17th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
9-12 May 2016, Budapest, Hungary

BEST PRACTICE IN APPLYING EMERGENCY RESPONSE TOOLS TO LOCAL-SCALE HAZMAT INCIDENTS

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Abstract:
A great range of hazardous materials are produced, transported and stored within our society and their accidental or malicious release may pose significant threats to human health, the environment and infrastructure. If such an event occurs, first responders and higher level decision makers require an understanding of the scale of the incident and risks it poses. Dispersion modelling within an Emergency Response Tool (ERT) can provide an effective means of providing the necessary situational awareness. However, providing accurate local-scale predictions within urban or industrial areas is a challenging problem due to the complex nature of the dispersion induced by local wind flows. In addition, the problem of estimating a source's emission characteristics introduces further uncertainties in the final evaluation of impacts.

There are now a large number of ERTs based on methods ranging from simple Gaussian plume calculations to complex computational fluid dynamics (CFD) predictions. Although sophisticated CFD methods should provide the most accurate predictions, they require much more input information and computational effort than Gaussian approaches. Given that first responders need information as rapidly as possible, there is a trade-off in accuracy of solution and execution time. However, a minimum level of accuracy is required to enable the correct decisions to be made and maintain the credibility of the ERT. This implies that the accuracy and processing requirements of models in ERTs, and the situations to which they may be applied with confidence need to be understood.

This question has been addressed by COST Action ES1006 through examining the performance of different modelling approaches, the range of hazmat incidents that may occur and the requirements of the various decision makers and actors involved. This has resulted in the development of a Best Practice Guidance Document. An important finding was that first responders often use only the simplest models, which may be subject to large errors when applied in the unsteady wind conditions associated with local-scale urban problems, although opportunities exist to use more sophisticated methods. The guidance therefore recommends that the choice of modelling method is based on the availability of information and time constraints, and that there is a need for greater engagement between scientists and practitioners to exploit state-of-the-art modelling more effectively.

***Key words:** dispersion modelling, emergency response.*

INTRODUCTION

The aim of the European Union Cooperation in Science and Technology (COST) Action ES1006 was to address 'Evaluation, improvement and guidance for the use of local-scale emergency prediction and response tools for airborne hazards in built environments'. The Action focused on complex urban areas as these are the environments in which releases of hazardous materials are likely to have the greatest impact, and the most difficult in which to provide accurate hazard predictions to support emergency responders.

A great range of hazardous chemical, biological and radiological materials are produced, transported and stored within urban areas. If these are released, either accidentally or maliciously, they may pose significant threats to human health, the environment and infrastructure. If such an event occurs, then in addition to personal protection equipment and first aid interventions, emergency responders and higher level decision makers ideally require, Emergency Response Tools (ERTs) that can provide them with the situational awareness necessary to make the appropriate decisions to best protect people and minimise environmental effects.

A wide range of ERTs are now available, ranging from simple stand-alone dispersion models to complex tools that provide a complete incident management system, able to receive inputs from a range of sensors and track assets, as well as perform the dispersion and consequence modelling. No matter how sophisticated the ERT is, though, its value to the emergency responder is entirely governed by the accuracy of its hazard predictions.

The dispersion models used to predict hazard areas in ERTs range from simple analytic Gaussian plume models to predictions generated using sophisticated computational fluid dynamics (CFD) codes. The complexity of local-scale atmospheric transport and dispersion processes in urban environments means that CFD methods should provide the most accurate hazard predictions, but they require substantially more input information and computational effort than those based on Gaussian assumptions. Given that first responders need information as rapidly as possible, there is a trade-off in time and solution accuracy. However, a minimum level of accuracy is required to enable the correct decisions to be made and to maintain the credibility of the ERT. This implies that emergency responders and decision makers need to understand the accuracy and processing requirements of the models used in ERTs, and the situations to which they may be applied with confidence. This leads to the need for a Best Practice Guidance (BPG) document as produced by COST Action ES1006.

COST ACTION ES1006 BEST PRACTICE GUIDANCE

In order for a BPG document to be useful to emergency responders, it has to be applicable to the full range of situations that they may encounter, and to the actors at a number of decision making levels. In addition, such guidance has been written for the emergency responder and not for the ERT developer. This means that it should be clear, succinct and avoid technical details, and these were considerations in developing the COST ES1006 BPG document (Armand *et al.* 2015).

The diversity of possi**b**le releases means that it is impractical to provide detailed guidance for handling every type. The approach adopted in ES1006 was therefore to assess databases of real accidents to identify a representative sub-set of likely hazard scenarios (Turner and Lacome 2014). The BPG was then related to four example scenarios in which local-scale effects were important and imposed different requirements on the ERT. These four scenarios consisted of:

- A neutrally buoyant release (i.e. a release in which density effects are negligible), as exemplified by the release of a small amount of chlorine within an urban area;
- A positive buoyancy release, as exemplified by a toxic plume produced by a warehouse fire;
- A dense gas release, as exemplified by a leakage of many tonnes of chlorine or LPG, involving the flashing and pooling of material;
- A dirty bomb that produces an explosive release of radionuclides.

The major activity undertaken by COST Action ES1006 was to conduct a series of four exercises in which the predictive performances of a range of dispersion models were compared. The different dispersion models were divided into the three categories defined in Table 1.

Table 1. Model types.

Model type	Description	Execution time
1	Models that do not resolve the dispersion around buildings. Typically semi empirical Gaussian plume/puff methods of varying complexity and sophistication.	Seconds to minutes
2	Models that resolve the dispersion around building by coupling rapid flow field calculation methods and Lagrangian Particle dispersion models.	Minutes to hours
3	Models that resolve the dispersion around and within buildings by adopting Eulerian CFD based approaches, such as RANS and LES modelling.	Hours to days

The principal reason for conducting the performance comparisons was that it was believed first responders often used only the simplest Type 1 models. This belief was confirmed through a survey of emergency responders and through information gained from first responders who participated in the four workshops run by the Action. There were two concerns associated with this, firstly that although simple models may easy to use and provide quick answers, they may be subject to large errors when applied to local-scale urban problems, and secondly that responders were not taking advantage of the more sophisticated approaches that could be used.

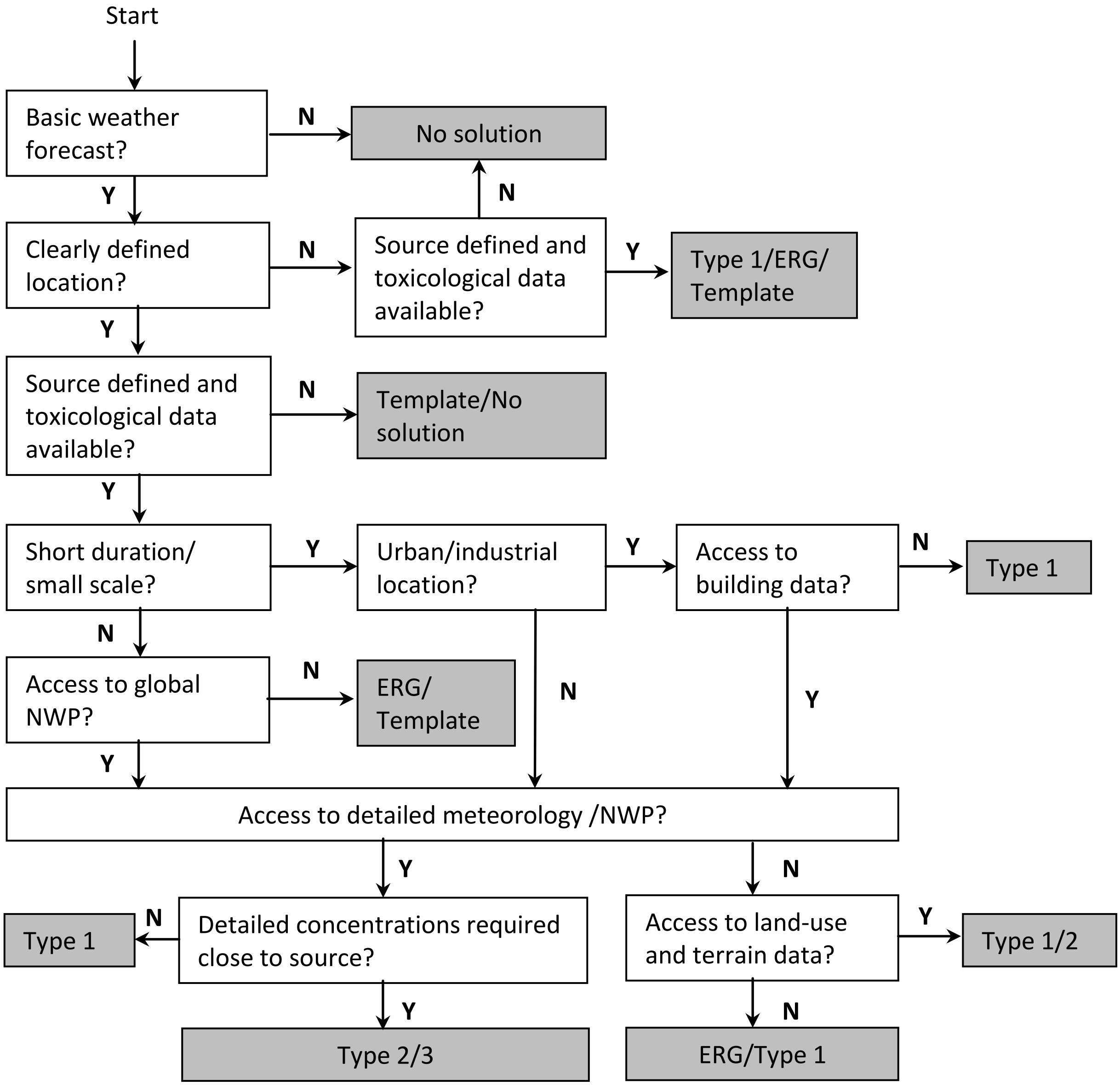

Figure 1. Emergency response modelling selection flowchart.

The four comparison exercises compared model predictions from some 20 models against dispersion data from wind tunnel experiments, an urban field experiment and from an actual incident. The wind tunnel comparisons showed that increasing model sophistication led to increasing model performance when the scenario was well defined. However, the performance differences reduced when the data was from the field rather than a wind tunnel, and as knowledge of the input conditions, such as the emission rate and meteorology, became more limited. These results led to the conclusion that emergency response modelling should be based on using the most sophisticated modelling approach possible, based on the input information and time available. This was reduced to the flowchart shown in Figure 1, which guides the user to an appropriate modelling response, or in the most information poor cases a simple Emergency Response Guidebook (ERG) (Transport Canada, 2012) solution or template, such as incorporated in the NATO Chemical, Biological, Radiological and Nuclear Warning and Reporting procedures (NATO, 2014).

Examination of Figure 1 highlights the importance of the quality of the input information on the modelling that can be undertaken and, implicitly the quality of the hazard predictions that are likely to be obtained. What is not evident in Figure 1, is that when considering local-scale emergency response scenarios, that Type 2/3 models may be able to capture features of the dispersion that cannot be predicted by the simplest models and provide a substantially enhanced level of situational awareness to aid decision makers, in addition to a basic hazard area prediction. This might, for example, be through identifying localised areas of high concentration (and hence increased exposure), such as in courtyards, or transport down side-streets, that simple models cannot resolve.

While the BPG developed by the participants of COST ES1006 focusses on guiding the emergency responder to the type of dispersion model to be used, it also identifies other factors that must be considered when using ERTs, such as the fact that there may be discrepancies between models and the need for the users to have appropriate training and experience.

TOWARDS IMPROVING EMERGENCY RESPONSE MODELLING

The work undertaken by COST ES1006 showed that a range of modelling options exist to support emergency responders and that different models may be required to handle different types of release. Furthermore, given sufficient input data and computational resources, it is possible to provide high fidelity local-scale hazard predictions. It has also suggested, however, that because of time and information constraints that the emergency response modeller should have a suite of modelling options at his disposal from the simplest Type 1 models to the more sophisticated Type 2 and 3 models,. The user might then rapidly produce an initial solution using a Type 1 model, but then refine the prediction by using Type 2 and Type 3 models as their solutions and more information become available to him.

It is implicit in the above that the modeller is remote from the emergency responder in order to have access to the data and computing resources required. Nevertheless, current developments in connectivity should enable this barrier to be broken down. The critical requirement is for the emergency responders and decision makers to have confidence in the modelling supporting him. This means ensuring that the models are adequately verified and validated for the situation in which they are being applied, and that the modeller has access to all the data (topographical, meteorological, etc.) required at an appropriate level of accuracy. It can be seen that this means that the goal is no longer to produce an ERT, but rather to produce an integrated emergency response system comprising the emergency responder, the communications system, the ERT and the modeller. In order to realise this, it evident that greater engagement is required between scientists and practitioners, to exploit the state-of-the-art more effectively.

CONCLUSIONS

The work of COST Action ES1006 led to the production of a BPG document for emergency response practitioners. This provided an overview of the state-of-the-art in dispersion modelling, and divided the models into three categories depending upon their level of sophistication. Based on the results from model performance comparison studies conducted within ES1006, it was concluded that emergency response modelling should be based on using validated models of a specified level of accuracy, using the most sophisticated approach available that can be supported by the input information and time available. However, in order to progress from the current position in which many first responders use only simplest models, to one in which they use more sophisticated methods that can provide substantial improvements in accuracy and situational awareness, it is evident that scientists and practitioners need to work collaboratively to establish confidence in the ERTs and implement the level of connectivity required to ensure that the modelling can be performed as part of an integrated emergency response system.

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