciding on shelter or evacuation. Recognised potential for trapping people within gas clouds – detailed risk assessment performed. High numbers of temporary and contract staff. Impossible to realise a site head-count for a major incident. Company has recognised shortcomings and is installing a new proximity card system.	
Others	**69**	No effective site muster capability – but although the site has around 2000 persons it is not densely populated – therefore would argue full muster not required. Sheltering policy effectiveness is highly dependent upon HF deluge working with high reliability. Make the link between performance standards. Local plant head count, casualty identification is readily achievable and regularly tested.	

9.6.2 Emergency alerting methods

Table (36) Emergency alerting

		Emergency alerting	
	Score (%)	**Comment**	**Indicators**
High score	**100**	3 distinct alarms – sheltering; criticality; fire. Plus off-site alarm. Checks have identified no alarm dead-spots. Back-up with PA system. Dedicated 2-way phones available for roll-call.	• Distinguish which hazards need a specific, different response, and ensure a discrete alarm. • Keep system simple – preferably only 3 distinct alarms – one site needs 4. • Have a reliable follow-up communication system available once people are mustered. If PA system is used, ensure coverage is adequate and that there is a back-up system – perhaps plant telephones or radios.
Low score	**50**	Fire alarms and site evacuation alarm. Latter would cause very serious site congestion. New system on trial – based on voice messaging over alarm system.	
Others		Several distinct alarms is a feature of other 100% scores, where HF or toxic gas alarm replaces criticality alarm. Another site uses dedicated telephone system to relay messages around site – to muster points and control rooms. – Old but highly effective system.	

9.6.3 Interface / relationship with emergency services

Table (37) Interface / relationship with emergency services

		Interface / relationship with emergency services	
	Score (%)	**Comment**	**Indicators**
High score	**100**	Expert interaction with local emergency services; fire fighting strategy on-site is controlled by highly experienced managers. Site and local emergency services work closely together under expert technical guidance. Expert risk assessment of fire-fighting and gas cloud control methods, based on extensive range of safety-case scenarios.	• Determine required activities for fire-fighting / gas cloud control and time-scale of scenario development. If site and external teams both required then: • Expect close liaison and development of mutual trust between site and local fire-brigade. • Expect site and external teams to practice together; have compatible (preferably the same) BA control systems; • Expect site to supply specialist expertise in chemical fire-fighting and gas-cloud handling – managers must be trained to direct fire teams – requiring a high level of fire-fighting competence. • Site must have sufficient numbers and expertise to perform at least a holding job until the emergency services arrive. • Expect site to have considered decontamination of casualties and worked out interface with ambulance service – and indeed local hospitals. • Is there an established system for transferring casualties to the Ambulance Services with full accounting integrity?
Low score	**56**	Rely on external ambulance and county fire-brigade. Expect fire brigade response in 15 minutes and deployment within 30 minutes. Deployment time is outside response required for worst-case scenario – to stop gas cloud moving over site boundary. This shortfall cannot be made up with on-site emergency response. Risk assessment flawed.	
Others		Site authorised by fire brigade to call up to 10 pumps, if required. Insufficient trained personnel on-site to contain or restrict gas-cloud spread – emergency services will arrive too late. A realistic target missed due to inadequate training and provision of simple, low-cost equipment such as portable, ground-mounted water sprays.	

9.6.4 Size and structure of emergency team

Table (38) Size and structure of emergency team

		Size and structure of emergency team	
	Score (%)	**Comment**	**Indicators**
High score	**100**	Large site has ample resources of trained and capable managers to fill a comprehensive range of emergency management positions. Team nicely resourced – not too many in core team. A need to watch numbers engaged in support teams. Emergency teams form up promptly and expertly for emergency exercises – have responded effectively in real incidents. Site has conducted an in-depth assessment of emergency team requirements and has established a sound command and control system. Importance of strong site emergency management team is embedded in culture; managers release staff for emergency training and regular exercises.	• Assessing manning levels and resources requires knowledge of how a variety of organisations work and why. Often this cannot be assessed accurately on paper – need to observe in exercises. Some key points: • Is there a defined role to take the weight of make-it-happen activity off the emergency manager? • Is there an information management element? • Can the initial response team cope for as long as they have to – in an out-of hours or call-in situation? • Assess challenges of running forward control point – are these consistent with seniority and capability of persons in charge? Is there adequate technical expertise present? • How many fully worked-up teams are available? – Worry if only one senior management team has been trained. • Team structure should be designed against worst-case scenarios. • Initially should man up beyond perceived requirement – can always man down later.
Low score	**50**	Emergency team would appear to be under-resourced without a deputy to support the emergency manager. This has been agreed in principle, but not yet implemented. Site emergency team has not exercised realistically for incidents other than environmental releases. The senior management team recognise that the increase in pace for a safety-related emergency would present challenges as yet unrehearsed. In practice, there could be difficulties in gathering sufficient senior mangers to the site.	
Others		24-hour shift cover for facility emergency management team – fully resourced, with support from call-in if required. Response time on average is 3.2 minutes; turnover of emergency staff less than 10% per year. Respond to over 300 emergencies (1/2 false alarms) per year.	

9.6.5 On-site medical facilities

Table (39) On-site medical facilities

		On-site medical facilities	
	Score (%)	**Comment**	**Indicators**
High score	**100**	Aim to exceed minimum legal requirements. 1 paramedic on each shift. Doctor and nurse in daylight hours. 1st-aider network. Range of medical facilities expertly assessed to cover adequate range of injuries arising from emergency incidents.	• The link to site emergency risks requires specialist assessment of the nature and degree of possible injuries; the likelihood of casualties surviving transport to hospital; the delays in substantive medical response from external ambulance or paramedic services. • A cursory assessment considers if reasonably practicable facilities are available to deal with the immediate effects of the emergency – e.g. blood-loss; gas inhalation; burns etc. • Is there a sound system for accounting for casualties and their movement from one responsible command entity to another? Is this fully integrated with the Ambulance Service's system for doing this (cf. Relationships with Emergency Services)?
		Almost all ERT are paramedics – trained by County Ambulance Service – authorised to make any medical decision on site. Can administer oxygen, CPR, but not drugs. Recognise in major event, could have severe injuries which will need rapid, on-site treatment.	
Low score	**50**	Immediate on-site response via trained 1st-aiders. 1st aiders can use defibrillators; also on-site fire team 1st aid trained. Lack specialist training in treatment of gas inhalation injuries. Medical facilities not linked to site hazards. Site is remote from nearest hospital capable of dealing with emergency injuries.	
Others		Manned ambulance with emergency technician (less than paramedic). Close liaison with local ambulance service. Risk assessment undertaken against current identified site hazard potential. Medical treatment room on-site, stocked to deal with foreseeable site injuries – but not for instance severe burns.	

9.6.6 On-site fire fighting

Table (40) On-site fire-fighting

		On-site fire-fighting	
	Score (%)	**Comment**	**Indicators**
High score	**100**	Equipped and trained to deal with serious fire risk on site. 3 tenders; 1 foam; 1 bulk foam; one vertical dry powder. Also new high pressure water spray for fire extinction. Very high standards of response team selection, training and motivation. Fire team leaders professionally trained by superior County fire service on site-bespoke exercise scenarios to in-house fire-service standards. Engender culture of mutual care and teamwork; aim to achieve long-standing teams. Respond in 3-5 minutes to any fire on-site	• Defined fire-fighting strategy for range of on-site hazards. • Performance standards for response times. • Fire teams, fire team leaders and selected managers trained in hydrocarbon or chemical fires – as appropriate. • Range and capability of equipment must match on-site demand – or by supplied in a timely way by external fire service. • Compatibility issues with external fire team include: BA equipment for joint teams; BA board monitoring; identification of forward control point leader and fire team leader. • Chemical decontamination facilities – using on-site or external services?
Low score	**56**	On-site fire fighting capability is small – in an emergency, fire fighters are spread thinly – not in a position to undertake gas cloud control. On-site team trained to fire-brigade standards. Resources in terms of manpower and / or equipment need review.	
Others		5 pumps on site; option granted by local fire brigade to call up to 10 pumps; employ ex-firemen in fire team – also on-site fire-fighting expert supervises their training. Up to date with recent fire-fighting developments. Five minutes maximum response team of fire service. Largest manageable scenario is 45m diameter. tank to be extinguished by (state of the art) mobile foam facilities.	

9.6.7 Out of hours cover from emergency management team

Table (41) Out of hours cover from emergency management team

		Out of hours cover from emergency management team	
	Score (%)	**Comment**	**Indicators**
High score	**100**	Bleeper system; initial emergency response from site team within 3.2 minutes. Called in first manager within 10 minutes – emergency manager within 30 minutes. Emergency manager has blue flashing light dispensation from local police. Distance of residence of emergency managers from site is specified. System respected by site senior management team.	• Role of emergency management team in support of immediate response team. • Consider means of call-out and how long does it take to initiate. • Comms link with incoming emergency manager so he/she can clutch in to situation and provide some guidance before arrival, always subject to safety – driving for instance. • Expect performance standards for response times. Initial site team incident response time is critical. For a small site team, out of hours, typically expect back-up from management team within 30 minutes. For a well-constructed site shift team, senior management back-up can be allowed a little longer. Suggest 1 hour as outside limit for on-site management support to a strong site team.
Low score	**50**	Ad-hoc, sequential call-out list for management team. Not sufficient for a large site. Considering training of shift team leaders to fulfil role of emergency management team outside normal hours, until a full management team can arrive. System untested – highly vulnerable.	
Others		Full emergency team shift cover for site emergency. Always a manager and technical advisor on call. Can achieve 1 person in off-site emergency room within 30 minutes. On call staff expected to be always contactable, no more than 1 hour from site and sober – no formal expression of this standard.	

9.7 TEAM PREPAREDNESS

9.7.1 Selection of emergency managers

Table (42) Selection of emergency managers

		Selection of emergency managers	
	Score (%)	**Comment**	**Indicators**
High score	**100**	Formal competency structure underpins selection criteria. Selection / training based on ability to manage; under pressure, emergencies which move outside the procedural envelope. 3 stages: aptitude tests and structured command interview; 3 week formal programme, covering a) ability beyond procedural envelope; b) practical emergency exercises of increasing complexity. Candidates do not necessarily have a plant background – therefore extensive training included in selection process.	• Do selection criteria for emergency managers exist that are more than management seniority and / or operating experience? Could for instance be based on articulated emergency management competencies. • Does selection criteria include in some realistic form emergency management capability? This can be assessed via interview; table-top (what-if) type exercises, or most robustly via real-time simulated emergency exercises • Selection via simulation exercises is a specialist subject. It is important that the assessor can distinguish the contribution of the potential emergency manager from the rest of the team and from disturbances in the system. Also exercises must be appropriately demanding. Exercises based on non-plant specific exercises are better for exposing understanding of principles; but plant-specific exercises give a truer test of performance standard. • Is any authoritative external expertise or standard setting applied to the process? • Is senior line management sufficiently involved?
Low score	**25**	1 emergency team can be fielded – this constitutes the entire group of trained and experienced senior managers. No structured selection process to select a wider catchment.	
		No selection criteria applied beyond management seniority and site operating experience.	
Others		Criteria for shift manager selection, in principle, includes capability in emergency management. In practice, lip service given to a selection process, with tendency just to engage senior post holders. May be tested in tabletop exercises, but not seriously in realistic simulation exercises. In sum, company committed to maintaining high standards, but . in practice ear-marked emergency manager has either to opt out or be very obviously out of depth / incompetent to be excluded from catchment.	

9.7.2 Essential knowledge defined for key players

Table (43) Essential knowledge

Criteria		**Essential knowledge**	
	Score (%)	**Comment**	**Indicators**
High score	**100**	Key members of emergency management team have a comprehensive, defined knowledge base that supports fully their role in an emergency. Key individuals must pass a demanding peer group test of their knowledge. Knowledge requirement is based on plant risk assessments and expert advice.	Is there a defined essential knowledge base, based on site risks. This could include: • site geography • knowledge of plant operation; • familiarity with key information – wind rose; toxic gas dispersion; • physical properties – and access to detailed information; • fire-fighting strategy for different chemical hazards; • emergency procedures; • emergency management, command and control theory.
Low score	**0**	No essential knowledge base defined – for anyone.	
Others		Emergency controller check-list mainly a list of physical features about the site. All key personnel receive training in procedures, technical issues and the subject of command in an emergency context. Forward control point managers must be degree qualified, typically 20 years chemical plant experience; comprehensive site knowledge base examined by peer group during viva and table-top exercises. Essential knowledge is not written down, but knowledge demonstration is fully documented.	

9.7.3 Emergency management competencies defined

Table (44) Defined competencies

Criteria		**Are competencies defined for emergency manager and team?**	
	Score (%)	**Comment**	**Indicators of adequacy – in priority order**
High score	**100**	Thorough emergency management competency package, covering knowledge, emergency procedures, principles of emergency management and performance in practical exercises.	Competencies can cover: • all features defined in essential knowledge above; • performance in realistic practical exercises. To be effective, the exercises should be real-time, realistic simulation; a number of observations of performance should contribute to the assessment – not just a snap-shot; assessment scenarios should move outside the procedural envelope.
Low score	**0**	No competencies defined.	
Others		Based on experience and training rather than formal assessment. Many site shift managers have handled real incidents. Assessment of competence is based on standard setter's personal experience, not underwritten by a competency framework.	

9.7.4 Defined requirements for training exercises

Table (45) Defined requirements for training exercises

		Defined requirements for training exercises	
	Score (%)	**Comment**	**Indicators**
High score	**94**	Detailed, comprehensive matrix of emergency exercises, cover every item of training for both on-site staff and off-site emergency services. Supported by specialist training in command; fire fighting strategy and emergency response. Each shift team conducts 12 exercises / year – some small, others large. Focus on building basic skills before progressing to more complex exercises.	• Training exercise programme should be aimed at the prevailing competence standard – with a view to making steady, consolidated improvement towards a target standard. • There is a tendency to exercise on a largish a scale without the underpinning regime of minor exercises required to perfect contributory skills. All the basics of muster; roll-call; establishing access control points; rescue of casualties; fire-fighting with different media; gas cloud dispersion; plant intervention; use of BA, etc, etc. should be exercised a little and often, to develop skills and keep them current throughout the team infrastructure. • Larger exercises should build on these basic skills, testing interfaces (both internally and externally) and emergency management skills. • Exercises of emergency management team may or may not deploy site teams simultaneously – there are different things to learn from both approaches. • Test across a wide range of worst credible and lesser, more realistic, events.
Low score	**0**	Training exercise regime not yet defined.	
Others		Comprehensive range of emergency scenarios – test each of six shift teams in three full or part exercises per team per year, plus two emergency control centre simulations per year with external coaching and review. Annual plant demonstration exercise. Shift teams run exercises for each other, to a good, realistic standard of simulation. Exercise fire teams and chemical teams together on site and separately in simulators.	

9.7.5 Defined requirements for refresher training

Table (46) Defined requirements for refresher training

Criteria		Defined requirements for refresher training	
	Score (%)	**Comment**	**Indicators**
High score	**81**	Steady rolling programme, culminating in 2 externally monitored exercises per shift per annum. Underpinned by competence assurance programme (cf Emergency Management Competencies Defined).	• Check emergency exercise programme covers all key players over a reasonable time-scale, and that all receive exposure to at least one major exercise in a 2 to 3 year period. • Simple features like familiarity with emergency arrangements and refreshing site knowledge with new developments should not be missed.
Low score	**50**	Training for emergency controllers every 2 years – more if required. Not really a comprehensive refresher training programme.	
Others		Repeats of table-tops and meeting of all emergency controllers in emergency room every 8 weeks.	

9.7.6 Competence assurance / assessment

Table (47) Competence assurance / assessment

		Competence assurance /assessment	
	Score (%)	**Comment**	**Indicators**
High score	**100**	All emergency managers and their deputies are certified as competent during a rolling training and competence assurance programme. Each manager is seen in action for a minimum of three weeks, in varying practical capacities. Some elements take place off-site and some in a demanding site emergency simulator. Accreditation based upon progress through programme and assessed capability consistently demonstrated against strict criteria. Combined training/assessment team of line management and external authority. System applied rigorously – some one-third elected for training do not achieve accreditation. Emergency managers begin the process with limited plant experience. Hence the high level of training input, and failure rate higher than other high-integrity approaches which start with more experienced managers.	• Competence of individuals in charge of emergencies is critical to the successful outcome. • Competence should be assessed on an ongoing basis – taking into account all available evidence: performance in training exercises; assessment events; real incidents. • Assessment of competence should never be based on a snap-shot one-off performance – these are unfair on the individuals concerned and frequently unrepresentative. • The key to assessing a competence assurance system is to examine the quality of the review. Possible facets are: command ability; leadership; decision-making; management of information; strategic grasp; delivery on actions. The whole must add up to more (not less) than the sum of the parts as an effective emergency management decision-making executive. • Emergency management is a practical subject – the assessment should be practically based – in as real an environment as can be provided – and suitably demanding. • Decisions on accreditation of senior emergency managers must ultimately be a senior line-management responsibility, whatever external advice may prove helpful.
Low score	**0**	No competence assessment scheme in place.	
Others		High but as yet un-formalised standards are applied to emergency controllers and deputies only. These undertake, with their teams, one or more days of simulation exercises as required – building up over a year or more into an ongoing assessment of performance. Some use external authorities to provide benchmarking collateral. In other cases, formal competency assessment liable to be superficial and polite system of peer review, involving external authority.	

9.8 EMERGENCY PLAN REVIEW AND TESTING

The remit for this project excluded emergency plans. A cursory assessment was included in organisation. We did however assess emergency plan review and testing.

9.8.1 Emergency plan review and testing

Table (48) Emergency plan review and testing

		Emergency plan review and testing	
	Score (%)	**Comment**	**Indicators**
High score	**100**	On-site plan is tested via a matrix of emergency exercises which reflects the range of major credible scenarios contained in the safety case. The matrix shows training requirements for all teams; across all plants and types of scenario. Testing and exercising takes place in tandem, according to a managed programme. Each shift team undertakes 12 exercises/year. Any gaps in the exercise programme are identified and corrected within the year. Emphasis on short, sharp exercises, building competence of teams up to large exercises with broad involvement.	• Emergency plan is made up of many discrete units, which can be exercised separately or combined into bigger exercises. Some elements, like testing communication channels, can be tested 'off-line'. • Each exercise should have a small number of discrete objectives, which build, through the exercise programme, into a comprehensive test of all the basic responses. For example: muster and roll-call; fire-fighting; gas cloud dispersion; casualty recovery; local evacuation. • The emergency management arrangements can only be tested in exercises of a certain scale – simulated for the management team only or involving site personnel fitting together a range of skills. The former allows concentration on emergency management arrangements and the latter on interfaces, interpretation of mandates, real-time responses. • In large exercises, a judgement on whether or not the emergency team hit their high-level objectives of saving life or controlling a fire should constitute the bottom line for a successful exercise.
Low score	**44**	Test process for management team is via slow time table-top exercises which double as training events. Tests at a practical level – eg. fire-fighting teams - are sound. The test process is pitched at a relatively inexperienced management team and is aimed at steadily improving capability. However process is not sufficiently testing to constitute a telling demonstration of capability.	
Others		Emergency plan tested via regulatory demonstration exercise. This tests every major plan element simultaneously and therefore demands a major accident scenario; does not test more realistic minor incidents. Quality of learning process heavily dependent on being able to field a large number of expert observers and scenario drivers. Some key learning points were missed.	

10 CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the report will directly refer to the remit of the research, and apply the results of our data analysis to the questions posed in the research objectives, which were;

"To develop performance indicators for the assessment of emergency preparedness in the Major Accident Hazard Industry."

The objectives of the project were to:

- **List the critical success factors of sound emergency management**
- **Define acceptable standards for emergency management training and competence demonstration**
- **Prepare a standardised methodology for use in the evaluation of both emergency exercises and emergency management training programmes.**

10.1 CRITICAL SUCCESS FACTORS OF SOUND EMERGENCY MANAGEMENT

There is a direct relationship between the strength of all the following critical success factors and either

- emergency management capability or
- performance in exercises,

Commonly there is a strong link with both. A full breakdown is provided in Section 9.1, supported by Appendix 1.

10.1.1 Senior management commitment.

Senior management commitment is demonstrated to be a strong influence on emergency performance. Without this underpinning, the whole emergency management system within a company will be fragile, insubstantial and vulnerable to adverse events.

10.1.2 Emergency philosophy

A robust emergency philosophy relates directly to emergency management capability. Topics examined were:

- Muster, shelter and evacuation.
- On-site emergency alerting.

- Relationship with emergency services, and associated on-site facilities.
- Size and structure of emergency team, including out-of-hours cover.

10.1.3 Emergency exercise regimes

- Effective regimes incorporate a proper balance of quality, scale and quantity.
- Less effective regimes tend to concentrate on occasional large demonstration exercises with inadequate foundations.

10.1.4 Emergency management structure and organisation

Inappropriate composition or balance in the team structure depresses effectiveness, for instance lack of a deputy emergency manager.

10.1.5 Command and control training, team continuity and experienced coaching in emergency exercises

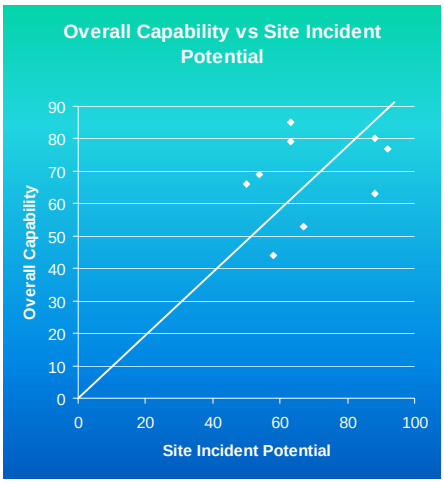
All enhance performance of the EMT in a simulated emergency.

10.1.6 Emergency management facilities

Proved important in that poor facilities depress performance. The corollary, that good facilities ensure good performance, has not been demonstrated. This leads to the conclusion that more than good facilities are required to achieve good emergency management.

10.1.7 Overall Capability vs Site Incident Potential

This diagram below shows that, in the context of emergency management, there is little relationship between the degree of challenge posed by the site and emergency management capability. A few deductions can be hazarded:



- None of the most demanding sites quite meet the necessary standard of performance set by the Site Incident Potential. All emergency arrangements demonstrate some areas of weakness that could be improved upon. The improvements would in all cases raise their capability above the line.

- It may be more straightforward for the less demanding sites to achieve an acceptable level of capability, due to the lower levels of resources, training and commitment required.

- Some sites set high standards, others are significantly under-prepared. This could be attributed to the particular company's organisational structure, background and the presence of a 'safety culture'.

10.2 DEFINITION OF ACCEPTABLE STANDARDS FOR EMERGENCY MANAGEMENT TRAINING AND COMPETENCE DEMONSTRATION

A four-level marking system was adopted for use in the majority of the EMPIRE model. Definitions for each element need to be examined in the specific context, for each of which guidance is provided. The broad criteria are as follows:

- 1 = unsatisfactory;
- 2 = below standard;
- 3.= satisfactory; and
- 4 = good.

Marks out of 100 and percentiles are used also. Generally the particular basis is self-evident and, thus armed, the EMPIRE model can be studied topic by topic from source to integrated major relationships and conclusions. Through the research and data gathering, the team compiled a set of observations made on site, which are indicators that the processes and practices leading to sound emergency management are in place. The information contained in the column 'Indicators' of tables 10 to 48 give a perspective by perspective breakdown of the observations.

10.3 STANDARDISED METHODOLOGY FOR USE IN THE EVALUATION OF BOTH EMERGENCY EXERCISES AND EMERGENCY MANAGEMENT TRAINING PROGRAMMES.

Emergency management is an individual combination of knowledge, skill, training, experience, communication and interpersonal skills, and it is difficult and indeed inappropriate to apply a singular set of rules. This study offers some heuristic guidance. The more data sets that can be added, the more secure the guidance will become. The EMPIRE model provides a framework for evaluation, and the TPRC provides a complementary approach. These elements are drawn together by substantial practical experiential advice in section 9 – the results.

The assessment approach recommended is based upon trends deriving from the 4260 points of numerical and observational data currently held within the EMPIRE study. Such a large amount of data behind the relationships we have observed and reported, gives some confidence the methodology achieves a reasonable level of accuracy, and provides sufficient information for an assessor to gauge the preparedness of a Major Accident Hazard Site.

Realistic emergency live exercises based on emergency simulations generally offer a good analogue of the reality of emergencies. Moreover, whereas computer simulations have their place as evaluative tools, only a live exercise will incorporate realistically the idiosyncrasies of human decision-making under pressure.

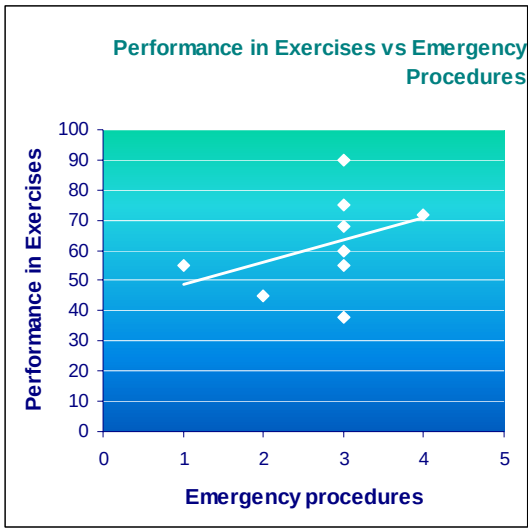
Thus analysis of live exercises is a key element of the testing of emergency plans. The crucial introductory point to make, however, is that this must not be done in isolation and at expense of other sources and indicators of overall emergency management capability. Live emergency simulation exercises used in isolation can seriously distort the overall evaluator perspective of the assessment. The reasons are explained in detail below.

In this section we advise that the assessment of emergency plans should be in three stages:

- review of documentation and policy discussions;
- site inspection of critical factors and site discussions; and
- thus-informed observation of emergency exercise, and subsequent discussions as needed.

Evidence from the EMPIRE benchmarking model suggests further that a thorough site visit can provide a reasonably accurate assessment of a site's emergency preparedness. The results of this preliminary assessment can then help focus resources and attention on sites and areas of greatest priority.

Figure (27) Performance in exercises plotted against emergency procedures



10.3.1 Documentation review - merits as an assessment tool

It was not possible to form a total view of emergency management capability from a review of emergency plans. Indeed, as shown in the diagram below, there was little correlation found between the emergency procedure scores and the scores for performance in exercises. There were several reasons for this:

- Some of the most effective emergency procedures were so succinct that there was only minimal articulation of the rationale behind them. They served the emergency team well in practice, but failed in describing the emergency philosophy. We determined the rationale through interviews with emergency preparedness managers and assessed the practicality through observing their use during an exercise;

- Detailed emergency procedures give confidence that issues have been identified and plans developed. The most detailed plans however proved to be of least use during an emergency because the team could not assimilate them. These plans gave confidence in the rationale for emergency arrangements, but bore no direct relationship to performance in exercises.

- Emergency procedures were not reviewed in detail. Such a detailed review is equally a heavy burden for a regulator. This section shows the limitations of a cursory review of procedures. There is no evidence however that a more thorough approach would have given a closer indication of performance in exercises.

10.3.2 Key indicators:

- Short and to-the-purpose emergency procedures, with a strong supporting rationale. This tends to be a hall-mark of realists, especially common amongst well-run sites that suffer quite frequent real incidents.

- Articulation of emergency philosophy, addressing all site emergency risks. Interviews to elicit this crucial element of the inventory is also a good way of establishing what vertical paths, levels and laterals of management take genuine ownership of emergency management.

10.3.3 Document review and site inspection of emergency preparedness

These key indicators notwithstanding, it was not practicable to form a comprehensive view of emergency management capability from a documentation review and discussions with the site management team alone. However it can be shown that a detailed review of emergency preparedness should give some useful pointers to an assessor, certainly enough to help pinpoint weak sites where it would be useful to observe exercises. Moreover a detailed assessment of a companies emergency preparedness before they undertake an emergency exercise can focus the simulation to issues where improvement is necessary and save unnecessary expense and effort.

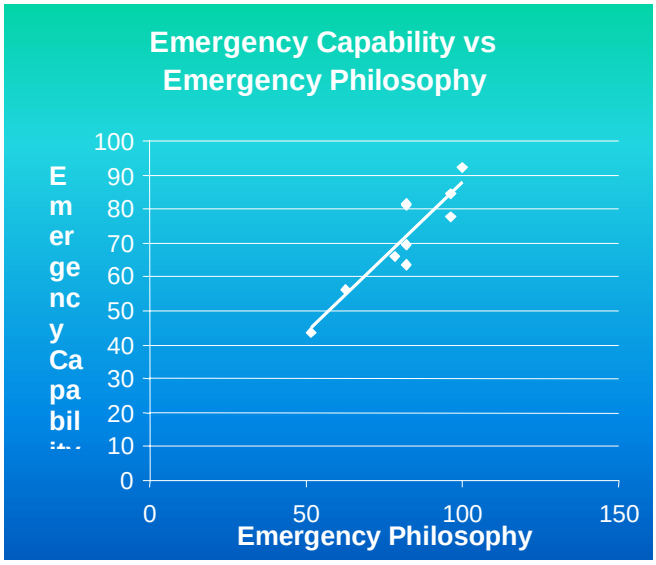
10.3.4 How good does the site need to be?

This can be deduced by studying and determining the relationship between the Site Emergency Capability and the Site Incident Potential (SIP). The key elements of this relationship form the hub of this Report.

10.3.5 How good is the emergency plan – take a strategic look

Figure 19 shows a visual data relationship between emergency capability overall and the company's emergency philosophy.

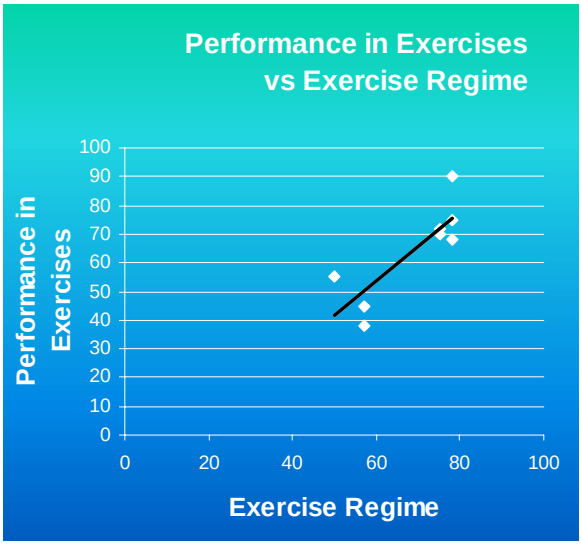
Figure (28) Relationship between emergency capability and emergency philosophy



Assess the emergency plan at a high level. Avoid too much site detail, by concentrating on the EM philosophy. EM Philosophy topics selected in this study were:

- muster, shelter and evacuation;
- emergency alerting (on-site);
- relationship with emergency services;
- size and structure of emergency team;
- on-site medical facilities;
- on-site fire-fighting; and
- out of hours cover from emergency management team.

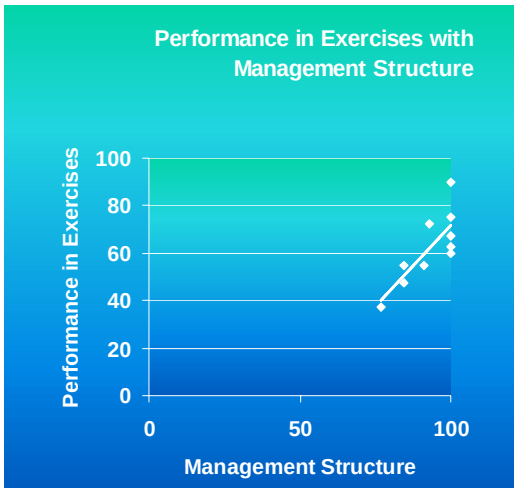
Figure (29) Performance in exercises vs exercise regime.



A key feature of the emergency plan is the emergency exercise regime. A finding from the study showed that there was a strong relationship between performance in emergency exercises and emergency exercise regime.

10.3.6 Are there enough people of the right calibre in an emergency management team?

Figure (30) **Performance in exercise with management structure**

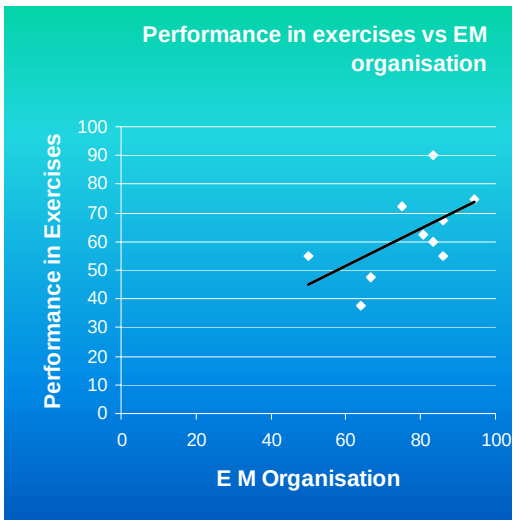


Emergency Management structure – having a good balance of people in the emergency management team, with appropriate roles appears to relate well with overall performance. Just one or two people missing or with an inappropriate role can have a significant effect on performance of the team. The roles missing were all significant members of the team, such as deputy emergency manager or information manager.

The data supporting this graph made no judgement on the calibre of persons allocated to the different roles – but obviously this will have a bearing.

10.3.7 How well is the emergency management team organised?

Figure (31) **Performance in exercises vs emergency management organisation.**

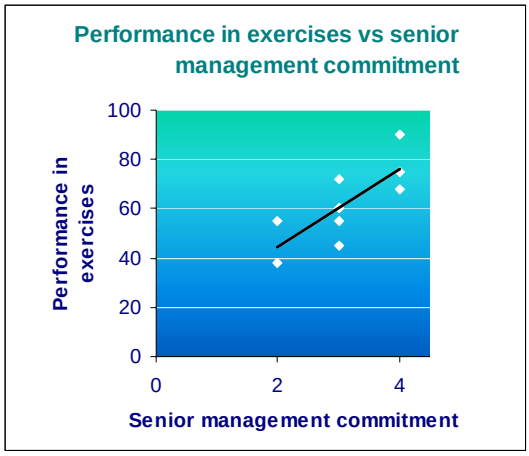


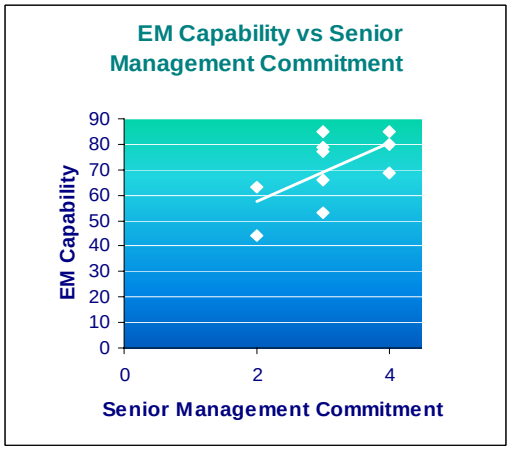
EM organisation is a mixture of organisational features, including procedures; call-out arrangements; team resources and internal mandates; mandates of command and control centres; contingency arrangements if key personnel unavailable and senior management commitment. Not all of the features scored could be expected to relate to performance in exercises, and this is indeed demonstrated in the results.

10.3.8 Importance of Senior Management Commitment

One feature, which does however correlate reasonably well, is commitment of senior management.

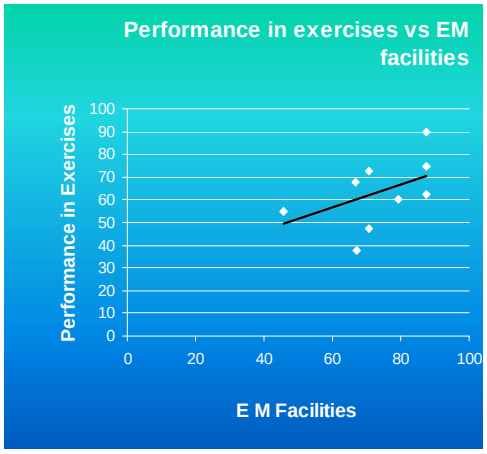
Figure (32) **Performance in exercises and emergency management capability vs senior management commitment**





10.3.9 Is the emergency management team supported by adequate facilities?

Figure (33) **Performance in exercises vs emergency management facilities**



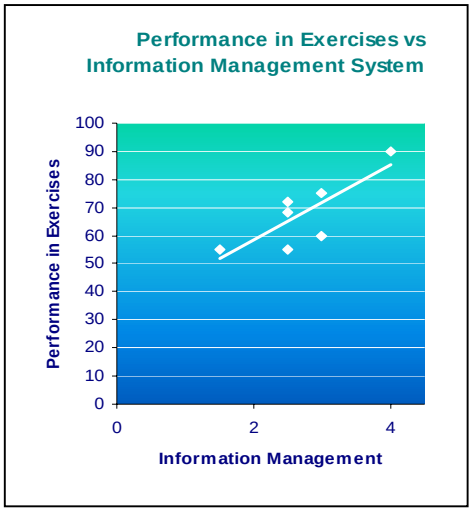
EM facilities included in the model are:

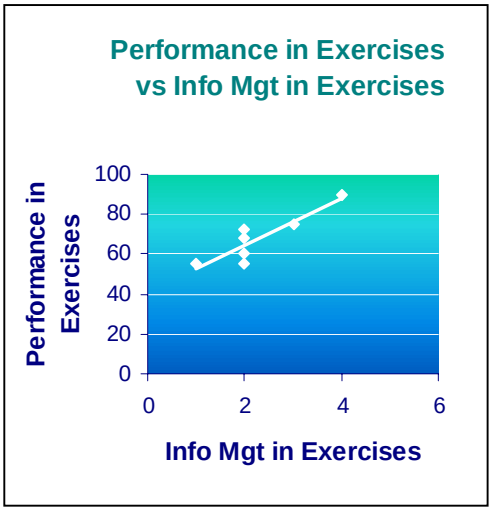
- Emergency control centre layout and provision.
- Information management facilities.
- Communications hardware.

Overall there is no visible relationship with emergency management performance. One expectation is that good performance in exercises is only possible with good facilities, and this is hinted at in the data; in that there are examples of both good and bad performance with good facilities, but no examples of good practice with poor facilities.

10.3.10 Information Management- some observations from the data.

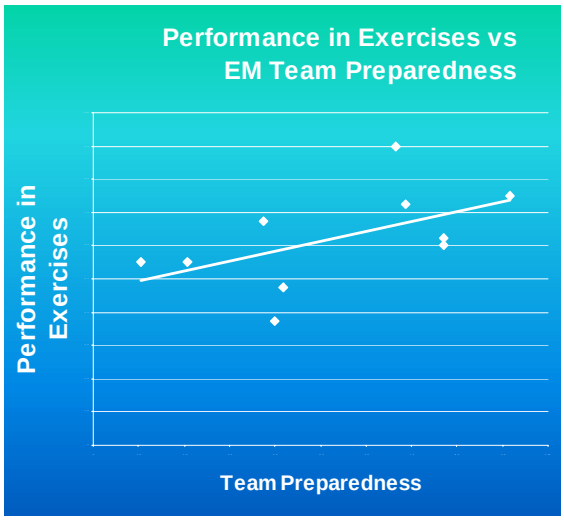
Figure (34) Performance in exercises vs information management.





Two companies did not offer exercises that used the information management techniques in the same way as the other sites. One was a tabletop exercise and the other a non site-specific exercise. Comparison of these sites with the other companies' exercise performance was therefore not valid. These two data points have been removed from the plot for this reason.

10.3.11 Is the emergency management team trained and competent?



A surprising result is the very weak visual relationship between emergency team preparedness and performance in exercises.

The constituent features of team preparedness scored in this exercise were:

- Selection process for emergency managers.
- Essential knowledge.
- Competencies defined.
- Training exercises.
- Refresher training.
- Competence assurance.

On further analysis of these scores we make a number of observations, which are summarised in table (50):

Table (49) Comments on correlation of individual team preparedness elements with performance in exercises

Topic Scored	Comment on results
Selection process for emergency managers	There is a wide variation in approach.
Essential knowledge	Would not expect this to correspond well to performance in a single exercise
Competencies defined and competence assurance	Not well established across the sample – wide range of results and no consistency of approach across sites.
Training exercises	0verall training in exercise did not relate well to the experts observations of performance in exercises on the day of the assessment.
Refresher training	Wide ranging standards across the sample

Given that we would normally expect to find a relationship here, we tested the scoring protocol against another approach. This data is not carried forward to the conclusions, and the method was carried out as a matter of interest, rather than scientific investigation. The relationships indicated by this comparison should be viewed with interest only, and not be taken as scientifically proven data. In the first scoring protocol we aimed score across a broad cross-section of preparedness features, covering the basics and also more advanced topics. In the second, we selected and then scored those features of emergency preparedness which in OCTO's professional experience, offers the greatest delineation of emergency management preparedness. The list is not intended to be comprehensive, just indicative and these scores have not been peer reviewed by the sites.

10.3.11.1 Trends of performance in exercises against emergency team preparedness

The topics selected were:

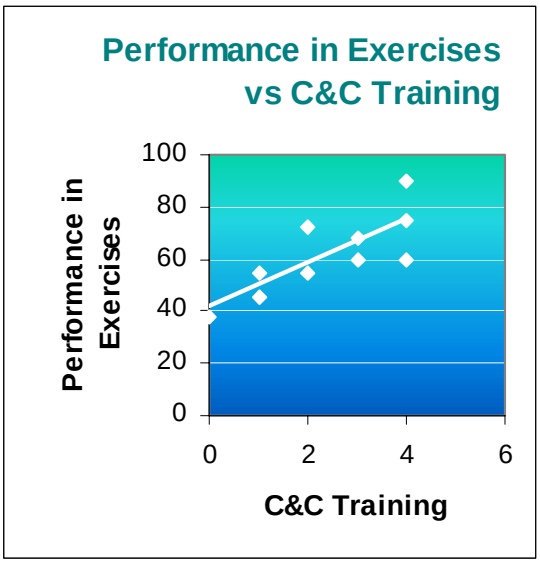
Table (50) Alternative team preparedness scoring protocol and comparison with the first.

Topic Scored in 1st protocol	OCTO suggested Topic scored in 2nd protocol	Comment on results
Selection process for emergency managers		No comparator
Essential knowledge	Command and Control training	A subset of the 1st protocol
Competencies defined and competence assurance	Competence Assurance	The same
Training exercises	Professional coaching of team in training exercises	The same
Refresher training		No comparator
	Team continuity. i.e. team members are well practised with one-another and tend to exercise together.	New topic

The trends are:

Figure (35) Performance in exercises vs command and control training

Figure (36) Performance in exercises vs team continuity



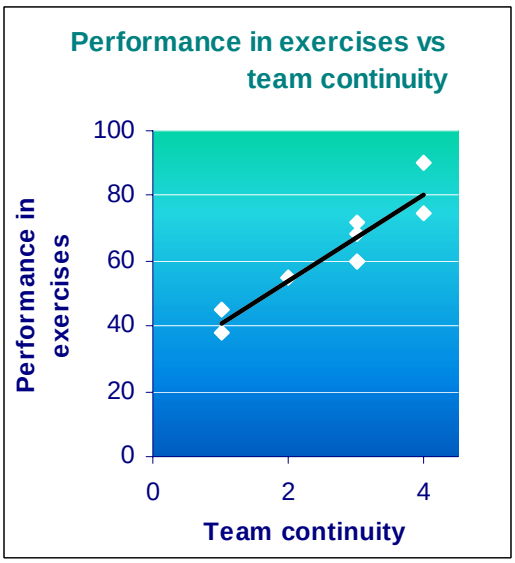
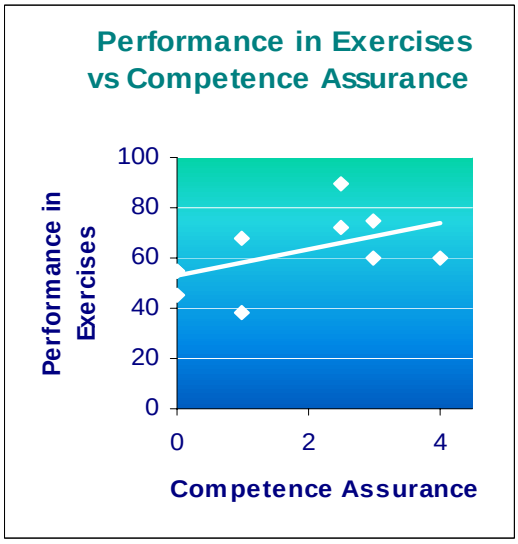
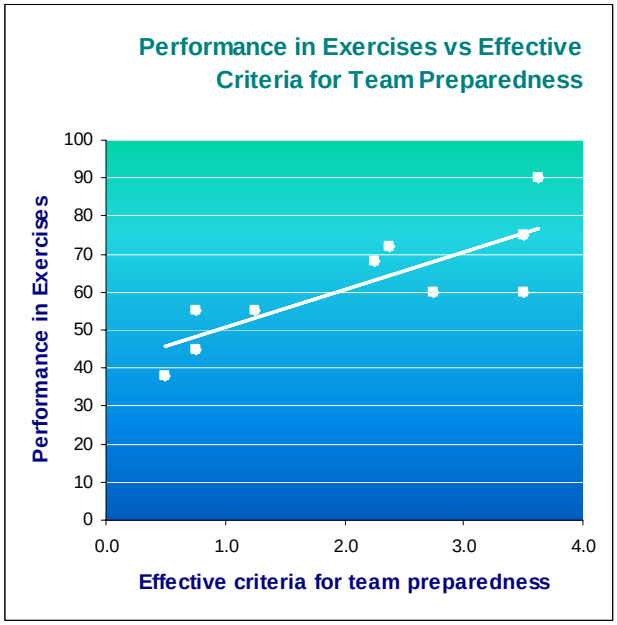


Figure (37) **Performance in exercises vs coaching in exercises**
Figure (38) **Performance in exercises vs competence assurance**



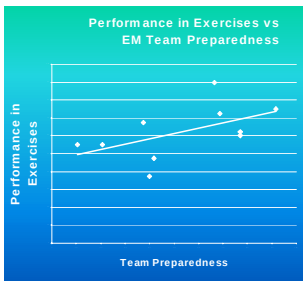
Overall relationship becomes:

Figure (39) **Performance in exercises vs effective criteria for team preparedness**



One of the outlying plots can be explained in that one well-prepared company fielded an inexperienced team for the exercise. There is no justification however for removing that data-point, since such variations in company performance must be expected, and would be possible in a real incident.

Cf.



10.3.12 Key principles

Examples of all the practices below were shown to good effect in the benchmark study.

Table (51) Key principles for assessing emergency exercises

Principle	Comment
1. Combine emergency training and testing so far as possible.	Keep records of all emergency training; and show how (most) training exercises contribute to an overall demonstration of capability.
2. Test the practical basics independently – fire-fighting; muster and roll-call; evacuation; plant shutdown; gas cloud dispersion; etc. once these are mastered, can integrate them into more expansive tests. For more examples – see Appendix 3, Section 3.7 on review and test emergency exercises.	Otherwise, the complex, expensive, all-embracing test will only demonstrate those failings, which could be recognised much more cheaply. An ideal way to achieve basic integration with the emergency services – their objectives at the practical level are site familiarity; equipment compatibility; practical interfaces. These can as readily be tested in small exercises as large. A reciprocal opportunity for the emergency services to train in a practical chemical environment. See (3.) for testing other external services links.
3. Table-top emergency procedures. Can be used to: • Familiarise managers with procedures and technical information; • Explore interface issues; command and control structure; • Refine and improve emergency procedures; • Exercise management decision-making in slow time and discuss issues – e.g. fire-fighting strategy, gas cloud control.	If table-tops are showing up many shortcomings, a large scale exercise is unlikely to be more productive. Table-top exercises will not in themselves constitute an adequate demonstration of emergency management capability , so once capability is consolidated at this level – need to move on. An ideal medium for exercising strategic links with external services – site fire-fighting strategy; casualty handling procedures, etc.
4. Full, real-time simulation exercises. Can be used to: • Train emergency management teams to a high level of competence; competence assessment; • Train and demonstrate real-time management decision-making; • Train and demonstrate real-time information management; • Exercise selective communication links and links with external bodies; • Refine team composition and command and control structure.	Much of this agenda can be achieved by exercising one command centre at a time using telephone and other communications injects against a prepared but reactive script. Major exercises involving several centres/levels need to be exceedingly well-prepared rarities. They will normally be more useful for testing and improving interfaces and demonstrating these than in providing intensive training for and testing of individual centres. Need to exercise with a cross-section of realistic safety-case emergency scenarios – some less demanding and some at the worst case. Where team continuity is achievable, exercise teams together for maximum training benefit and standard of performance.

Principle	Comment
5. Set training and / or demonstration objectives/questions for every exercise. These can include: • Did procedures work – i.e. did they serve the overarching purpose of saving life and mitigating consequences?; • Did team manage the emergency effectively?; • TPRC assessment (see Section 8.2 and Appendix 2); • Did exercise develop better understanding and links between site and external agencies?; • Did exercise test team structure and adequacy and use of emergency facilities?	Exercises, to be of value, should be demanding; conduct an assessment in the spirit that failure of some elements is expected – otherwise it was not a realistic test. Most important is that the emergency team can cope with things going wrong and still steer the emergency towards a successful outcome – i.e. lives are saved; consequences to public and environment are mitigated.
6. Full site exercise – exercising all site players. More emphasis here on demonstration and practice rather than concentrated training. Objectives include: • Testing interfaces – site emergency management team; local plant emergency response team; incident control; fire brigade; ambulance; etc. Interfaces that would not normally have a presence on-site can readily be simulated; • Identify potential problems of co-ordination.	The final essential demonstration of emergency preparedness. For maximum cost effectiveness, undertake only when a good standard is reached in less comprehensive exercises. If this approach is adopted, can then use all the smaller exercises as demonstrations of the essential elements. The large exercise need only be held periodically – to demonstrate that the parts do come together into a coherent whole. Once muster and roll-call is complete, most people can be stood down – unless evacuation (probably a major issue) is to be exercised realistically.
7. Review each exercise thoroughly. Include: • Did exercise meet objectives, - if not, what can be learned?; • Procedures / reference information – where do they need revision?; • Hardware / emergency management facilities– what needs to be modified / adjusted? - anything new required?; • Training – who needs more in what?; • Assess how team performed- both within and outside procedural envelope; • Incorporate TPRC assessment - was life saved; were consequences mitigated?; are TPRC results consistent with expert observation?	Welcome all failures as valuable learning points – encourage them to come forward. Identify actions to address all shortcomings and track their progress to completion and close-out. DON'T: • Assess exercise in terms of "were procedures followed?". The final criteria must be outcomes. Emergency procedures are important, but are not the last word in emergency response. DO: • Recognise in the review that emergencies move outside the procedural envelope. • Examine quality of the in-house review – the more searching, the more competent is the management team.

10.3.13 Assessing performance of emergency management team

The features of emergency management team performance that were assessed in each exercise:

- Evidence of senior management commitment – resources, time & involvement
- Mandate – firm, documented, understood and interlinking
- Qualities of emergency controller – leadership and decision-making
- Qualities of deputy emergency controller – leadership and support
- Information management function – integrated, secure and reliable
- Team performance – cohesive, supportive and interactive
- Adequacy and effective use of resources – are they there, good quality and used?
- Adequacy and effective use of facilities during exercise – are they there, good quality & used?
- Intra- and extra-procedural envelope – exercises what they know, or takes them beyond
- Quality of scenario – planned, resourced, realistic, debriefed & learned from?

Each item was judged against the specifics of the exercise scenario – using the guidance in Section 8.3. Results can be seen in Section 9.

Further details of the EMPIRE system, TPRC model and the techniques used in Emergency Exercise observation and assessment are available from OCTO Ltd.

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12 APPENDIX 1 – EMPIRE IN DETAIL

12.1 FRAMEWORK FOR THE ASSESSMENT OF EMERGENCY STRATEGY

The framework includes a method of assessing the EMg strategy. These are seen through three matrices, the ***Risk Potential Matrix*** (P-matrix – Figure (40) and the emergency ***Risk Management Capability Matrix*** (C-matrix – Figure (41)) and the ***EMg Competence Matrix*** (E-matrix- figure (42)). The aim is to provide a means of linking the site incident potential and emergency management strategy through six key Emergency Risk Management Goals.

1 Initiate rapid response.
2 Control Incident and prevent escalation.
3 Facilitate Evacuation, escape and rescue from danger.
4 Protect life (timely medical help).
5 Protect the environment.
6 Protect assets.

12.1.1 Risk Potential

The risk potential is found by imposing weightings (with expert guidance from OCTO Emergency Management consultants) which measure the impact of site Incident potential on the 6 risk management goals (Figure(40).

In the model, high-level risk management goals are represented as the rows of the P, C and E matrices. The columns of the P-matrix are the indicators under the site incident potential (see section 8). The cells of the P matrix are populated with the assessors weightings which represent the assessors assessment of the **impact** of site incident potential (P-matrix weights).

Figure (40) **Risk potential matrix or P-Matrix**

Risk Potential Matrix

Incident Risk Management Goals	Overall Average	Inventory MAH materials	Complex technology in scenario	Site Pop. density - WCS	MAH diversity under same EMT	Speed of scenarion devt.	Offsite risk
Incident Risk Management Goals	**67**	**50**	**50**	**100**	**50**	**75**	**75**
Initiate Rapid Response		0	1	0	0	2	0
Control Incident/reduce escalation		2	1	0	1	2	0
Facilitate Evacuation Escape and Rescue		2	0	2	0	2	0
Protect life - beyond EER		0	0	2	0	0	2
Protect environment		2	0	0	0	2	2
Protect Assets		**2**	0	0	0	2	0

12.1.2 Risk Management Capability

The rows of the C-matrix are, again, the 6 management goals. The columns of the C-matrix are the Emergency Management strategy perspectives figure (41). The six emergency management strategy perspectives shown figure (41) are described in detail in sections 11.4 – 11.9. The overall figure for EMg risk management performance and its distribution over the risk management goals can be seen in the last column (far right) of figure (41).

Figure (41) **Risk management capability or C-Matrix**

Emergency Risk Management Capability Matrix

Incident Risk Management Goals	Overall philosophy balance	Management structure	Organisation	Facilities	Preparedness	Planning	Overall E-M Performance
Incident Risk Management Goals	**82**	**100**	**81**	**79**	**75**	**69**	**81**
Initiate Rapid Response	2.4	1.0	2.3	2.0	1.0	4.0	78
Control Incident/reduce escalation	3.0	4.0	3.0	3.8	4.0	3.0	81
Facilitate EER	3.3	4.0	3.3	3.5	4.0	3.0	82
Protect life - beyond EER	3.0	4.0	2.2	2.5	2.0	3.0	83
Protect environment	2.3	4.0	2.6	3.5	4.0	2.0	82
Protect Assets	2.7	4.0	2.6	3.5	4.0	2.0	82

The overall EMg Performance metrics (end column right) are calculated using the following measure

EMg Performance in risk goal j is given by $E\_MPerf(j) = \frac{\sum_i w_{ij} S_i}{100 \sum_i w_{ij}}$

In the case of the Risk management capability matrix the weights are calculated from a more detailed matrix, which extends across all the indicators in all perspectives.

For example, the overall philosophy balance perspective (1st column of matrix in figure (41)) is calculated from the matrix in figure (42) by averaging the weights along each row with the result shown in the far right column of figure (42). The headline score of 82 for overall philosophy balance in figure (40) is the arithmetic mean of (88,100,50,100,63,88,88). Thus the end column of weights in figure (42) is the same as the first column of weights in figure (41) the other columns figure (41) are likewise calculated. For example the detailed facilities matrix is shown in figure 43).

Figure (42) Detailed philosophy matrix

Emergency Risk Management Capability Matrix

	Philosophy							
	Muster, shelter, evac. & roll-call	Emergency Alerting systems	Relation with emergency services	EMT size & struct.- year round cover	On site medical treatment capability	On-site fire fighting capability	Out of hours response from EMT	
Incident Risk Management Goals	**88**	**100**	**50**	**100**	**63**	**88**	**88**	
Initiate Rapid Response	3	4	1	3	1	4	1	2.43
Control Incident/reduce escalation	1	3	4	4	1	4	4	3
Facilitate EER	4	4	4	4	1	4	2	3.29
Protect life - beyond EER	1	1	4	3	4	4	4	3
Protect environment	1	1	3	3	1	3	4	2.29
Protect Assets	1	1	4	4	1	4	4	2.71

Figure (43) Detailed facilities matrix

Emergency Risk Management Capability Matrix

	Facilities						
	Setting up EMT	Layout of ECC	Backup for ECC	Info Mgt. & Display in ECC	Info Mgt. & Display on-scene	Comms. Range, Sec'ty & Redundancy	
Incident Risk	**100**	**100**	**50**	**100**	**25**	**100**	
Initiate Rapid Response	**1**	**1**	**1**	1	4	4	2
Control Incident/reduce escalation	**4**	3	4	4	4	4	3.8
Facilitate EER	**2**	3	4	4	4	4	3.5
Protect life - beyond EER	**2**	1	2	2	4	4	2.5
Protect environment	**2**	3	4	4	4	4	3.5
Protect Assets	**2**	3	4	4	4	4	3.5

Note that the weights at the detailed indicator level are scored between 1 - 4 and represent the assessors estimate of the impact of the indicator on the risk management goal.

In general terms: w_{ij} = **Impact of** [indicator j] **on** [Risk Goal i]

The reason for generating weights at the detailed level is for ease of scoring by the assessor. In practice it has been found to be easier to generate a weight at individual indicator level than at the perspective level.

12.1.3 Emergency Management Competence

This metric has been developed to assess how well emergency management are matched to the site incident potential for each of the six risk management goals

The Emergency Management Competence is defined as follows:-

Competence for risk goal j = E-M score for risk goal j ÷ SIP score for risk goal j

These are represented by the three columns in figure (36). Column 1 (left) is the SIP score for each risk goal, column 2 is the EMg score for each risk goal and column 3 (right) is the competence for each risk goal.

The EMg scores and SIP scores are defined as

EMg Score for risk goal j = distribution of EMg for risk goal j x EMg headline

and

SIP score for risk goal j = distribution of SIP for risk goal j x SIP headline score

$$\text{Where distribution of E\_M for risk goal j} = \frac{\sum_i w_{ij} S_j}{\sum_i \sum_j w_{ij} S_j}$$

$$\text{and distribution of SIP for risk goal j} = \frac{\sum_i w_{ij} S_j}{\sum_i \sum_j w_{ij} S_j}$$

The sum of the distributions is 100% and so the sum of the distribution x headline score returns the headline score (bottom value of the columns).

Figure (44) E-M Competence Matrix

E-M Competence Matrix

Incident Risk Management Goals	SIP	E-M	Competence
Incident Risk Management Goals	**67**	**79**	**1.19**
Initiate Rapid Response	7	9	**1.4**
Control Incident/reduce escalation	12	16	**1.3**
Facilitate EER	15	16	**1.1**
Protect life - beyond EER	12	11	**1.0**
Protect environment	13	13	**1.0**
Protect Assets	8	14	**1.7**
	67	79	**1.19**

A value of 1 or greater for each risk goal means that the company has matched the E-M strategy to the site incident potential for each goal. For the case shown the company is competent in all categories and is competent overall, (overall_competence=1.19). It is possible for a given company to demonstrate a competency values less than 1 for a given risk goal, while maintaining an overall competence greater than 1.

12.2 DESCRIPTION OF THE INDICATORS

The indicators, described below, have been grouped into 7 perspectives, as illustrated in Fig.1 of the main report.

Table (52) Emergency Management Indicators

P	Perspective	Category	Interpretation
0	Site Incident Potential	Potential	The scale of Major Hazard Incidents - as measured by level of difficulty in responding - that must be managed
1	E-M Philosophy	Products	How management has prepared itself for major hazards
2	Management Structure		
3	Infrastructure and Facilities		
4	Performance in Exercises		
5	Planning	Process	
6	Team Preparedness	Preparedness	

We regard perspectives 1 to 4 as outputs or products of planning and preparedness as shown in fig.1 of the main report. A good overall performance must include a balance of each of these perspectives with good planning and preparedness underpinning the four products.

Perspective 5 refers to emergency planning. The score in this category is based a combination of documentation and discussions with the company. The indicator the quality of the process used by the organisation to document its requirements and plans. The development of detailed indicators under the planning category was outside the scope of the report, but could be accommodated by the framework if required in the future.

Category 6 refers to the degree of preparedness. This perspective measures such issues as education, training as well as feedback and learning from exercises and real incidents.

12.2.1 Perspective 0: Site Incident Potential

Under this perspective, the main risks inherent in the emergency scenarios have been identified. The identification of hazards is a relatively well understood, straightforward process using such techniques as HAZOPS, QRA, etc. But an additional element is to identify accurately the envelope of emergency scenarios.

The SIP score is a qualitative measure of the health and safety risk to which the company is exposed and can be assessed by the metrics listed below. To some extent

the indicators are exploratory. Part of the research has been to identify what (if any) elements actually dominate the emergency response arrangements.

Table (53) Site Incident Potential Indicator with example scores

	Site Incident Potential Indicators	**S_m**	**S**	**S/S_m%**
1	Number of Hazards on site			**4**
2	Size of Inventory in major hazard scenarios	4	2	50
3	Complexity of technology affecting E-M	4	2	50
4	Site Population density – worst case	4	4	100
5	Diversity of hazards under same management	4	2	50
6	Speed of scenario development	4	3	75
7	Level of off-site risk	4	3	75

Scoring of SIP indicators is in the range (1, 2, 3,4). This is converted to a % value by dividing the score for the site by the maximum allowable score of 4 in this case, so that a rating of 2 translates to a score of 50%.

Table (54) Score rationale for SIP:

Score	**Interpretation**
1	Relatively straightforward demand is placed on the emergency organisation / emergency management team
2	More challenging – but not beyond a modestly provisioned organisation and modest site capability
3	Demanding challenge for emergency management team
4	A severe challenge for the emergency management team

There is a clear link between these indicators and risk. There is also a degree of overlap between some of the indicators.

12.2.2 Perspective 1: E-M Philosophy

Figure (45) E-M Philosophy Indicators with example scores

		M	Q	A	Tot	P2	P3	Tot
1	Muster shelter and evacuation of personnel	1	3	4	88	3	4	88
2	Emergency Alerting systems	1	4	4	100	4	4	100
3	Relation with emergency services	1	2	2	50	3	2	56
4	Size and structure of EM team as yr. round cover	1	4	4	100	4	4	100
5	On site medical treatment capability	1	3	2	63	3	2	63
6	On-site Fire fighting capability	1	3	4	88	4	4	94
7	Out of hours response from E-M team	1	3	4	88	3	3	81
		Score			**82**	**Overall**		**83**

Seven E-M strategy indicators have been identified. In developing a score for this the Scoring rule adopted is S = M.(A+Q+P+L)

The activity or physical provision is successful if

M Activity was actually carried out
Q Deliverables were good quality
A Activity goals were aligned to overall strategy
P The process was acceptable
L Company was fully prepared for the activity

P and L have been scored separately.

12.2.3 Perspective 2: Emergency Management Structure

Figure (46) Management Structure Indicator with example scoring

i		X	Y	S
1	Emergency Controller	1	1	1
2	Deputy Emergency Controller	1	1	1
3	Information manager	1	1	1
4	On-scene Liaison	1	1	1
5	External Communications	1	1	1
6	Personnel Accounting	1	1	1
7	Communications Officer	1	1	1
8	PR Liaison	1	1	1
9	Logger	1	1	1
10	On-scene incident controller	1	1	1
11	Fire team Leader	1	1	1
12	Medical Officer	1	1	1
13	Other in on-scene team	1	1	1
14	Technical Specialists	1	1	1
	INTEGRITY (%)	**100**		

The role list can be regarded as a good practice (for sites that fall under COMAH regulations). The assessor checks the actual roles provided by the company against this list for role provision and necessity. In appropriate circumstances one person can hold more than one role in the team.

12.2.4 X_i is the role provision indicator interpreted and can take values X=1 when provided and Y=0 when not provided. Y_i is the necessity indicator for E-M role i and can also take values of 0 or 1.

The role scores if it is both "provided and necessary" i.e. Si = Xi . Yi

The overall integrity score is an arithmetic mean calculated as

$$\text{Integrity} = 100.\ \text{SUM}(Si) / N_i$$

12.2.5 Where N_i = 14 is the number of necessary role players during an emergency. The role "other in emergency team" is not considered necessary and so has been removed from this table.

12.2.6 Perspective 3: Organisation and Facilities

Figure (47) Organisation and Facilities Indicator with example scores

ORGANISATION / FACILITIES	A	U	U_m	S%
1 Emergency procedures - content presentation and layout	1	3	4	75
2 Call out arrangements	1	4	4	100
3 Setting up emergency team	1	4	4	100
4 EM Organisation resources	1	4	4	100
5 Mandate for Decision making within em mgt. Team	1	3	4	75
6 Relationship between members of EM team	1	4	4	100
7 Contingency arrangements if key personnel not available	1	3	4	75
8 Mandate for Decision making at on-scene Command	1	2	4	50
9 Mandates for muster checkers	1	3	4	75
10 Layout of emergency control centre	1	4	4	100
11 Backup for emergency control centre	1	2	4	50
12 Information Management and Display in ECC	1	4	4	100
13 Information Management and Display on-scene	1	1	4	25
14 Range security and redundancy of communications	1	4	4	100
15 Evidence of senior management commitment	1	3	4	75
UTILITY	**80**			

Organisation and facilities have been considered as separate perspectives. Facilities are represented by indicators 3, 10, 11,12,13,14. Organisation is represented by indicators 1,2,4,5,6,7,8,9,15.

The Scoring protocol is as follows.

The Score for Indicator i is given by: $S_i = 100.A_i.U_i / U_{im}$ %

Where A is the availability of the element (A = 1 when available and A=0 when not available). U is the usability of the element given that it is available and can take a range of values from 1 to 4. U_m is the maximum usability score.

Thus for element 11 the score is S_{11} = 100x1x2/4 = 50%. This indicates that a back up emergency control centre exists but has fewer facilities.

The list of indicators can be regarded as a good practice checklist. Any element not present or unavailable due, for instance, to disrepair, scores zero (A=0) for that element.

The overall score for the site facilities is an arithmetic mean of the scores calculated as Utility = $SUM(S_i) / N_{fi}$, where N_{fi} =15 is the total number of facility indicator elements.

12.2.7 Perspective 4: Performance in exercises

The performance of an exercise is the best available analogue of reality outside of an incident and is the only realistic safe method of demonstrating and developing emergency management capability. This score is therefore of primary importance.

There was no use of virtual reality media for testing, just different types of practical emergency exercise.

Figure (48) Performance in Exercises Indicator with example scores

		M	**Q**	**Q_m**	**P_E%**
1	Performance of emergency manager	1	2	4	50
2	Performance of deputy if present	1	2	4	50
3	Functionality of information management System	1	2	4	50
4	Team performance	1	2	4	50
5	Effectiveness of mandates	1	2	4	50
6	Quality of Scenario	1	4	4	100
7	Procedural envelope	1	2	4	50
8	Review and learning process	1	3	4	75
9	Adequate and effective use of resources during exercises	1	2	4	50
10	Adequate and effective use of facilities during exercises	1	3	4	75
	Qualitative PE Score	**60**	%		

The scoring of this indicator is based on an existence measure (M) and a quality measure Q. The quality measure is normalised with Q_m the maximum score for a given indicator. The performance score for a given indicator in this category is

$$P_{Ei} = 100. M_i. [Q_i / Q_{iM}]$$

The overall PE score is generated as

$$PE = SUM\ P_{Ei} / N_i$$

12.2.8 Perspective 5: Planning

Although emergency planning involves a large number of activities, it was agreed that these would not be covered in detail for this study. For completeness, however, two areas, preparation of on site plan and review and testing were considered important and included in the bench marking exercise.

Figure (49) Planning score matrix

	M	P1	S	prod	P2	P3	Tot
Prepare On site Emergency Plan	1	3	3	75	3	3	75
Review and testing of EM plans	1	2	3	63	4	3	75
		Score		**69**	**Overall**		**75**

The scoring protocol involved asking several key questions as follows. "Have the plans been carried out? (yes=1, no=0). How well have they been carried out? (P1= 1,2,3,4) and how well have they been aligned to regulatory and stake holder requirements? (S= 1,2,3,4). The score of 69% represents an average of the two indicator scores

The two further questions relate to process of planning and the preparedness (competency) to plan

12.2.9 Perspective 6 - Team Preparedness

Six key performance indicators have been identified for the preparedness perspective. These are shown in the table below. The team preparedness score involves identification of essential knowledge required for a given role and the competency required of each role. Another important measure is the requirement for training and refresher training. The fifth measure is how competence has been assessed and the selection process for emergency managers.

Figure (50) Team preparedness

	M	P1	S	prod	P2	P3	Tot
Identify essential knowledge required for each role	1	1	1	25	1	1	25
Define EM competencies for each role	1	3	3	75	3	3	75
Define requirements for training exercises	1	4	4	100	3	3	88
Define requirements for refresher training	1	2	2	50	2	2	50
Assess competence	1	4	4	100	4	4	100
Selection Process for Emergency Managers	1	4	4	100	4	4	100
			score	**75.0**	**Overall**		**72.9**

The scoring protocol involves testing whether the 6 preparedness tasks have been carried out (yes=1 , no=0) , how well they have been carried out (1-4) and how well they are aligned to regulatory requirements (1-4). For the example shown the Score sums to 75%. Two further parameters, P2 (1,2,3,4) and P3 (1,2,3,4), refer to the company's management processes and competence to prepare for emergencies. Only the outcome scores (M,P1 and S) were carried forward to the risk management capability matrix shown in figure (41).

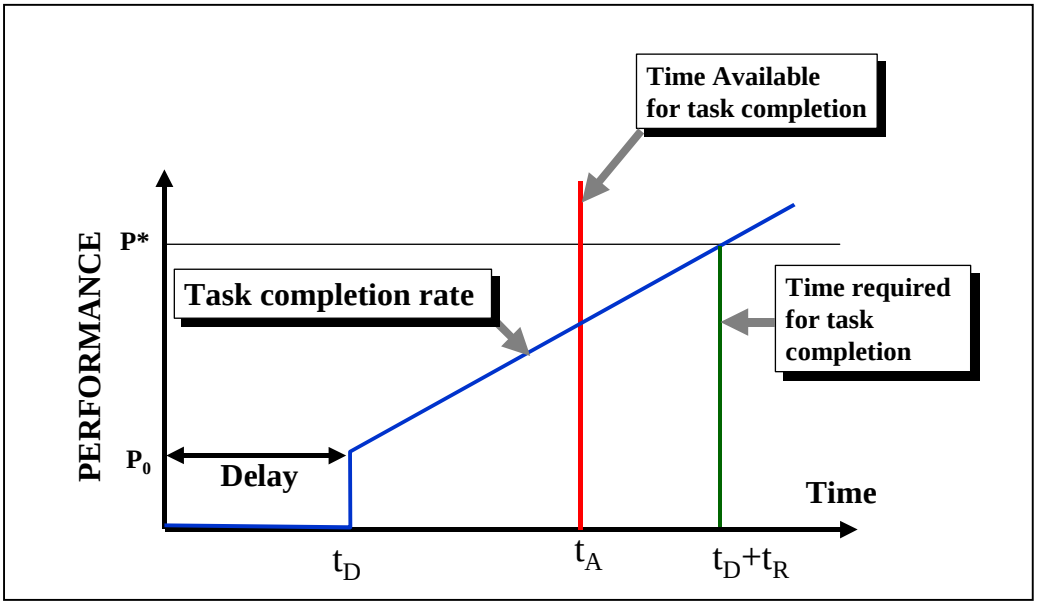
13 APPENDIX 2 – THE TPRC MODEL

The Task performance Resource constraint model or TPRC is an alternative method of assessing the performance in exercises. A deterministic model, described in section 6.1, below has been developed. A probabilistic model has also been developed in previous research funded by EPSRC and Octo. The probabilistic model is considered too detailed for application in this study. The deterministic model is simpler to apply and has been used to assess the emergency management exercises viewed as part of the project. These are described in Section 6.2

13.1 DESCRIPTION OF THE TPRC MODEL

Emergency management in exercises can be viewed as a set of time and resource limited tasks performed by the team in managing an emergency incident. Each task has a goal or objective, a start, duration and end, plus one or more resources (including time itself) to support the task. The nature and amount of work to be carried out, the work rate and the time and resources available and their rate of consumption are key factors, which can be related to the overall performance.

Figure (51) Task Performance Resource Constraint Model Time Required



In the model, a distinction is drawn between the time required to complete a task, given the particular conditions, (related to the nature of the task), and the time available to complete a task. The latter will, in general, be limited by time or some

other resource. These points are explained below and illustrated in Fig46 for the simple case of a single task.

The nature of the task determines the amount of work necessary to complete the task. The required task duration depends both on the total amount of work required to achieve the task objective and the work rate or the rate of progress towards successful task completion. For simple routine tasks, with well-defined procedures, in which there is little or no special learning required e.g. a person moving from position A to position B as in a mustering task. There will be little uncertainty in the time needed to undertake such tasks. In this simple case P* is the distance to be travelled and the task completion rate is the speed of personnel movement. These are (or should be) well defined in emergency management plans

At the other extreme, a problem-solving task may be very complex, poorly defined, with no procedures or prior experience and a significant learning process to achieve the task objective. In this case there is likely to be a great deal of uncertainty both on how much work is required to achieve the objectives and on the rate of progress.

Examples of tasks in this category are emergency management tasks, which involve diagnosis of a complex problem. The task requirement, P*, in problem solving tasks can be equated to the level of information required and the task completion rate to information gathering and knowledge accumulation rate.

13.1.1 Time Available

The time available to complete emergency management tasks will be dominated by the speed of scenario development or rate of escalation. If the task completion rate is insufficient, i.e. time required is greater than time available, then there will either be a short fall in the required performance or late completion of the task. These two modes of failure may result in very different consequences depending on the context.

A delay in the initiation of a task has a significant effect on the likelihood of successfully completing a task within the time available. The greater the delay, the greater the risk of a shortfall in performance or late completion. Hence the importance of a timely response.

The performance measure is calculated as a normalised performance ratio P / P* given by:-

$$\frac{P}{P*} = \frac{P_0}{P*} + \varepsilon\left\{1 - \frac{P_0}{P*}\right\}\left\{\left[\frac{t_A - t_D}{t_R}\right]\right\} \qquad (1)$$

Where $P_0/P*$ is the normalised prior knowledge of a particular emergency management task. The time available to perform the task is t_A. The time t_D is the delay to the start of the task, t_R is the time required to perform the task and ε is the

competency of the person performing the task. When the person is fully competent $\varepsilon = 1$.

Equation (1) can be extended to represent a sequence of subtasks, (i), related to an overall task or activity as shown in equation (2). This equation also includes a competency factor $\Sigma\varepsilon_{ij}$ this is the summation of competency factors for the each person (j of them) involved in task(i). Factor $\Sigma\varepsilon_{ij}$ is taken as 1 for an acceptably competent person / team and so the required time for task i, t_{ri}, is interpreted as the time required for a competent person to perform the task. This is a judgement made by the assessment team. The term $\Sigma\varepsilon_{ij}$ has values less than 1 when the persons are judged to be less than fully competent.

$$\frac{P_i}{P_i^*} = \frac{P_{io}}{P_i^*} + \left\{\left[1 - \frac{P_{io}}{P_i^*}\right] . \sum_{j=1}^{N} \varepsilon_{ij}\right\}\left[\frac{t_{ai} - t_{di}}{t_{ri}}\right] \qquad (2)$$

For each subtask (i), the normalised score P_i / P^*_i is summed in proportion to the amount of work in each subtask so that the overall performance at time t is given by:

$$Y(t) = \sum_{i=1}^{M} x_i . \frac{P_i}{P_i^*} \qquad (3)$$

The TPRC model parameters then are as shown below.

Table (55) TPRC model Parameters

x_i	Proportion of work in subtask i to overall task
P_{oi}	Prior knowledge for subtask i
t_{ai}	Time allowed for task i to be completed
t_{ri}	Time required for the task i completion
t_{di}	Delay time for subtask I
ε_{ij}	Competency matrix (task i, person j)
N_i	Number of persons working on task I
M	Total number of tasks

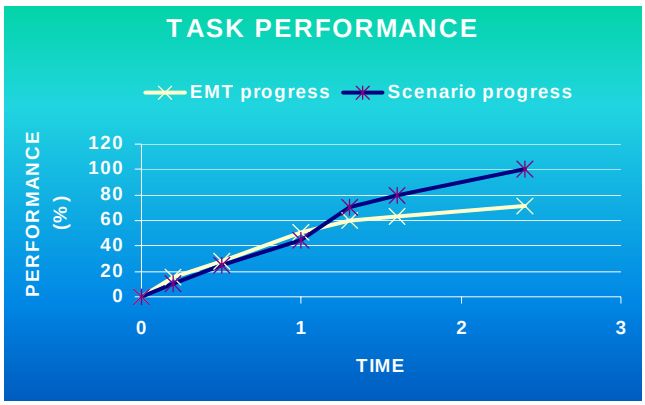
A typical example of data used in the TPRC model is shown in the table below. The competency matrix is represented by the last four columns of the table. Rows represent tasks and columns the persons involved in the task. The population of the competency matrix requires a competency assessment to be made at the time of the exercise for each person involved in a particular task.

Table (56) **TPRC data sheet**

						Competence Matrix			
T(i)	x_I	P_{oi}	t_{ai}	t_{ri}	t_{di}		1	2	N_j
1	15	0%	0.5	0.7	0.7	**1**	1		1
2	10	0%	2	1.6	0.5	**2**	1		1
3	15	0%	0.8	1.8	0.2	**3**	0.7	0.8	2
4	30	50%	1.5	2	0.5	**4**	1		1
5	10	30%	1.8	2	0.7	**5**	1	1	2
6	20	50%	1.7	1.8	0.2	**6**	1	0.7	2

Person 1 in task 1 is judged to be competent. Persons 1 and 2 in task 3 are judged to be less than competent. An example plot using the data in the above table is shown in Fig. 47.

Figure (52) **Example TPRC result**



The plot shows the first task as negative because the time available is less than the time required. Thereafter the performance is positive and finally achieves a value of about 70%. The required performance plot is simply.

$$Y_{req}(t) = \sum_{i=1}^{M} x_i \qquad (4)$$

Equation 4 is the same as equation 3 with the performance ratio P/P^* set to 1 for each task.

13.1.2 Scoring the Task Prior Knowledge Section

Each task is given a percentage score, relating the level to which the task has been completed prior to the incident. This is defined as prior knowledge, but also applies to non-knowledge accumulation tasks, ad refers to the level of preparedness or proceduralisation of the task.

There is reluctance attached to assigning any task 0% prior knowledge, as this indicates that the installation has no pre-conception that this task might be required in an emergency. There are some tasks that have such a remote chance of occurring that they are not considered as viable incidents for planning purposes, but they may well be briefly mentioned in the documentation. If it has been mentioned or considered previously, then there is a small amount of prior knowledge. Similarly, there should be no circumstance of a task being awarded 100% prior knowledge, as this indicated that the task has already been completed prior to the incident. After consideration, the maximum of 60% prior knowledge has been defined. If more than 60% of a task has been completed before the incident, then it is defined as preparedness or mitigation measure, rather than an emergency management activity. To maximise the potential of this model as a generic base, scores have been attached to different levels of prior completion.

Each task is assigned a score from the following table, based on observation of the exercise and prior interview and research on the installation concerned.

Table (57) Task prior knowledge scores – score protocol

SCORE	DESCRIPTION
15%	There is some level of technical documentation, diagrams or data relating to aspects of the task necessary for successful completion. This includes site plans, data sheets, chem.-data and climatic or process related monitoring information. This indicates that the possibility of the task arising in an emergency has been considered.
30%	There are checklists available giving a breakdown of aspects of the tasks, in a logical and structured format. The aim of the checklist would be to assist the Emergency team in achieving success in the task. This indicates that the task has been foreseen, and some detailed though applied in terms of stages of completion of the task.
45%	There are formalised procedures, and associated training / exercising / familiarisation schedules connected to the completion of this task. This indicates that the site has foreseen the probability of this task occurring as high, and taken action to ensure that a high level of awareness and familiarity are achieved, in relation to the successful completion of this task. Examples include response to alarms, shelter, evacuation and muster, initiation of Emergency situation and formalised emergency service training (fire and medical procedures)
60%	There is an automated / computer controlled / electronic system in place to aid the successful completion of the task. A system of this nature removes some of the human 'processing' of the task, and provides a technological solution to achieve greater efficiency and accuracy in the task. Examples include plume prediction, electronic muster and intelligent access systems and GIS based site information and data retrieval systems. This indicates that the timely and accurate completion of the task has been defined as a priority, and investment made to maximise the efficiency.

13.2 TPRC RESULTS

13.2.1 Installation A

Scores for the Efficiency / Competency requirements of the TPRC model.

The scores used in the task completion efficiency section of the TPRC model are derived from the exercise observation. The justification for the efficiency scores for Installation 'A' are given in the table below. To back up this score, cross-references are made to the OCTO assessor's scores and comments regarding the exercise performance in specific areas.

In the case of Installation A's tasks, there are six relevant scores awarded in the exercise performance assessment. The assessor's scores are given in response to the observation of a site exercise, and background information from pre-exercise and post-exercise research.

Table (58) Efficiency / competency scores for installation A

TASK	SCORE	COMMENTS
Establishing the ECC	1 to EMT	Good example of well-rehearsed procedures, no negative suggestions in assessors comments to suggest that this procedure was anything less than expected on the site. Time required was well within target.
The mustering of the incident zone	0.5 to EMT 0.75 to Site Staff	Ran behind the targets set, and was the beginning of the process of rescuing the casualties. Two parties involved – ECC and Site Staff. Although facilities and training were in place for efficient mustering, problems were on behalf of EMT and the Site Staff. The issues of poor information management and poor control of the casualty rescue by the EM are raised in the assessors scoring, and are relevant to this task.
Determining the severity of the event.	0.75 to EMT	Crucial to response. Ran just ahead of the time allowed. The task involves communication, interpretation of various alarms and panel signals and access to knowledge of the plant and process. The management of information by the EMT is commented upon throughout assessment, and there is also a score given for the use of facilities.
Inventory, Process and status of the concerned building	0.5 to EMT	Requires the EMT to access more information and utilise technical data. This task took almost double the time allowed, and there was confusion amongst the EMT on this subject. Comments regarding information management, team interaction and overall forward planning of the EMT apply here
Mobilise off-site monitoring,	0.5 to EMT	Involves mobilising the team from a site some distance away. Time delay can occur if EMT do not realise necessity to call-out monitors, until later in the scenario. Forward planning by the EMT would have foreseen that the team might be required later in the scenario and called them out early, on a speculative basis. This did not occur. The Monitoring team are not being assessed. Their response to the call-out was within defined limits.
Rescue of Casualties	0.4 to EMT 0.5 to FCP	The efficiency of the control and conduct of this task is commented upon widely, and thought to be deficient in several key areas. Crucial aspects of information exchange and control influence from EMT to FCP are noticeably problematic in this area. As a result, the casualties in the exercise were rescued well beyond the acceptable targets.

Table (59) Prior knowledge for installation A

TASK	SCORE
ECC Established	45%
Muster Incident Zone	45%
Determine severity of incident	60%
Inventory, Process & status of building	15%
Mobilise Off-site Monitoring	45%
Rescue of Casualties	30%

13.2.2 Resource performance metrics for Site A

Figure (53) Resource performance metrics for Site A

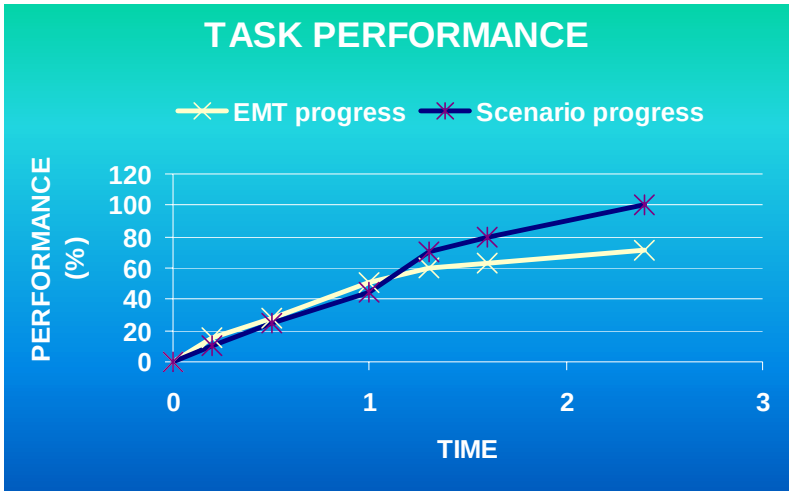
Tasks	List of Tasks to be carried out in meeting project goals		Units	Range
xi	proportion of work in task i to overall task (%overall task)		%	0-100%
Poi	Prior knowledge (% of task i)		%	0 - 100%
ti	time allowed for task i to be completed		hours	N>0 hrs
Ti	Time required for the task i to be completed		hours	N>0 hrs
Δti	delay time for task i		hours	N>0 hrs
εij	competancy matrix (task i, person j)	ε =1 is the norm	none	ε>0 hrs
N	Number of persons working on task i		none	N>0

Figure (54) TPRC results for site A

Tasks	xi	Poi	ti	Ti	Δti	ij	EMT	FCP	STAFF	other	other	N
ECC established	10	45%	0.2	0.1	0	1	1					1
Muster incident zone	15	45%	0.3	0.5	0	2	0.5		0.75			2
Severity of event?	20	60%	0.5	0.3	0	3	0.75					1
Inv'try, Process & status	25	15%	0.3	0.6	0	4	0.5					1
Off-site Monitoring	10	45%	0.3	1	0.5	5	0.5					1
Rescue of casualties	20	30%	0.8	1.5	0.6	6	0.4	0.5				2
Total	100											
										T= 71.13 %		

The model for 'Installation A' gives an overall score of 71%, which means that successful, competent management of the overall situation, was not quite achieved. A score of 100% would indicate that a competent response achieved success in the scenario, while a score of greater that 100% indicates that a level of success beyond the requirements of the scenario was achieved. The graph shows that the management response was slightly above the requirements of the scenario until the time=1 point. From here on, it drops below the scenario line, indicating that the response was no longer successfully managing the situation. This deficit can be attributed to the issues of casualty rescue, mobilising off-site monitors and determining the inventory of the incident building and process involved. These tasks ran behind the target times, and an improvement in any of these aspects would result in a marked increase in the overall score.

Figure (55) **Installation A TPRC result**



The graph shows two plots:
y1 vs x and y2 vs x.
y1 = actual task completion rate
y2 = allowed task completion rate

13.2.3 Installation B

Each task is assigned scores from the following tables, based on observation of the exercise and prior interview and research on the installation concerned.

Table (60) Efficiency / competency scores for Installation B

TASK	SCORE	COMMENTS
Rescue of Casualties	0.9 to EMT 0.9 to FCP	The efficiency with which the casualties were rescued was a good example of a well-planned procedure. There are no negative suggestions in the scoring to suggest that this process was anything less than what is expected on the site, and the time taken to complete the task was outside, but close to the performance target. The casualty rescue began as soon as the environmental conditions in the plant had subsided sufficiently to allow re-entry.
Move EMT to Back-up ECC	0.9 to EMT	This within the time target set, but was a relatively new procedure. The EMT was the only group involved in this task, and the facilities available are mentioned in the scoring as new, and still bedding down. With scores for the EMT and EM being 100%, but the task fell a little behind time
Off-site monitoring data	0.75 to EMT 0.85 to Monitors	Gathering offsite-monitoring data was important to the response, and task ran well behind time allowed. The task involves mobilisation of the team, followed by feedback and interpretation of data. Delays occurred due to problems in securing safe routes for the mobile team. The management of information is mentioned, along with comments related to the performance of the facility level management, but the crucial issue in this task was in the hands of the ECC.
Shelter & Warning	1 to EMT	Shelter and warning of the site and proximity population was carried out within the time allowed and comments reflecting the good management of information, strong leadership and forward looking approach with good use of facilities.
Plugging the leak	0.75 to EMT 0.85 to FCP	Leak plugged - an engineering task taking place at the incident scene, was delayed by the time taken for the environmental conditions to subside. By the time the leak had been plugged, the system had shed the majority of its contents. While this task is limited by the severity of the leak and technological restrictions, efficiency is shown within the confines of the plant characteristics.
Accounted for all staff	0.9 to EMT 0.8 to staff	Being a key process in determining the safety of employees, this task is important in the overall management of the emergency. Some issues arose concerning the presence of external contractors on site, the large population of the site and re-locating of sheltered personnel. Overall, the procedure ran close to the target time, and from observation was very efficient and well managed.

Table (61) **Prior knowledge for Installation B**

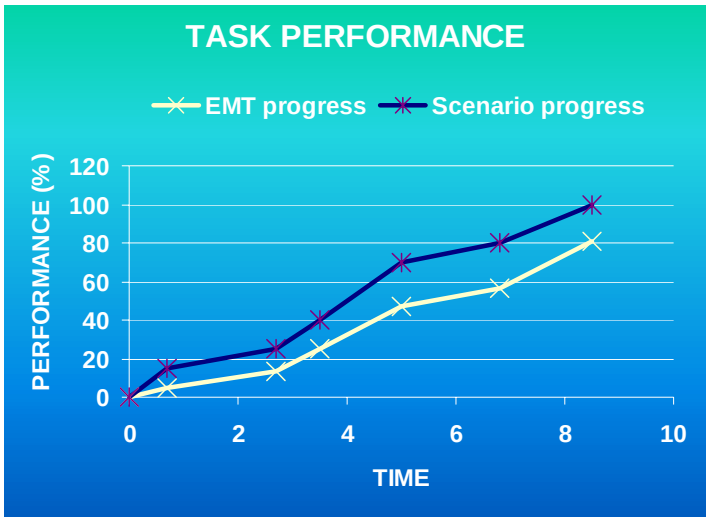
TASK	SCORE
Rescue casualties	30%
Move to back-up ECC	15%
Off-site monitoring	60%
Shelter & warning	45%
Leak plugged	30%
Accounting for all staff	45%

13.2.4 Resource performance metrics for Site B

Figure (56) **TPRC results for Installation B**
Figure (57) **TPRC results for Installation B (a) data (b) Performance vs. time plot**

Tasks	xi	Po	ti	T	Δti	ij	EMT	FCP	staff	monitor	other	N
Rescue injured	1	30	0.	0.	0.	1	0.	0.				2
Back-up ECC	1	15	2	1.	0.	2	0.					1
Off-Site monitoring	1	60	0.	1.	0.	3	0.7			0.8		2
Shelter & Warning	3	45	1.	2	0.	4	1					1
Leak Plugged	1	30	1.	2	0.	5	0.7	0.8				2
Staff accounted	2	45	1.	1.	0.	6	0.		0.			2
Tot	10											

T 80. %



The graph shows two plots:
y1 vs x and y2 vs x.
y1 = actual task completion rate
y2 = allowed task completion rate

13.2.5 Results for Installation B.

Installation B EMT scores 81% for their overall success in the scenario. They seem to remain consistently in the wake of the incident progress, although only lagging by a short distance. The data shows the team to be efficient in what they have achieved, which indicates a good level of training and preparedness on behalf of the site. The task of shelter and warning the site and proximal population took longer than the target time, and because of the high importance weighting of this task, it affects the overall progress and overall score. The rescue of the casualty occurred as soon as the environmental conditions allowed re-entry into the incident building, as the gas concerned was at a high temperature and leakage was occurring under considerable pressure. Significant time was lost in the gathering of off-site monitoring data, due to problems concerning the safe routes off-site which could be taken by the monitoring team. There seems to be no reason why the methodology for off-site data collection, relay and interpretation would not be timely and efficient in other circumstances.

13.2.6 Installation C

Each task is assigned scores from the following tables, based on observation of the exercise and prior interview and research on the installation concerned.

Table (62) Efficiency /competency scores for Installation C

TASK	SCORE	COMMENTS
FCP established	1to FCP	The efficiency with which the FCP was established. There are no negative suggestions in the scoring to suggest that this process was anything less than what is expected on the site, and the time taken to complete the task was within the target time.
Establishing ECC	1 to EMT	The establishing of the ECC ran ahead of the time target set, and was the beginning of the tactical management of the incident. Score of 1 to EMT.
Mustering the incident zone	0.75 EMT 0.65 Staff	Mustering the incident zone was crucial to the response, and a task that ran just behind the time allowed. The task is very proceduralised, and minor issues arose regarding the location of external contractors on site. The management of information by the EMT is commented upon throughout the assessment, alongside the strong leadership and communication within the ECC but perhaps a little less vigorous beyond there.
Extinguishing the fire	0.7 ECC 0.6 FCP	The extinguishing of the fire is a critical task, as it ensures that the risk of BLEVE is minimal. Several comments are made by the assessor, regarding the lack of a forward-looking approach, slight weakness of the FCP team, and late recognition of the need for some fire-fighting aspects. This task took slightly longer than the time allowed. A score of 0.7 is given to the ECC and 0.6 to the FCP.

TASK	SCORE	COMMENTS
Results from off-site monitoring,	0.9 to EMT	Results from the off-site monitoring, involves mobilising site resources, and directing a monitoring route to establish the movement of contamination. The procedure itself is not complex, although time delay can occur if the EMT do not realise that it is necessary to call the team out, until later in the scenario. The monitoring team are not being assessed, as their input was simulated in realistic time, the decisions of the ECC in terms of mobilisation and direction of the resources are being scored, and the activity was carried out successfully within the time allowed. Comments relating to the excellent communications, but also the lack of formal forward-planning are considered.
Isolating the leak	0.7 EMT 0.7 FCP	This is a technical task, which is dependent upon the preceding tasks of extinguishing the fire and making a safe approach to the tank. Comments by the assessor regarding the forward-looking aspect being weak in the FCP and fire fighting resources being delayed are taken into account. The leak was isolated within the target time, and this is a key factor. The issue of the risk of re-ignition after isolating the leak was brought to bear at the end of the exercise, when the fire brigade showed reluctance in stating that there was no risk of re-ignition, the police were keen have the area declared safe for the purposes of traffic flow, and the EM had to decide whether to authorise the all-clear.

Table (63) Prior knowledge scores for installation C

TASK	SCORE
Rescue casualties	30%
Move to back-up ECC	15%
Off-site monitoring	60%
Shelter & warning	45%
Leak plugged	30%
Accounting for all staff	45%

Resource performance metrics for Installation C

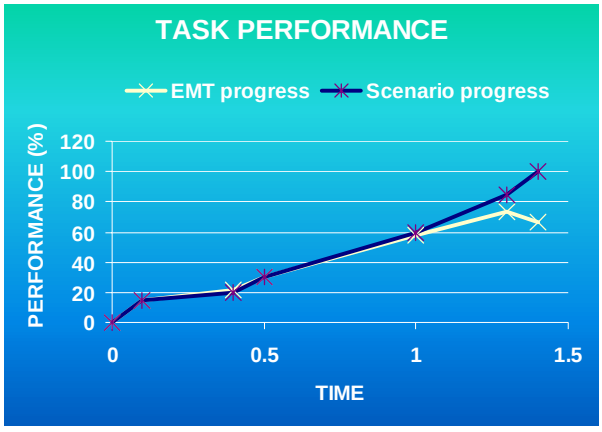
Figure (58) Resource performance metrics for Installation C

Tasks	List of Tasks to be carried out in meeting project goals	Units	Range
xi	proportion of work in task i to overall task (%overall task)	%	0-100%
Poi	Prior knowledge (% of task i)	%	0 - 100%
ti	time allowed for task i to be completed	hours	N>0 hrs
Ti	Time required for the task i to be completed	hours	N>0 hrs
Δti	delay time for task i	hours	N>0 hrs
εij	competancy matrix (task i, person j) ε =1 is the norm	none	ε>0 hrs
N	Number of persons working on task i	none	N>0

Figure (59) TPRC results for Installation C (a) data (b) performance –time plot

Tasks	xi	Poi	ti	Ti	Δti	ij	EMT	FCP	STAFF	other	other	N
Set-up FCP	15	45%	0.1	0.1	0	1		1				1
Set-up ECC	5	45%	0.3	0.2	0	2	1					1
Incident Zone mustered	10	60%	0.1	0.2	0	3	0.75		0.65			2
Fire extinguished	30	45%	0.5	0.6	0.1	4	0.7	0.6				2
Off-site monitoring	25	30%	0.3	0.2	0.2	5	0.9					1
Leak isolated	15	30%	0.1	0.8	0.7	6	0.7	0.7				2
Total	100											
										T= 66.83 %		

13.2.7 Results from Installation C



The graph shows two plots:
y1 vs x and y2 vs x.
y1 = actual task completion rate
y2 = allowed task completion rate

Installation C scores 68 % in the overall model, and the progress of the team against the scenario progress compares favourably throughout the incident, until Time=1, when their progress drops below the level of success required to keep on top of the incident. The departure from scenario progress is due to the delay in extinguishing the fire, which results in a long delay before the team is able to plug the leak concerned. The actual task of plugging the leak is carried out well, but due to the delay it is not sufficient to make the overall task a success. Better management of FCP fire-fighting resources is recommended in the assessor's comments, and clearly, with a more efficient response to that task, the overall score would improve.

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