

BENCHMARKING EMERGENCY MANAGEMENT GOOD PRACTICE – THE EMPIRE STUDY

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INTRODUCTION

During 2000, OCTO and Cranfield University undertook a benchmarking study on emergency management and emergency planning for the Health and Safety Executive. The result was the Empire benchmarking model – Emergency Management Performance Indicators and Risk Evaluation. Empire looks in depth at the quality of emergency preparedness on a major hazard site, relating standards of preparedness to site risks, and comparing also practices across major hazard industry. This paper describes briefly the structure of Empire. It goes on to describe how performance in emergency exercises was assessed and how, in detail, standards of performance in emergency exercises were related to training and exercise regimes. The purpose of the presentation is to describe how best to target effort to achieve maximum value from emergency management investment under COMAH.

THE EMPIRE APPROACH TO ASSESSING EMERGENCY PREPAREDNESS

Empire stands for 'Emergency Management Performance Indicators And Risk Evaluation'. It is a database model of emergency preparedness which assesses:

- the effectiveness of the site's emergency preparedness as a comparison with other major hazard sites; and
- the effectiveness of the site's emergency preparedness in relation to the site risks.

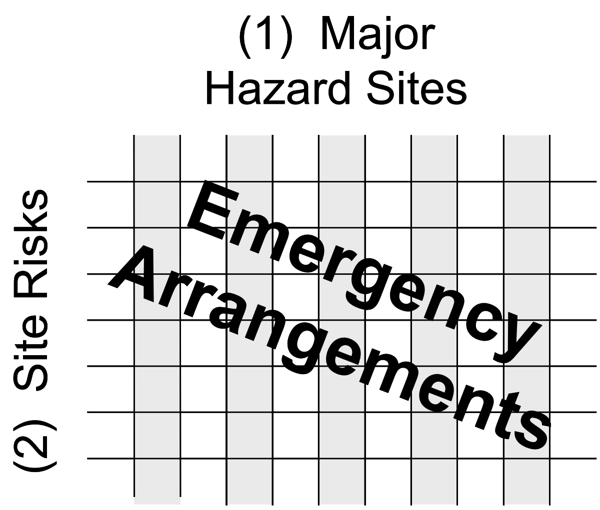


Figure (1) **Empire assesses emergency arrangements wrt other major hazard sites and site risks**

EMPIRE IS FOUNDED ON 3 KEY PRINCIPLES:

1. **Standards of performance are set by industry practitioners against agreed score criteria.** A key strength of Empire is that every value judgement in the study has been agreed with the industry participants concerned. This comprises in total some 2370 performance scores with associated rationale. To assist this process, 702 score criteria were developed for the project. All were derived from existing industry good practice and were agreed by industry collaborators to be appropriate. They have been applied consistently throughout the project.

2. **Judgement on adequacy is made from two perspectives – good practice and site risks**. The first is a straightforward comparison with existing good practice; the second is a judgement in relation to the site risks. In order to achieve the second perspective a separate assessment was carried out to translate the site major hazards, based on COMAH safety case or equivalent, into the demands that the COMAH scenarios place on emergency response arrangements.

3. **The measurement techniques should not 'lead' the results**. Given that the basis of data collection for this project is heavily reliant on expert judgement, great care has been taken to minimise subjectivity in both collection and interpretation of results. This was in part addressed in Principle 1. Secondly the Empire model as developed has no implicit value judgements of which components are 'good' or 'bad'. This point can best be explained once the overall structure of Empire is understood and is therefore addressed in more detail in the section on Maintaining Objectivity below.

Founded on Principles 1,2 and 3, Empire is a research tool. Used with circumspection, the large amount of data collected in the Empire model can be used to learn more about industry good practice and identify features which appear to contribute to good emergency response.

THE EMPIRE MODEL HAS THE FOLLOWING STRUCTURE.

It uses a balanced score-card approach to assess 82 indicators of emergency preparedness across 6 different emergency management perspectives and two exercise assessment perspectives:

- emergency philosophy
- emergency management structure
- emergency organisation
- emergency facilities
- emergency plans
- team preparedness

and

- qualitative assessment of performance in exercises
- quantitative assessment of performance in exercises

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

- The Site Incident Potential (SIP).

HOW DATA WAS COLLECTED

We invited and were delighted to receive the enthusiastic response of a number of experienced players across a good cross-section of major hazard industry. All the sites who took part had COMAH chemical hazards. Since the original research, more sites have joined in and the list of participants now comprises: Associated Octel; Avecia; AWE ; BHPP; BNFL Sellafield; BP; BNFL Thorp; ICI; IneosChlor; Pfizer; Scottish and Southern Energy; Shell; Urenco.

Each site shared with us its detailed emergency arrangements and subjected itself to an intensive and comprehensive assessment of its emergency preparedness. In addition to reviewing documents and conducting interviews with key personnel, we watched an exercise specifically offered by the company as a demonstration of emergency capability.

DERIVATION OF THE EMPIRE MODEL

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).

The detailed structure of the Empire model was established through an iterative process starting with the COMAH regulations and a list of established good practice, contributed by OCTO. Each indicator was scored in detail, against parameters such as availability; effectiveness, alignment with strategy and company in-house capability. Contributions were then invited from industry collaborators to check for missing or superfluous elements. During the data-gathering process, the model was refined several times to reflect industry requirements. Finally, all the individual scores were ratified by the company concerned as a realistic representation of each element of its emergency preparedness.

The final structure is shown schematically in Figures 2 and 3 below:

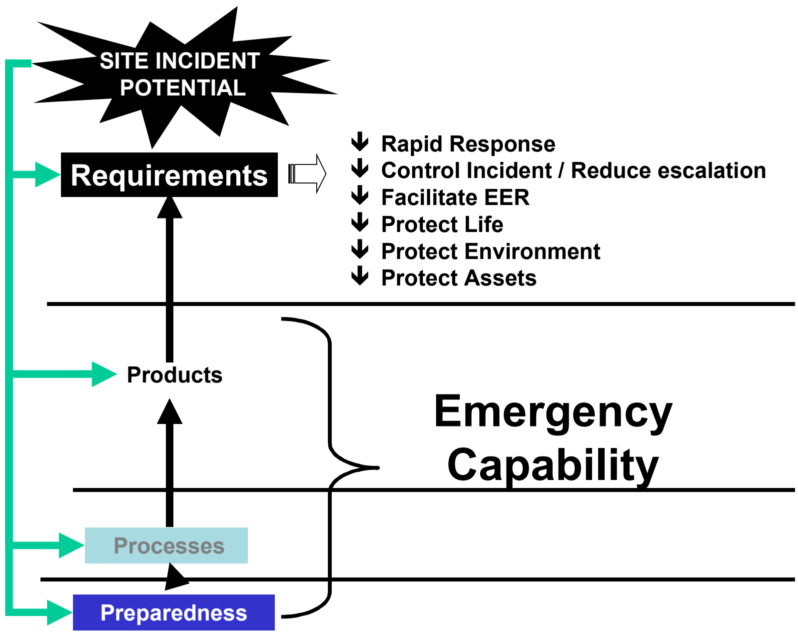


Figure (2) **Overview structure.**

The Site Incident Potential (SIP) is a measure of difficulty for emergency management on site. It comprises an aggregation of the following elements:

- inventory in major hazard scenarios
- complexity of technology
- site population density
- diversity of hazards

- speed of scenario development
- level of off-site risk.

The SIP scale is calibrated to be compared directly with the emergency capability of the site.

The emergency management capability perspectives are illustrated in Figure 3.

At each stage this is assessed in the context of the strategic requirements of the site emergency arrangements, namely:

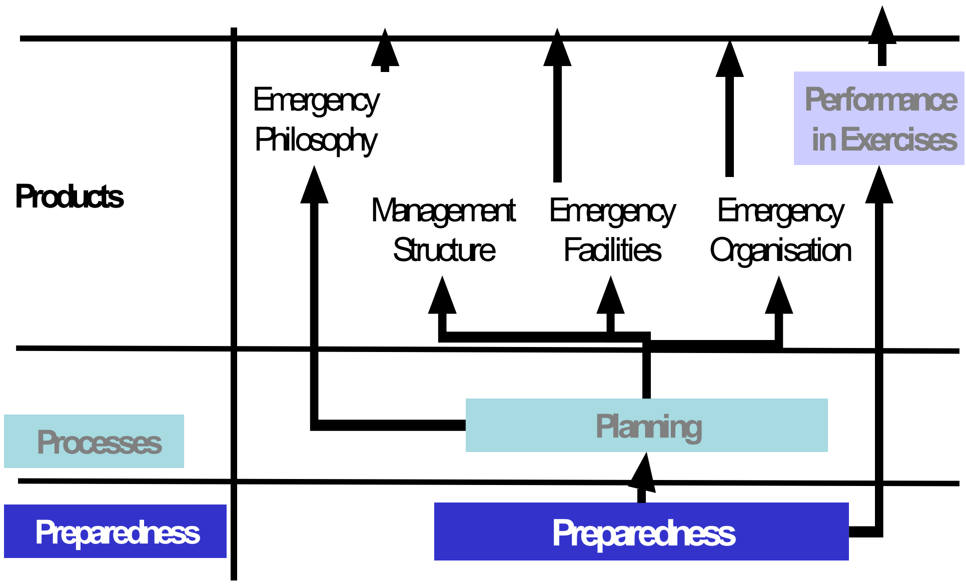


Figure (3) Structure detail.

- initiate rapid response
- control incident / reduce escalation
- facilitate evacuation escape & rescue (EER)
- protect life (beyond EER)
- protect environment
- protect assets.

The links between Site Incident Potential, Strategic Requirements and Emergency Management Capability are achieved through a series of relationship matrices. Each matrix is as simple as possible, and easy to tune to site requirements if necessary. For most sites, the standard matrices served without modification. Sites with specific unusual factors, for instance particularly sensitive environmental risks, found that a minor adjustment better reflected its situation.

MAINTAINING OBJECTIVITY

Principle 3 of the Empire model is that the measurement technique should not 'lead' the results. In developing the overall structure of the model, each emergency perspective was sub-divided into a number of elements. The critieria for selection of these elements was that they should apply equally to each participant OR they should be based on some independent source, such as the COMAH regulations. Table 1 illustrates the basis for selecting elements of the team preparedness perspective.

Table (1) Basis for selecting elements of the team preparedness perspective

Team Preparedness Element	Basis for Inclusion in Model
Selection of key staff for emergency duties	Guidance to Schedule 2 of COMAH Regulations 1999. Para 357 "arrangements for selecting and recruiting competent personnel".
Essential knowledge for key players in emergency response	Guidance to Schedule 2 of COMAH Regulations 1999. Para 370 "in order to find the necessary combination of theoretical and practical knowledge".
Emergency Management Competencies Addressed	Guidance to Schedule 2 of COMAH Regulations 1999. Para 357. Management of Health and Safety at Work Regulations 1999. Regulation 8 – "Nominate a sufficient number of competent persons to implement those procedures in so far as they relate to the evacuation from premises of persons at work in his undertaking." "A person shall be regarded as competent … where he has sufficient training and experience or knowledge and other qualities to enable him properly to implement the evacuation procedures."….
Competence assurance / assessment for other key players	Guidance to Schedule 2 of COMAH Regulations 1999. Para 357.
Defined requirements for training exercises	Guidance to Schedule 2 of COMAH Regulations 1999. Para 357. "identifiying and meeting their training needs, monitoring their performance …." Schedule 5 "arrangements for training staff in the duties they will be expected to perform …". Guidance to COMAH Regulation 11, Para 227 "all relevant staff in all shifts in all the relevant organisations should be fully trained in their expected response in the event of an emergency."
Defined requirements for refresher training	As above.

A similar principle in selecting the relevant elements was applied for each perspective. For Management Structure, Organisation and Facilities the roles examined were a comprehensive set derived from all the industry participants. Emergency Philosophy and Emergency Plans were derived from the COMAH regulations and guidance, with contributions from industry. The two are closely related in that the Emergency Philosophy is primarily the justification of the approach taken in the Emergency Plan.

ASSESSING EMERGENCY EXERCISES – THREE METHODS

METHOD 1 - ASSESSMENT OF EMERGENCY MANAGEMENT TECHNIQUE

As the closest available analogue of reality, a part of the project was to observe how well each company performed in a demonstration exercise. The focus in exercise assessment was both the effectiveness of emergency management technique and the effectiveness of exercise response in saving life and otherwise mitigating consequences of the incident.

Those elements of emergency exercise performance examined at the exercise were:

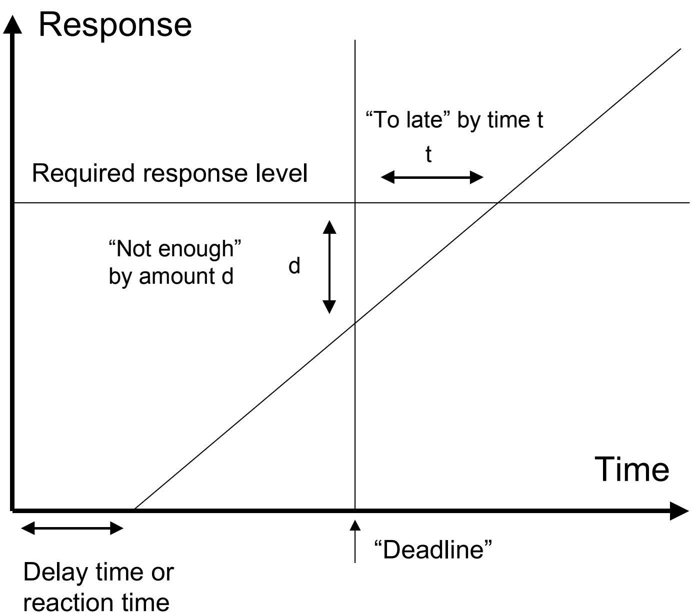
- qualities and performance of emergency controller
- qualities and performance of deputy emergency controller, where present;
- discharge of mandates;
- information management;
- team performance;
- adequacy and use of resources;
- adequacy and use of facilities;
- performance outside procedural envelope;
- quality of the scenario
- review and learning process.

Detailed score criteria were prepared for each element and agreed with industry collaborators during the scoring process.

METHOD 2 - TPRC

A key determinant of performance was the success of the team in achieving sufficient response in a certain time, as illustrated by the Task Performance Resource Constraint (TPRC) model in Figure 4.

Figure (4) 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.

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 4 for the simple case of a single task.

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. 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 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.

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 is shown in Figure 5.

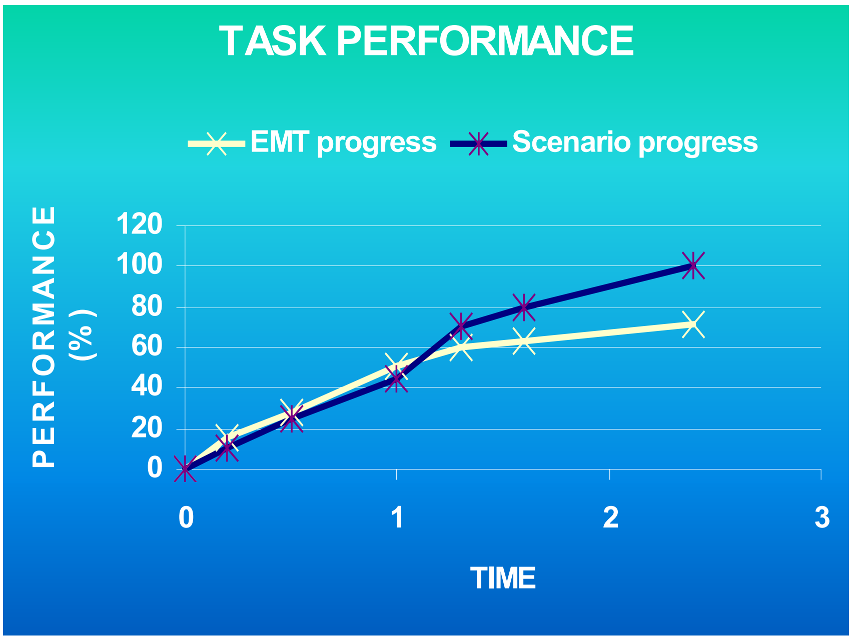


Figure (5) **TPRC Output plot.**

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

The scenario selected for demonstration included a number of features that were "manageable" to test the skill of the emergency manager. Those emergencies which are so unmanageable that the only actions to be taken involve evacuation were avoided as scenario examples.

Typically, there was a minimum of 2 escalation points within the scenario to show management of changing circumstances. The emergency manager and team did not know in advance which emergency scenario has been selected for the exercise.

Preliminary data collection

Preliminary data collection established the objectives of the exercise and the extent to which it included elements of training and elements of assessment. A copy of the emergency scenario yielded the following information: the planned timings, the key inputs and the fixed escalation points.

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

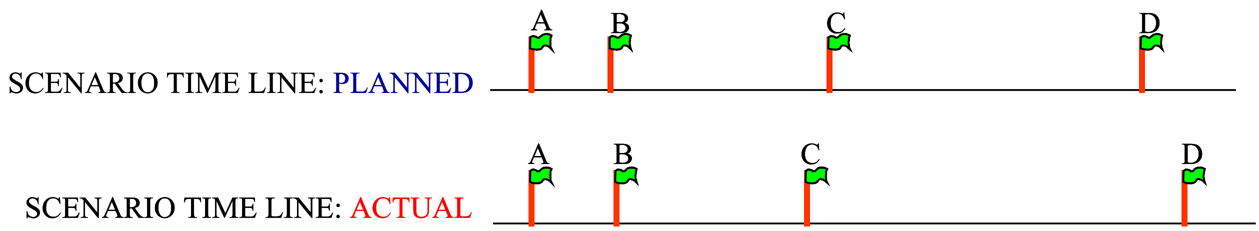


Figure (6) Scenario timeline

Against this time-line we then monitored both the timing of the scenario and the timing of the emergency team responses throughout the exercise. Accurate time recording to a suitable accuracy took place by writing a time log based on direct observation, and was facilitated by use of a video camera with a time base.

At each defined escalation point we applied the TPRC model – collecting measurements as defined in Figure 4.

There are Inherent Limitations in Assessing Exercises

The following inherent limitations in assessing emergency exercises were taken into account:

- 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 a series of exercise demonstrations 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.

We showed earlier in Figure 5 the results of applying the model to the analysis of a scenario.

The dark line shows the progression of the scenario and the light line the actions of the emergency team. It can be seen that in the initial stages, the team were on top of the emergency, responding appropriately and in good time. Later on, the team fell behind as the emergency escalated. The critical end result here was that the team failed to rescue a casualty before unacceptable injuries were sustained.

METHOD 3 - RANKING

For various reasons it was not possible to undertake a full TPRC analysis for each emergency exercise demonstration. The principles of the technique could however be readily applied in a semi-numerical way by ranking the relative performance of emergency teams with each other. The ranking criteria used took a scale of 1 to 10 for two parameters – key objective achieved in terms of sufficient resources allocated, and key objective achieved in terms of resources deployed on time. These two measures were applied to the primary aim of the exercise, whether it be the saving of life on-site or the mitigation of consequences off-site or the protection of the environment.

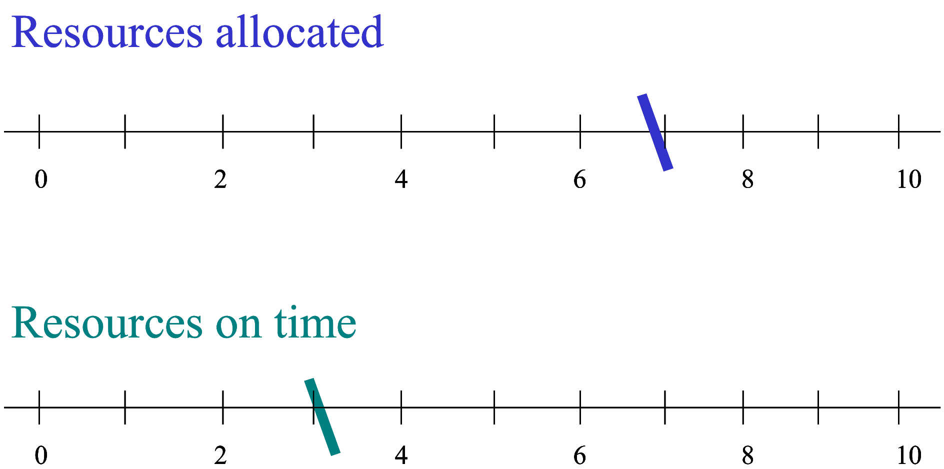


Figure (7) Example of ranking methodology

SOME RESULTS FROM THE EMPIRE INVESTIGATION

COMPARING DIFFERENT METHODS OF ASSESSING EXERCISES

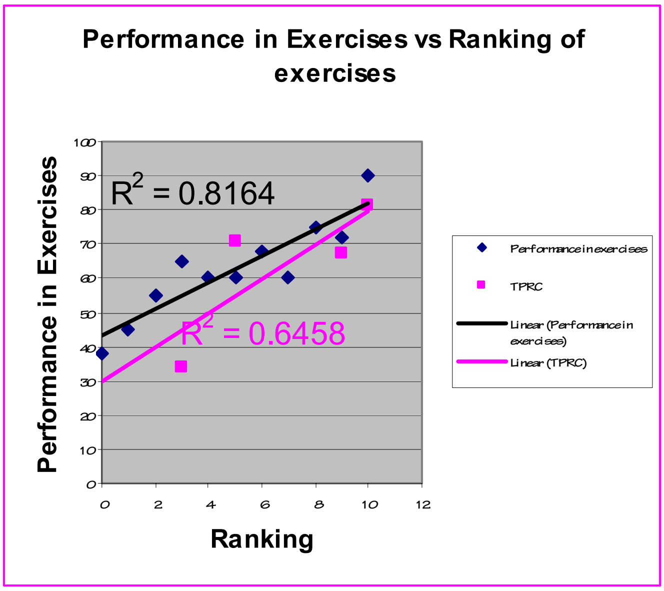


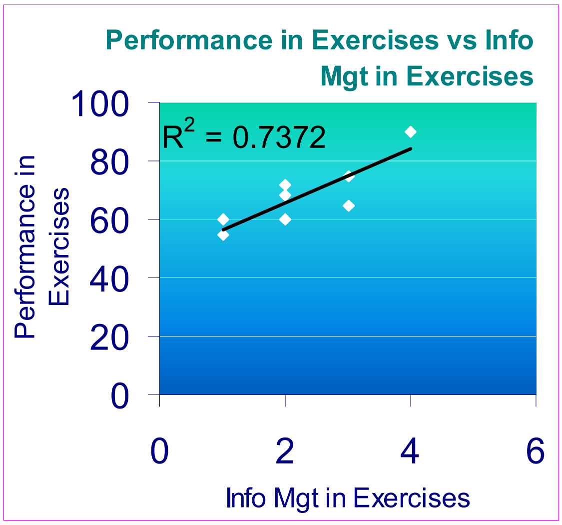
Figure 8 shows the relationships between the different means of assessing performance in exercises. In all graphs shown in this paper the R^2 value is NOT given with a view to demonstrating correlation but simply with a view to expressing the relative strength of the relationship between variables. In a study such as this, with largely empirical data, a value of ABS $[R^2]>0.5$ is considered significant. Only results with ABS $[R^2]>0.6$ are presented in this study as substantial positive indicators.

Figure (8) Comparison of three methods of exercise assessment

Here it can be seen that the measurement of performance in exercises by two of the three techniques co-incide reasonably well. I.e. performance measured according to management technique co-incides with ranking of performance according to whether or not exercise objectives were met. The third measurement, the TPRC plot, shows an encouraging pattern, but is limited to 4 data points.

From these results we can start to conclude that overall achievement in emergency exercises is linked in some way to management performance. We now move on to examine these potential relationships in more detail.

INFORMATION MANAGEMENT IS AN ENABLER OF GOOD EMERGENCY MANAGEMENT TECHNIQUE



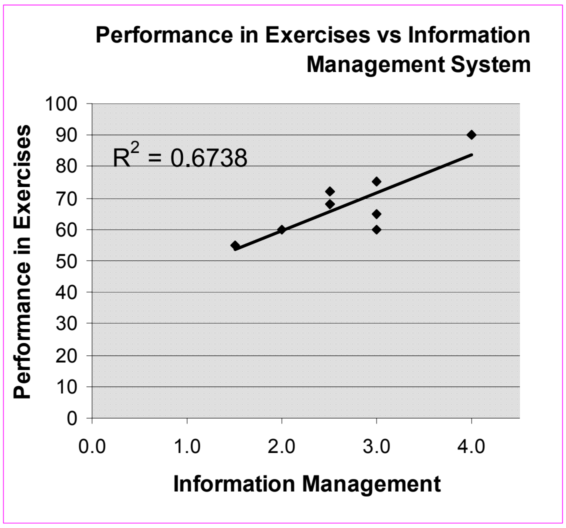
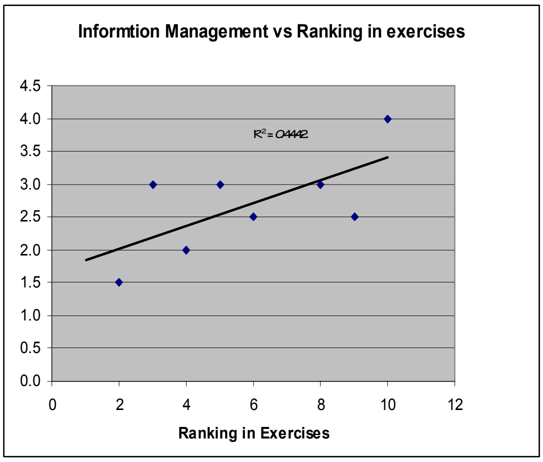


Figure (9) **Performance in exercises vs information management**
Figure (10) **Performance in exercises vs information management system**

From Figures 9 and 10 we can see that the information management system proved to be a key enabler of emergency management performance in exercises. A strong performance in information management was evidenced by the emergency manager being provided with the service of having information presented to him or her in a clearly expressed and readily accessible form. A clear and up-to-date display of both the current situation and a forward plan was in evidence throughout. Information management was not however the only determinant, as the relationship with the ranking in exercises metric demonstrates – Figure 11. The relationship here is much weaker, showing that there are other factors in play which have a bearing on achieving objectives.



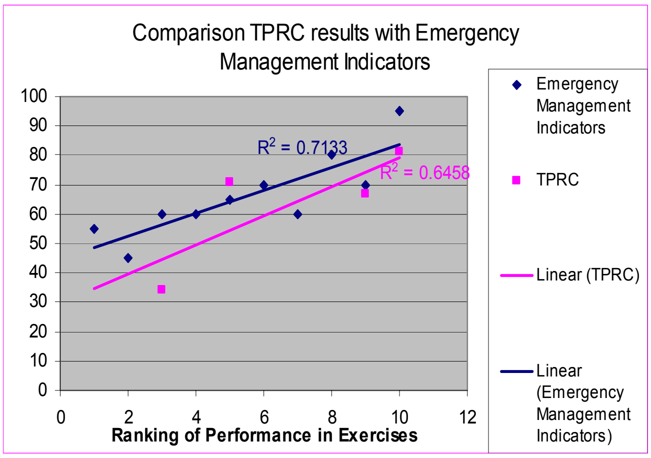
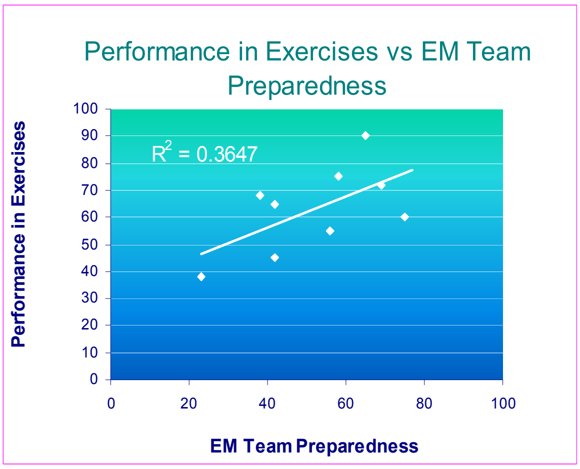


Figure (11) **Information management vs ranking in exercises**
Figure (12) **Comparison of TPRC results with emergency management indicators**

KEY INDICATORS OF EMERGENCY MANAGEMENT PERFORMANCE RELATE TO ACHIEVMENT IN EXERCISES

Figure 12 plots the average aggregate of a number of emergency management factors against achievement of exercise objectives, as measured both by ranking and by TPRC. The factors included are: performance of the Emergency Manager and Deputy (where relevant), information management in exercises, effectiveness of the emergency team in working together, and the suitability of the team's roles. An encouragingly strong relationship is shown, indicating that the variables selected can offer a good indication of likely performance with respect to the delivery of key resources for the saving of life and mitigation of consequences of the incident.

EFFECT OF TEAM PREPAREDNESS ON PERFORMANCE IN EXERCISES



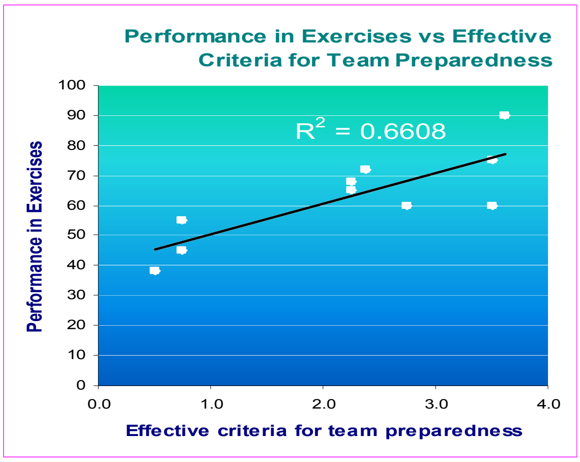


Figure (13) Performance in exercises vs Emergency Management team preparedness
Figure (14) Performance in exercises vs effective criteria for team preparedness

A surprising result is the very weak visual relationship between emergency team preparedness and performance in exercises as shown in Figure 13.

The constituent features of team preparedness scored here were:

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

On further analysis of this scoring protocol we can make a number of observations, which are summarised in the 2nd column of Table (2):

Table (2) Comments on correlation of individual team preparedness elements with performance in exercises

Topic Scored (as shown in Figure 13)	**Comment on results**	**Topic scored in Effective Criteria (as shown in Figure 14)**
Selection process for emergency managers	There is a wide variation in approach.	No comparator
Essential knowledge	Would not expect this to correspond well to performance in a single exercise.	Command and Control training
Competencies defined and competence assurance	Established in about ½ the sample – wide range of results and no consistency of approach across sites.	Competence Assurance
Training exercises	0verall training in exercise did not relate well to the experts' observations of performance in exercises on the day of the assessment.	Professional coaching of team in training exercises
Refresher training	Wide ranging standards across the sample	No comparator
		Team continuity. i.e. team members are well practised with one-another and tend to exercise together.

Given that we would normally expect to find a relationship between team preparedness and performance, we tried an alternative approach to scoring team preparedness. In the first scoring protocol (column 1 of Table 2), we scored across a broad cross-section of preparedness features, covering the basics and also more advanced topics. In the second, (column 3 of Table 2) we selected and then scored team preparedness against a sub-set of more closely-targeted training features. These scores were subsequently tested and validated with industry participants. The aggregate results show a much closer relationship, as illustrated in Figure 14. Of the individual plots (not shown) the strongest relationships were observed for Team Continuity, Command and Control training, and Coaching in Exercises. That Command and Control proved to be the only subset of essential knowledge that was selected in the 'Effective Criteria' reflects not that it is the only relevant area of essential knowledge, but more that it is the only area that can reliably be demonstrated by watching an exercise. Most exercises can test only a very limited span of essential knowledge, and the remainder of essential knowledge is best assessed in ways that lie outside the scope of this study.

Since Command and Control is frequently misunderstood, a description as applied in this paper is offered here. As an aggregate term, Command and Control encompasses both the authority of an individual to take charge of a situation and the structured processes by which that authority is discharged. In the context of an industrial emergency the processes can include, although not exclusively, decision-making under pressure, information management, team management, structured communications and briefing. Team continuity is defined in Table 2. Coaching in Exercises refers simply to the process of having an independent and informed observer analysing the performance of the team and individuals and assisting them in critiquing their performance and identifying areas for improvement.

MANAGEMENT PERFORMANCE IN EXERCISES IS IMPROVED BY EXERCISING EFFECTIVELY

A strong relationship was observed between the type and nature of training exercises undertaken throughout the year and performance of the emergency management team in the demonstration exercise. (Figure 15.)

The features of the exercise regime which scored highly in this study were those which exercised all the basic processes on-site and then exercised and tested emergency management independently to a good standard before putting the whole together in large, demonstration exercises. Poor performances were evidenced where the exercise regime concentrated on putting too much together at a time and not addressing the basic elements first. For instance, where individual items such as personnel accounting systems or action monitoring or sourcing safety case reference material had not been addressed as an individual item except in large exercises, learning had not been consolidated and there was a tendency for exercises to simply re-inforce existing (and often bad) practice, instead of building up good practice. In all cases, contributors had some difficulty in demonstrating comprehensiveness of their exercise regime across all safety-case scenarios, work-teams, plants, and chemicals.

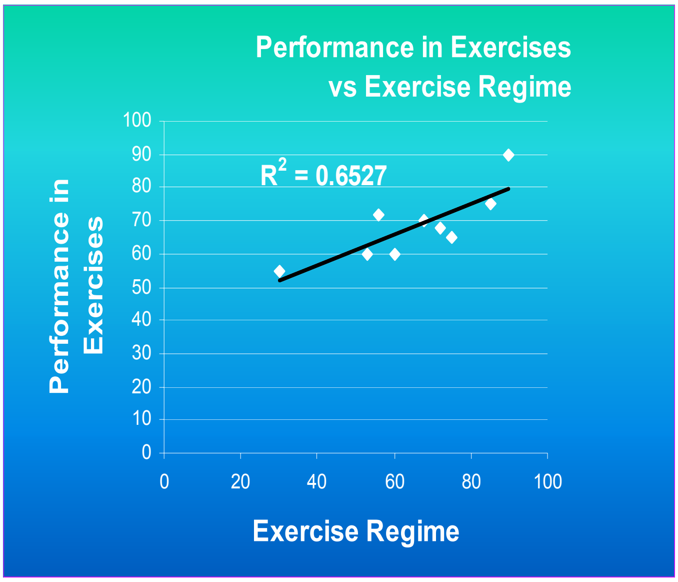
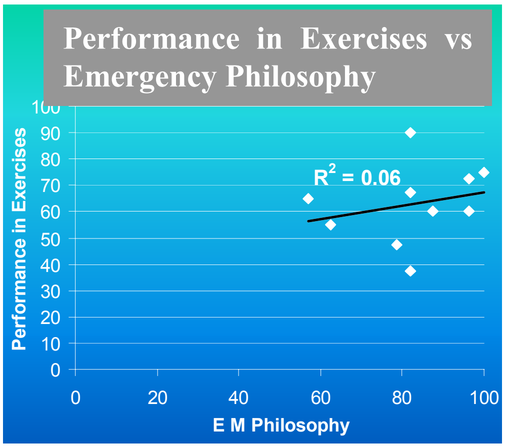


Figure (15) Performance in exercises vs exercise regime

TESTING OF DATA RELATIONSHIPS

The data has been subjected to an extensive process of testing to establish if the correlation approach was suitable. Care was taken throughout the study to ensure that the data was selected so as not to 'lead' the results. Once gathered, many data relationships were plotted. Many failed to demonstrate any relationship. For instance Performance in Exercises did not relate to Emergency Philosophy. A similar result was obtained, in that performance in exercises did not relate to quality of emergency procedures (a variable related to Emergency Philosophy). In all cases of negative results identified, there was a satisfactory explanation. For instance, we would not expect a close relationship between performance in exercises and emergency philosophy. In the case of Philosophy vs Management Structure, there is no possible relationship from the way the data variables have been construed. This too is confirmed when we plot the results.



Philosophy vs Management Structure

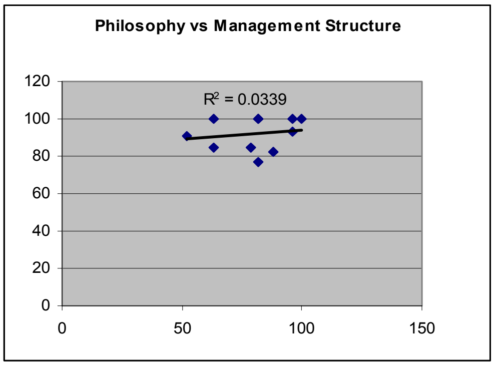
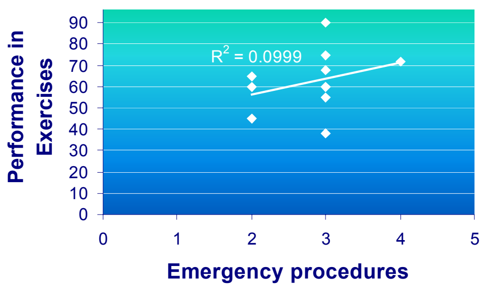
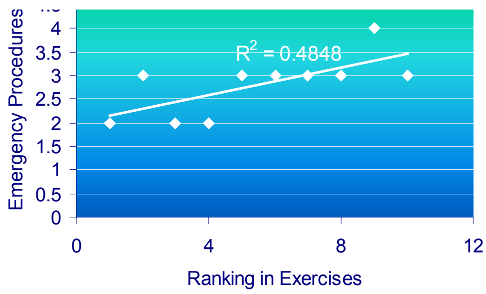


Figure (16) **Four graphs illustrating poor relationships**

Performance in exercises vs emergency procedures



Ranking in exercises vs emergency procedures



We recognise that the common factor in all of the value judgements is that of the researchers, primarily OCTO, specialists in emergency and crisis management. We have attempted to address this limitation on the data by assessing performance in exercises independently through ranking and TPRC techniques, which have been performed jointly with Cranfield University, and by having every data variable verified by industry practitioners. In our view these people represent some of the most experienced and knowledgeable individuals in major hazard industry emergency management and their value judgements have both independence and accuracy. To give a flavour of the quality of the verification process, between 10 and 20% of the individual element scores were debated between OCTO and the industry experts and in all cases agreement was reached. The rest were agreed without debate.

Such is the complexity and variation in the large number of data points collected – some 3000 to date, that it is impossible to adjust individual data points to give a particular result. The data sets have to be taken at face value and interpreted accordingly. It was concluded therefore that the graphs which showed a strong trend, as measured by the gradient of the line and the R^2 coefficient, could be interpreted as showing a relationship between the variables or their groupings.

CONCLUSIONS

All conclusions are based on the premise that performance in real emergencies correlates well to performance in realistic exercises.

1. Performance of emergency response teams in saving life and mitigating the effect of an emergency is enhanced by effective emergency management.

Key areas on which to focus in assessing emergency management performance in exercises are: the performance of the emergency manager and deputy; the information management process; the effectiveness of the team in working together – the team dynamic; and, finally, the roles within the team and the suitability thereof.

2. Information management is an enabler of good emergency management.

The skill of being able to display a clear and up-to-date picture of the current situation and forward plan plays a significant role in supporting the emergency management process.

3. The training regime selected can be expected to have a significant bearing in subsequent performance in demonstration exercises.

Steering training away from unstructured exercises and towards targeted training exercises, with command and control principles applied, robust information management systems and keeping individuals together in teams all have a direct bearing on the effectiveness of the emergency team.

4. The exercise regime selected can have a significant bearing on subsequent performance in demonstration exercises.

Establish a regime of simple, inexpensive exercises, with clear performance standards, and train and exercise until these performance standards are met. Build up the elements of on-site emergency response to a good standard; a little and often would seem to be the key. Overlay emergency management exercises on a firm foundation of basic skills and, again, build up these elements until they can be put together with confidence in large, demonstration exercises.

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