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Project report

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Abstract

Learning lessons from accidents is a fundamental principle in preventing technological accidents and mitigating their effects. In 1982, recognising the paramount importance of this principle, the first EU Seveso Directive created a mechanism for sharing of lessons learned from chemical accidents among Member States by establishing the Major Accident Reporting System (MARS) managed by the European Commission's Joint Research Centre (JRC). Through MARS (now called eMARS), EU competent authorities provide information on the sequence of events leading to a chemical accident, so that authorities and operators around the EU, and even the world, can learn from the event. The lessons learned are extracted from a report generated by (what should be) a thorough and systemic investigation to identify direct causes and underlying factors. Chemical accidents tend to have complex causality such that investigation and analysis requires a methodical approach to sort through causality that has several dimensions and interlinkages. Therefore, choosing an accident analysis methodology, or methodologies, to use in the investigation is fundamental to obtaining reliable and useful results. This decision requires understanding the strengths and weaknesses of various methodologies and selecting the optimal tool or tools, given the objectives of the investigation, the nature of the accident, and the limits of available resources.

To help provide support to such decisions, and with the view to improving reports of major accidents in eMARS, the JRC organised the Accident Analysis Benchmarking Exercise (AABE) with volunteers from a cross-section of competent authorities, researchers, and industry experts to explore a number of accident analysis methods and compare their usefulness in revealing direct and underlying causes from selected chemical accidents. The objective of the first part of the AABE was to compare the results produced by application of different methods to analyse a defined set of accidents and evaluate the use of the methods against agreed criteria. The second phase of the exercise was intended to use the experiences of the analysts in this process to create a tool that might be support a wide range of experts, who are expert in process safety but not necessarily in accident analysis methods, to produce or review accident investigation reports. This document summarises the activities and results of the first phase of this project and the direction proposed by the group for the second phase.

1 Project background and objectives

Accident investigators are faced with many choices when launching an investigation. One fundamental decision centres on choosing an accident analysis methodology or methodologies. This decision requires understanding the strengths and weaknesses of various methodologies and selecting the optimal tool or tools, given the objectives of the investigation, the nature of the accident, and the limits of available resources. The accident investigation community seemingly has many different methodologies at its disposal but often inadequate resources to test and explore the merits and drawbacks of each tool.

1.1 Chemical accident investigation and analysis under the EU Seveso Directive

This dilemma has become particularly apparent in the domain of chemical accident risk management in the European Union (EU). Under the EU's Seveso Directive for controlling major chemical hazards (2012/18/EU), the European Commission (EC) established the Major Accident Reporting System (MARS and later renamed eMARS). The Directive obliges companies to submit major accident reports to the competent authorities and the competent authorities are mandated to report these major accidents to the EU's eMARS accident database[1], managed by the Major Accident Hazards Bureau of the EC's Joint Research Centre (JRC-MAHB). The purpose of this requirement is to facilitate learning and disseminate lessons from these cases in order to improve chemical accident prevention and mitigation of potential consequences.

With the Seveso Directive now in its fourth decade of implementation, eMARS remains in place as a cornerstone of the EU chemical accident prevention strategy. Furthermore, eMARS has become the established database for exchanging chemical accident reports among OECD countries who are increasingly using it as a global reference tool for the study of chemical accidents and how to prevent them. It also the database to which Parties are expected to report chemical accidents with transboundary impacts under the Convention on Transboundary Effects of Industrial Accidents of the United Nations Economic Commission for Europe (UNECE).

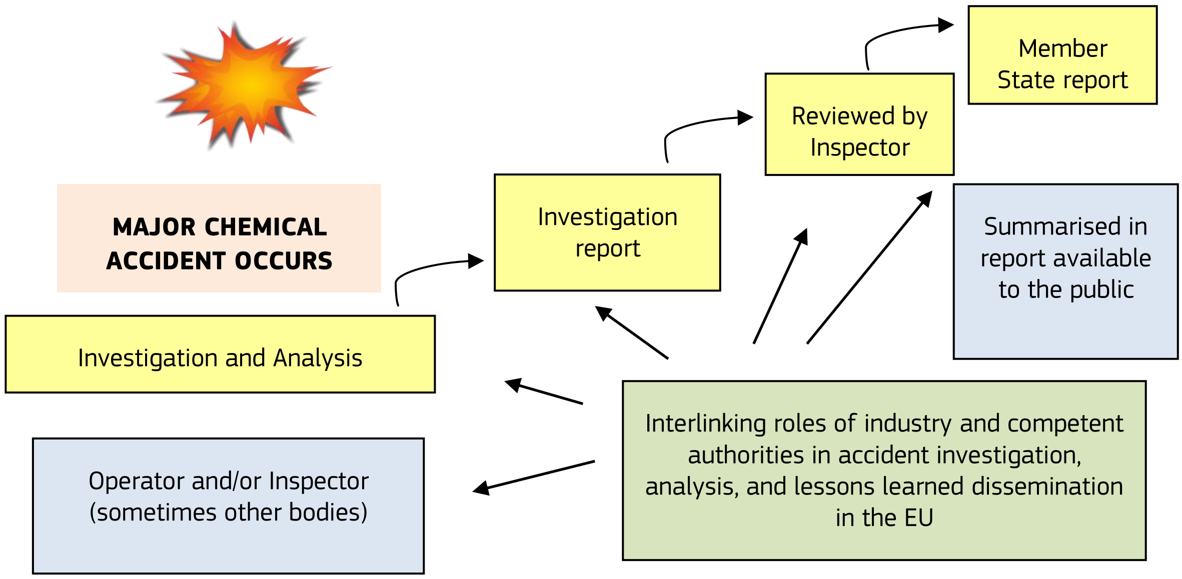
The Seveso Directive further imposes a number of expectations on competent authorities and industry tied to chemical accident investigation and lessons learned. For competent authorities, their duties may include:

- conducting an accident investigation
- collecting information on major accidents in order to support other investigating authorities
- providing input to investigations conducted by the operator
- reviewing the investigation report of the operator or of another authority
- reporting major accidents and near misses to the eMARS database
- informing the public about major accidents,
- advising the operator on corrective actions following major accidents and implementation of lessons learned to limit the consequences of major accidents in future

In addition, the Seveso III Directive, which was implemented in 2015, added a new requirement for operators to this list. An operator of an upper tier establishment is now obliged to conduct a review of historical accidents with similar substances and processes and consider for their own operation the relevant lessons and recommendations with respect to the adoption of specific risk control measures. This new duty has no doubt stimulated interest in the lessons from past accidents and at the same time increased the demands placed on accident databases, both to support operators and to assist inspectorates in reviewing the information provided by the operators.

[1] https://emars.jrc.ec.europa.eu/en/emars/content

Figure 1 How the process works – from major accident to lessons learned



1.2 Chemical accident analysis and the process safety expert

Through various exchanges over the years, it has become increasingly clear that, when confronted with a major accident on one of their sites, many industrial sites and competent authorities, while sufficiently and even abundantly competent in chemical process safety, lack competence in accident investigation and analysis. This lack of expertise in this specific area hinders otherwise capable staff in conducting effective investigation of chemical accidents and identification of their lessons learned. The lack of competence often is a result of finite resources that are prioritised to ensure competence in more routine safety requirements, such as safety management and inspection, as well as a very limited exposure to major accident events. Moreover, this community is not well-supported by tools or training that take account of the diversity of situations that they may encounter or to their funding and time constraints.

The challenge facing both government and industry (especially small and medium size enterprises) is how to select and apply accident analysis and investigation methods that are suited to their resources, competences and objectives. Indeed, under the EU Seveso Directive (2012/18/EU), the two communities often have linked roles. The operator produces an investigation report, and the authority analyses the report, sometimes together with the results of its own investigation. They can have an influence on each other's work, particularly in improving the outcomes as illustrated in **Figure 1.**

There are numerous methods for analysing and investigating accidents but very few guidelines for how and when to use these methods, and how to conduct an investigation. Some methods cover both the investigation and the analysis, but generic guidance with practical advice on how to conduct an investigation is not widely available. This gap in the toolbox creates a challenge for those inspectors and industry personnel alike who are not routinely working with accident investigations. In their roles, they may never be directly involved in an accident investigation but they may need to monitor and provide input to investigations, they may need to review results, make their own reports and recommendations from them, and use lessons learned in their work. For all these tasks, they will need to recognise when good methods for investigation and analysis have been followed, and when results are both comprehensive and credible. The lack of any standardised approaches for the chemical accident community in particular can result in poorly structured accident reports that prevent the reader from gaining a coherent account of the event and render the task of developing recommendations especially problematic.

The need for more guidance on good practice for chemical accident investigation and analysis has long been a topic of discussions between the JRC-MAHB and the Seveso competent authorities. As part of this ongoing exchange, Sweden and JRC-MAHB organised a workshop in 2012 for Seveso inspectors focused on the challenge of investigating major accidents, of disseminating lessons learned and maintaining a lessons learning culture. (Weibull et al., 2020) The workshop identified a number of common challenges faced by inspectors:

- An inspectorate has inadequate experience or competence to analyse the company's accident report to determine that it is reasonably complete and accurate
- An inspectorate has inadequate experience to play a leading role in an investigation team (where it is a direct participant)
- An inspectorate has to investigate an accident of unusual complexity or with unusual or unfamiliar processes or substances
- An inspector is assigned a leading role in an investigation with insufficient training in accident investigation
- Inspectors are randomly assigned responsibility to report an accident to the European Commission with insufficient training in causal and lessons learned analysis.

Moreover, inspector exchanges revealed that only some Seveso inspectors have knowledge about investigations methodologies or have access to relevant tools and expertise. Many inspectors at the workshop did not feel that they or their colleagues had a lot of knowledge about investigation methodologies.

In contrast, there were some participants that were trained or had access to experts or tools such as checklists within the inspectorate to support investigation work. Indeed, it was generally agreed that such tools should be available to all Seveso inspectors if possible. They could even include background explanations so that non-experts can use them efficiently.

With this result in mind, the JRC-MAHB conceived the Accident Analysis Benchmarking Exercise (AABE). Its intention was to generate information and tools that could assist process safety experts in industry and government experts in conducting chemical accident investigations and analyses. This report describes the results of the project and its outputs.

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2 Project implementation and results

The AABE was conceived as a study that could provide practical insights to the process safety community in choosing an analytical approach for investigating accidents, and in analysing and drawing conclusions from an investigation report. The vision of the project was to engage a cross-section of experts working for or with competent authorities and industry to take part in an exercise to look at how different methods could be useful in different investigation contexts. Given that accident investigation and analysis methods has been studied by a wide variety of experts globally, and that it is a shared concern of many industrial countries around the world as well as rapidly emerging economies, the JRC chose to broaden the collaboration to partners outside the European Union.

The objective of the AABE was to compare findings produced by application of different accident investigation and analysis methods to a defined set of accidents and evaluate the use of the methods against agreed criteria. The criteria was designed to evaluate the effectiveness of the method in helping to generate different types of information, as well as its user-friendliness, and other relevant strengths and weaknesses associated with its application. This part of the exercise resulted in development of an analytical framework for process safety experts in making decisions about which analytical methods to use for analysing and investigating accidents, depending on the objectives, the type of accident, resource constraints, etc.,

The project was also intended to produce ideas for development of additionall tools and resources building on the project results. In particular, much of the discussion at the end of the project focused on getting practical information to the eMARS reporting community, mainly Seveso inspectors, to facilitate improvement of accident reporting to the eMARS lessons learned database. The end result of these discussions was a proposal to develop a handbook for Seveso inspectors on investigative and analytical practices. The participants made a list of factors that could form the framework for the contents of this handbook.

2.1 Design of the accident analysis benchmarking exercise

At the launch workshop the participants agreed to analyse selected past accidents using various investigation reports that are, for the most part, publicly available. The primary objective of the exercise was to compare the results produced by application of different accident analysis methods. It was not intended to recommend a best single method. The preferred end goal was to answer the question of how to choose methodologies that could meet the objectives established for the investigation. The operational aspects of the exercises and further elements (selection of methods and criteria for selection, accident(s) studied, etc.) were determined by the participants. [2]

Inevitably, accident investigation reports contain varying levels of detail. Workshop participants agreed that the exercise would encompass analysis of data-rich and data-poor cases. It was considered that the potential advantage of data-rich cases was to illustrate the full versatility and limitations of the different methodologies. However, many accident investigations are conducted with limited objectives and resources which result in incomplete investigation reports. Therefore, it was determined that both types of cases should be analysed to address a broad spectrum of issues that may arise in analysing a particular accident, and to ensure that an evaluation of the weaknesses and strengths of each method takes into account limitations imposed when the accident information is far from complete.

The teams were invited to select their own accident for analysis. The majority chose well publicised accidents to analyse, such as Buncefield[3], Texas City[4] and technological disasters caused by the 2011 earthquake in Japan[5]. A few teams also chose other lesser known accidents for analysis.

[2] A complete description of the AABE project, and references and resources for accidents and methodologies considered in the project, can be found at: https://minerva.jrc.ec.europa.eu/en/shorturl/benchmarking_exercise/description_of_benchmarking_exercise_public#CASE%20STUDIES

[3] A major fire at an oil storage terminal that started on 11 December 2005 in Hemel Hempstead, United Kingdom, considered Europe's largest fire during peacetime.

[4] A massive explosion and fire at a petroleum oil refinery in Texas City, TX, USA on 23 March 2005. The disaster resulted in the deaths of 15 people and injuries to at least 180 others.

[5] The accidents studied included the meltdown at the Fukushima Daiichi Nuclear Power Plant in Ōkuma and a major explosion at a Japanese petrochemical complex in the northeast city of Sendai.

It was decided to break down the analyses into three explicit phases and use appropriate methods for each phase as below.

- Phase 1: Chronology e.g. Step/ECFA
- Phase 2: Causal e.g. Bow Tie, Change Analysis
- Phase 3: Underlying causation e.g. AcciMap, MTO

Teams were tasked to work through an accident analysis starting with a chosen method from Phase 1, accident chronology, then progressing to Phase 2, accident causation and then finally to Phase 3, underlying causation. It was agreed that the results of the exercise would be shared at a future workshop hosted by MAHB.

2.2 Selection of accident analysis models for the exercise

From a modelling standpoint, many experts agree that accident investigation and accident analysis belong to the same discipline but that they are at different points in the accident analysis continuum. Investigation includes a specific tool for obtaining the data for the analysis. However, the investigation is driven by the analytical objectives. As much as possible, the report and its conclusions must go hand in hand with the purpose of the investigation. The key question of the investigation centres on who is going to use the report and for what purpose. The analytical model pre-identifies what the investigation must reveal and then the same analytical model analyses the resulting findings.

There are numerous accident analysis models for examining accident data and producing conclusions and recommendations. These models are simplified representations of accidents and each model emphasises different aspects of an event, its causes and contributing factors. Accident models are closely related to risk analysis methods as well as accident investigation methods, the difference being mainly timing (before or after an accident). During the exercise a total of eighteen accident analysis methods were used across the study teams and these with relevant web references are listed in **Table 1**.

Table 1 List of analytical methods used

#	Method	Web Reference
1.	Accimap	http://tiny.cc/gew45y (Page 61)
2.	ARIA 3 (BARPI method)	http://tiny.cc/q8m55y
3.	Barrier Analysis	http://tiny.cc/gew45y (Page 30)
4.	Bow-Tie	http://tiny.cc/4jy45y
5.	CAST (Causal Analysis using System Theory)	http://tiny.cc/zhx45y
6.	Chronology Description	No web reference. This is a simple timeline.
7.	DISC (Design for Integrated Safety Culture)	https://tinyurl.com/y23r2djn
8.	ECFA (Events and Causal Factors Analysis) ETBA (Energy Trace and Barrier Analysis) MORT (Management and Oversight Tree)	http://tiny.cc/dex45y
9.	ECFC (Event and Causal Factors Charting)	http://tiny.cc/gew45y (Page 27)
10.	ESReDA Cube	http://tiny.cc/o8x45y
11.	Event Tree (ETA)	http://tiny.cc/gew45y (Page 39)
12.	Fault Tree (FTA)	http://tiny.cc/gew45y (Page 37)
13.	MTO (Man, Technology and Organisation)	http://tiny.cc/gew45y (Page 50)
14.	Organisational Analysis of Safety (OAoS)	http://tiny.cc/ydn55y
15.	Root cause on a tiered sorting basis	No reference. This is a technique derived from multicriteria decision analysis
16.	STEP (Sequential Timed Events Plotting)	http://tiny.cc/gew45y (Page 45)
17.	Storybuilder	http://tiny.cc/v8v45y
18.	Tripod Beta	http://tiny.cc/xyw45y

Six teams managed to complete their chosen analyses and report the results to MAHB (out of the original eleven teams). Two teams completed the exercise by mid-2017 (Teams 6 and 8) and four teams reported completing the exercise in 2018 (Teams 1, 3, 4, and 7) The teams with their selected analysis methods are shown in **Table 2**. Naturally, the selected accidents that the teams analysed will be of interest to the reader and details are included below. The working assumption is that these accidents are representative, and that similar results and experiences would be obtained in using the same methods to analyse other major accidents.

Table 2 Team summary and chosen analysis methods

Study team	Accident[6]	Methods
1	Shell Moerdijk (2014)	Storybuilder, STEP, AcciMap, CAST, DISC
3	Toxic cloud in Belgium	BARPI's Method – ARIA 3
4	BP Texas City (2005)	Organisational Analysis of Safety, Energy Trace and Barrier Analysis (ETBA), Events & Causal Factors Analysis (ECFA), MORT, ESReDA Cube
6 Nuclear	Fukushima (Natech)	Fault Tree, Event Tree
6 Chemical 1	Cosmo Refinery (Natech)	STEP, Event and Causal Factors Charting, Barrier analysis on a tier-based sorting
6 Chemical 2	JX Refinery (Natech)	STEP, Fault Tree, Event Tree, MTO
7	Buncefield (2005)	STEP, Tripod Beta, AcciMap, CAST
8	Tianjin (2015)	Bow Tie, AcciMap

2.3 Implementation of the project

It was recognised that the exercise depended substantially on volunteer efforts and that a clear framework was necessary from the outset to guide the study teams. Shortly after the workshop, the teams were asked to submit a Team Information Form to JRC-MAHB that included details on team composition, the selected accident, methods to be applied for each phase and expected milestones and anticipated finish dates for the entire exercise.

For this reason, a few simple mechanisms were introduced to help keep teams motivated throughout the duration of the project and to facilitate communication to ask questions and compare experiences while the project was still ongoing, in particular:

- A team information form
- A methods evaluation table and SWOT analysis
- Final project workshop 2018

The project website was also established to provide a window to the public on project developments. It also had a private space for updating team members on progress, including publishing interim and final results.

[6] More information on these accidents is provided in links and documents on the AABE project website.

2.3.1 The Team Information Form

In the Team Information Form, each team reported its learnings and observations from using the various methods during each of the three phases of the exercise. This official reporting was supplemented during the exercise by periodic conference calls between MAHB and the participants and regular one-to-one exchanges by email and phone. Once a team finished the benchmarking exercise, they were asked to complete a Methods Evaluation Table.

The team reports were mainly a communication tool for sharing experiences and challenges during the exercise and for documenting findings and observations while the work was ongoing. The reports also helped to keep the loose group of volunteers together as a community. In particular, they helped motivate teams to continue the work despite longer than expected delays due to scarce resources and other priorities. The forms also provided a record of the project that was then used as a basis for the Methods Evaluation Criteria Table that each team was required also to complete. The summary of results for each phase was intended to capture the experiences of the teams in using the methods during the study and is outlined in **Table 3**.

Table 3 Team Information Form categories for each phase of the exercise

Description of exercise and methods used
Accident(s) studied
Expectations of outcomes
References used by the team, including tools, websites, publications.
What was the result of this process? e.g., -findings -questions, gaps in information that you hope to resolve in the next steps -scope of the investigation -limitations imposed by information available -potential themes already emerging -gaps in information
If you were an investigator or inspector, what questions would you ask the site following this analysis?
Advantages/ Disadvantages
Summary of experience working with the method(s) and advice for inspectors using these methods

2.3.2 Methods Evaluation Table and SWOT analysis

An important objective agreed at the launch workshop was the evaluation of the selected accident investigation methods based on team experiences. Hence, each team reported their final results in the Methods Evaluation Table. The table consisted of evaluation criteria described in Chapter 3. The topics were intended to capture the degree to which the level of effort required to understand how to use the method as well as the value of the method at each phase of the accident analysis. Since the questions themselves provided only objective responses, teams were encouraged to elaborate on their responses in the additional comments.

Despite the commonly held view that a quantitative result is more objective and robust, it is also apparent that investigation is a matter of knowledge, skill, expertise and capability which are features that are not readily quantifiable. Indeed, the criteria chosen to evaluate the analytical methods leaned more towards a qualitative character, mainly derived from the work carried out by Munson and Sklet. Therefore, in addition to the evaluation, the teams were invited to conduct a SWOT analysis on each method using the definitions below.

Strengths: Positive aspects of any kind, e.g., ease of use, results, logic used…

Weaknesses: Negative aspects of any kind, e.g., ease of use, results, logic used…

Opportunities: What kind of positive outcomes may result from the strengths?

Threats: What kind of negative outcomes may result from the weaknesses?

2.3.3 Final project workshop 2018

A workshop to present and discuss the AABE project findings was hosted by JRC-MAHB on 12-13 December 2018 in Ispra, Italy. This event featured presentations of the results of the various groups who participated in the Accident Analysis Benchmarking Exercise (AABE). The purpose of the workshop was to

- Compare the results of the exercise and identify important findings about the analytical process and methods used
  - Things that worked
  - Things that worked less well
  - Limitations (information available, methods)
  - Strengths and weaknesses of different methods
- Understand how these methods might guide the development of a tangible product for safety experts on accident analysis
- Envisage what such a product would look like especially in terms of scope, framework, tips and "mini" tools
- Identify possible information gaps related to accident analysis generally or specific methods where future collaboration might benefit.
- Generate ideas on how to use the outcomes of the benchmarking exercise to improve the outcomes of investigations

The findings from these three aspects of the project are presented in the next chapter.

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3 Results of the team exercises

In this section, the outputs of the Team Information Form, the Methods Evaluation Table and SWOT analysis are described. The 2018 workshop served as an opportunity for participants to review and discuss these outputs in depth by participants and to exchange ideas on how the information could be used to create a tool or tools for chemical accident analysis in future. Ultimately, it was determined that the team findings presented in the Methods Evaluation Table and SWOT analysis already provide useful tools for investigators to decide which mechanisms to use in a specific accident investigation. For other practitioners, they could also help guide understanding of how certain conclusions were reached in the investigation reports, based on the kinds of methods used in the investigation, and also potentially take into account their strengths and weaknesses in identifying causality.

3.1 Highlights from the Team Information Forms

The Team Information Form captured the experiences of the teams in the application of analysis methods. Some selected comments as far as advice to other inspectors are reproduced below.

"**STEP** is particularly suitable at the beginning for the documentation of the collected data and for the determining the need of additional data. At the beginning it is good to list all "actions", "actors" and "time" e.g. in Excel. Different colour Post-it notes help when defining the timeline and what information is still needed. It is possible to analyse also "positive events" in the accident. It might be recommended to make a "lighter" STEP analysis (the collection and organisation of data, the chain of events) and in addition AcciMap in order to determine more extensive underlying factors."

"**ACCIMAP:** If you want to check how deep your investigation is : use the different levels (you can create your own levels and add them depending on the breadth and depth of the organisational structure. Add link(s) to government and other organisations in the surrounding environment of the organisation)."

"**ACCIMAP:** In our authority the accident is described graphically by AcciMap in the accident investigation report. We think AcciMap is descriptive in the authority's investigation report (sociotechnical levels, incl. legislation."

"**TRIPOD BETA:** Some latent failures seemed to have a long chain [of underlying causes] and it was difficult to put the chain in the diagramme. For example, with Buncefield, there was a long chain (with missing links) that led to corporate management failures and a long chain that led to failures in the supplier and installation of equipment. It almost discourages you from making these connections because it is visually clumsy."

"**TRIPOD BETA:** [One] had to look up possible barriers and why they might have failed individually. Sometimes this required a little research, but it was very helpful. For example, [the] team originally indicated a missing barrier of "sprinkler failure" in two locations. In one location, [it was discovered] that there would not have been a sprinkler (not good practice) and for the second, [one] had to assume that there WAS a sprinkler system but it was knocked out by the explosion."

"It was quite difficult to get information from the past events. Also, the tool **Bow-Tie** and **AcciMap** did not make possible to catch all information in its format, [one] would have needed more room for [one's] thoughts and findings but the [tools have] their limits."

Some of the teams noted that the application of the accident analysis method showed gaps in the information produced in the original investigation.

"For many accidents it is difficult to find information in accident investigation reports on the corporate governance arrangements. Often it is instructive as someone who is reviewing an investigation report to identify what is absent rather than what is included. "You find what you seek""

"There are many questions raised by the **CAST** analysis that are not answered in the accident report but would have guided the investigation in terms of what questions to ask. There were many factors that probably were related to the poor safety culture and safety management system at Shell, but these were not included in the accident report so the CAST analysis could only speculate about why they occurred."

Except in one case, these gaps were noted in the third phase of the analysis (underlying causation). In the exceptional case, the investigation report contained limited technical information for the second phase (direct cause), but was abundant information on organisational factors. These observations are consistent with the findings of research conducted by Strömgren et al., in which it was concluded that no accident analysis method can fully support all phases of an accident investigation.

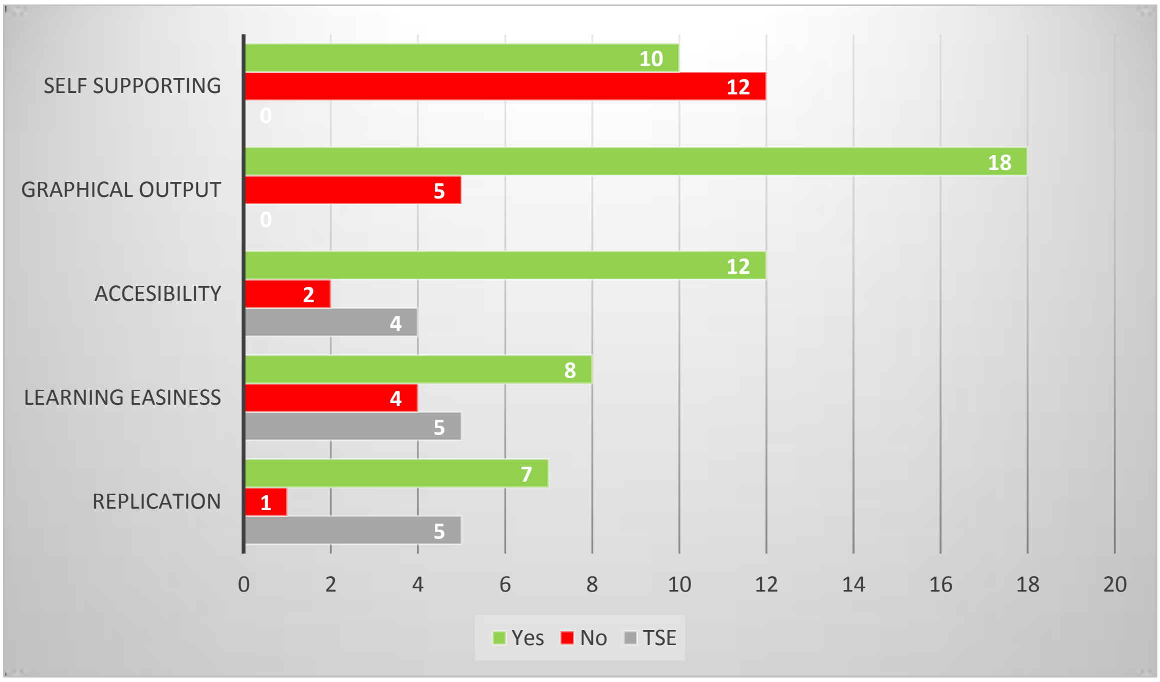
3.2 Evaluation of accident analysis methods using objective criteria and SWOT analysis

The project participants determined that the project should also aim to produce a semi-quantitative evaluation of each method used to help potential future investigators and analysts to choose appropriate methods and to also evaluate the results of investigations where a particular method, or methods, has been used. For each response categories, the participants were required to choose from a range of predetermined responses as shown in **Table 4.** The results of the Methods Evaluation Table are compiled in **Table 5** and **Figure 2**. The table aggregates the results of twenty-five individual method evaluations. STEP, Tripod Beta, AcciMap, Fault Tree and Event Tree analyses received evaluations from more than one team.

Table 4 Methods Evaluation response options

Criteria	**Description**	**Range of possible responses**
Self-supporting	Some methods intend to cover the whole event analysis process whereas others could be (are) used as input for other analysis methods	Yes/No
Graphical output	Some methods propose a diagramme of the accident sequence (graphical representation of the scenario). It is intended to help understanding of the event and to provide a tool for better communication between investigators	Yes/No
Accessibility	For some methods documentation is freely accessible while for others documentation incurs a charge.	Yes/To some extent (TSE)/No
Learning easiness	Can method be used with no "extensive formal accident analysis training" and/or with no "deep" knowledge about some scientific domains (e.g. sociology, engineering science…)	Yes/To some extent (TSE)/No
Scope of analysis	A method will address different levels of the sociotechnical system.	1. Work and technological system
		2. Staff level
		3. Management level
		4. Company level
		5. Regulators and associations
		6. Government level
Duration	According to method used duration of an analysis could differ	Days/Weeks/Years
Replication	Even if an analysis method allows some flexibility, it needs to be sufficiently robust so that its results/outputs do not depend on the analyst(s) [different analyst(s) would reach (more or less) the same result applying the same method on a specific event]	Yes/To some extent (TSE) /No

Figure 2 Analysis of objective scoring



Key to the Table

Phase	1= chronology	2=causal causes	3= root cause	TSE = to some extent
Scope	1=the work and technological system	2=the staff level	3=the management level	
	4=the company level	5=the regulators and associations	6=the Government level	

According to the team evaluations, as shown in **Figure 2**, less than half of the methods were self-supporting, including Organisational Analysis of Safety, ETBA, CAST and AcciMap. Teams disagreed on whether STEP, FTA and ETA were self-supporting. The graphical output was notably high for most methods, with the exception of ETBA, the Chronology Description method, and Organisational Analysis of Safety. Two methods (Barrier analysis and Tiered Root-Cause) were not rated in this aspect. Where accessibility was rated as was largely considered positive but mixed in regard to ease of learning. Most methods were applicable to up to the 4th level of the socio-technological system, with a few methods also achieving analyses for regulators and policymakers. Nearly half of the methods needed only a few days to apply to the selected cases, while results were achieved with six methods in a matter of weeks, and three methods were indicated as taking a few months to complete. A good portion of the methods seemed fairly easy to learn even if application was more complicated in some cases, and therefore, took more time to achieve results.

Table 5 Methods as evaluated by different teams

Method	Team	Phase	Self-supporting?	Graphical Output?	Accessibility?	Learning easiness?	Scope of investigation	Duration	Replication?
AcciMap	7	3	Yes	Yes	Yes	Yes	1–6	Weeks	Yes
	8	3	Yes	Yes	Yes	Yes	1–6	Weeks	Yes
ARIA 3 (BARPI method)	3	1,2,3	No	Yes	TSE	Yes	1–4	Days	Yes
Barrier Analysis	6	1,2,3					1–6		
Bow Tie	8	2	No	Yes	No	Yes	1–4	Days	Yes
CAST	7	3	Yes	Yes	TSE	TSE	2–4	Days	
Chronology Description	6	1	No	No	Yes		1–6	Weeks	TSE
ECFA	4	1	No	Yes	Yes	Yes	1	Days	
ECFC	6	2,3	No	Yes			1–6		
ESReDA Cube	4			Yes	Yes	No	1–6	Weeks, Months	TSE–No
ETBA	4	2	Yes	No	Yes	Yes	1	Days	
Event Tree	6	3	Yes	Yes	TSE	No	1–2	Months	Yes
	6	2,3	No	Yes			1–6		
Fault Tree	6	3	Yes	Yes	TSE	No	1–2	Months	Yes
	6	2,3	No	Yes			1–6		
MORT	4	3	No	Yes	Yes	TSE	1–4	Weeks	
MTO	6	2,3	No	Yes			1–6		
Organisational Analysis of Safety	4	1	Yes	No	Yes	TSE	NA	Weeks	TSE
		2	Yes	No	Yes	TSE	1–2/3	Weeks	TSE
		3	Yes	No	Yes	TSE	3–6	Weeks	TSE
Root cause on tiered sorting basis	6	2,3					1–6		
STEP	6	1,3	No	Yes			1–6		
	7	1	Yes	Yes	Yes	Yes	1–4	Days	Yes
Storybuilder	1	1,2,3	No	Yes	Yes	Yes	1–4	Days	TSE
Tripod Beta	7	2,3	No	Yes	No	No	1–4	Days	

Table 6 SWOT analysis of methodologies used (p. 1 of 4)

Method	Strengths (Positive aspects of any kind, e.g., ease of use, results, logic used, etc.)	Weaknesses (Negative aspects of any kind, e.g., ease of use, results, logic used, etc.)	Opportunities (What kind of positive outcomes may result from the strengths?)	Threats (What kind of negative outcomes may result from the weaknesses?)
AcciMap	Easy to understand the principles Does not require commercial software. The output can be adapted to suit the case in question.	Requires intensive work on tracing information and mapping it to the correct level of the system. Does not have a graphical tool, so the analysis is conducted by hand. Not formally standardised.	Opportunity to discover the relationships between actions within the system. Makes very clear that technological failures have causes within the organizational and management system (and possibly also external influences and drivers.	The work involved and lack of formalised "boxed version" means that the principles must be learnt first and then the information sorted before developing the final AcciMap. This is a lot of work, which may lead to the approach being rejected as it is not seen as being standardised.
ARIA3 (BARPI)	Concrete and rational output Emphasize the distinction between disturbances and organisational causes	Does not allow to underline positive actions. Focused on the causal understanding (no element on consequences)	Communication tool between inspection body and operators Supposed blocks allow to raise questions and missing information => force deeper analysis	Focused on plant operator responsibility only
Barrier analysis	Sufficient from the point of digging into root causes and handling the facts.	Listing approaches may cause confusion if the accident Contains many simultaneous events, using of charting Methodologies can be much more convenient in such case. It does not force the analyst to consider a further domain of the accident.		

Table 6. SWOT analysis of methodologies used (p. 2 of 4)

Method	Strengths (Positive aspects of any kind, e.g., ease of use, results, logic used, etc.)	Weaknesses (Negative aspects of any kind, e.g., ease of use, results, logic used, etc.)	Opportunities (What kind of positive outcomes may result from the strengths?)	Threats (What kind of negative outcomes may result from the weaknesses?)
Cause and Events Analysis	Good technique for simple and straight-forward events	Listing approaches may cause confusion if the accident contains many simultaneous events, using of charting methodologies can be much more convenient in such cases.		
ESReDA Cube	Emphasises learning. What may be learned from the individual facts of the event and who could benefit from the learning? A communication tool. Facilitates discussions amongst stakeholders on identified topics. It assists the user to use a systematic approach to look at an accident and discuss about it. Integrated and systematic way of looking at an event (near miss, incident, accident), taking stock of the organisational context, level of stakeholder responsibility and depth of learning required.	Results depend on the scope of the analyst(s). Analyst(s) need to be clear, both on the viewpoint and goal, of the analysis. If a team of analysts is formed, convergence is needed in understanding chronology of events and related causes. Should not be used as a stand-alone method, but as a supporting method, as it is more like a model, rather than a method. Does not include timeline of events or causality.	Model may be used before the investigation as a planning tool. Model may be used during the investigation to identify what has been missed in the investigation so far. Model may be used at the end of the investigation to pinpoint recommendations to specific stakeholders. Model may be used after the event to analyse the event or to analyze the investigation process itself.	When planning resources, use of the Cube will also require another method for chronology and causality to be used beforehand. This must be catered into the decision on whether to use the Cube.
Fault Tree Analysis Event Tree Analysis	Root cause analysis Flow and Sequence are clear	Only one accident (not suitable for multiple accidents)	Should be used in combination with other methods	

Table 6. SWOT analysis of methodologies used (p. 3 of 4)

Method	Strengths (Positive aspects of any kind, e.g., ease of use, results, logic used, etc.)	Weaknesses (Negative aspects of any kind, e.g., ease of use, results, logic used, etc.)	Opportunities (What kind of positive outcomes may result from the strengths?)	Threats (What kind of negative outcomes may result from the weaknesses?)
MTO	• Root cause analysis • Barrier analysis • Change analysis	Only one accident Actors are not clear	Should be used in combination with other methods	
Organisational Analysis of Safety	Easy to use. Goes beyond the “human” error paradigm. Provides with a global vision of the situation	Time (and therefore money) consuming method. Definition of efficient improvement can call for questioning. It’s easier to find out organisation pathological factors rather than resilient factors Organisational paradigm is not yet fully stabilized. Lack of ability to "reflexivity" for the managers	Possibility to make fundamental improvements in safety	Results of analysis not acknowledged not to say denied or refused

Table 6. SWOT analysis of methodologies used (p. 4 of 4)

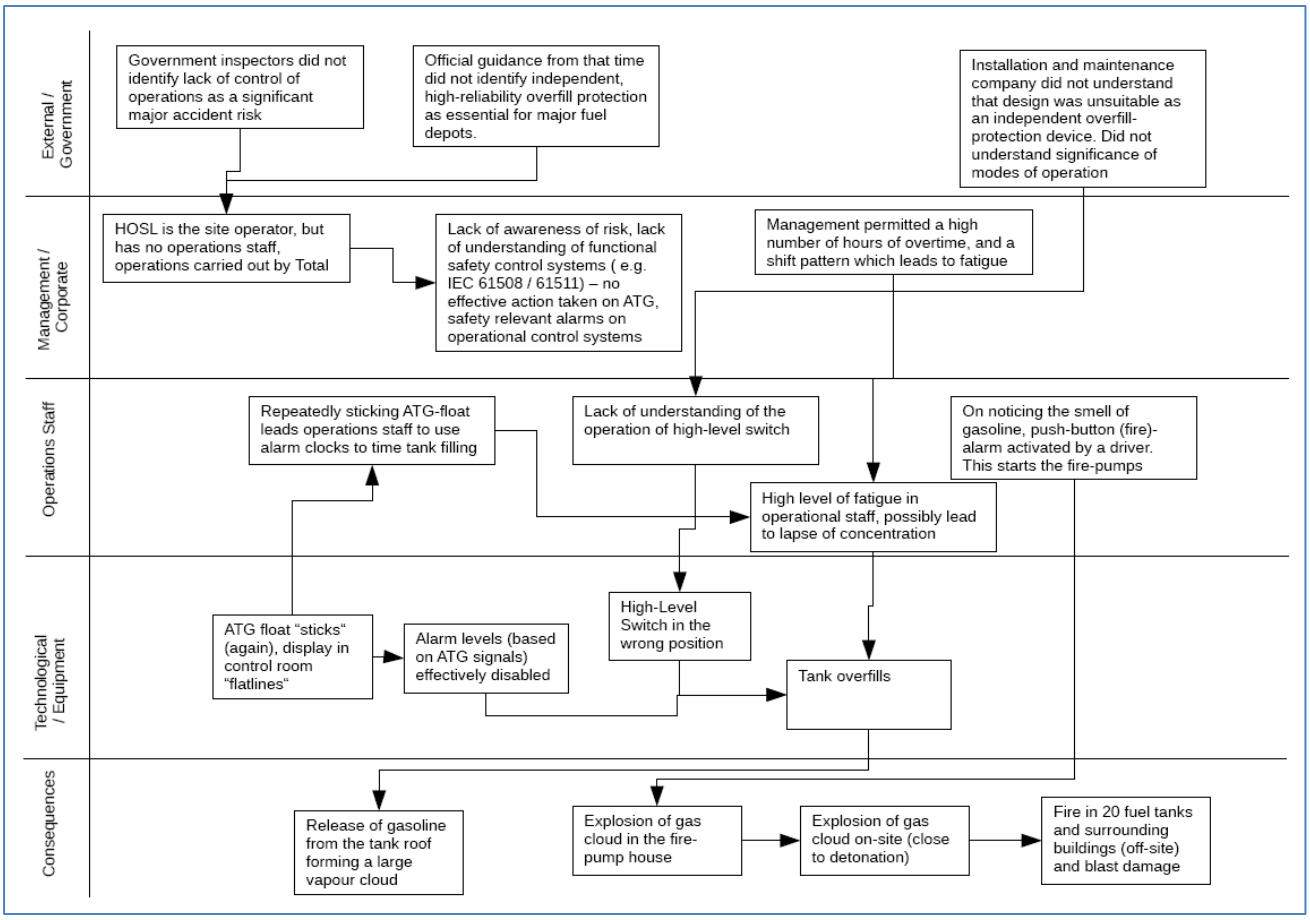
Method	Strengths (Positive aspects of any kind, e.g., ease of use, results, logic used, etc.)	Weaknesses (Negative aspects of any kind, e.g., ease of use, results, logic used, etc.)	Opportunities (What kind of positive outcomes may result from the strengths?)	Threats (What kind of negative outcomes may result from the weaknesses?)
STEP	Very easy to use with just pencil and paper. Simple and transparent output. Time sequence is described. Actors and subjects are clear. STEP is modified as new information surfaces and thus it is also useful in pointing out the grey areas where more information is necessary	Very simplistic. Only provides a timeline and list of actors No Barrier analysis. Relation among actors is not clear	Easy choice for any safety expert no training needed. Provides a timeline of events as a starting point for analysis	Another method is required to analyse what caused each event on the timeline
Tripod Beta	Detailed barrier analysis provides strong foundation for many types of indirect analysis. With software, the output is very user friendly. Without software, it is not possible.	Requires purchase of software. May require some training to use, but if one has already worked through a bow-tie analysis, self-training may be possible. Becomes difficult to work with in complex cases because the graphic presentation becomes too large for a computer screen Does not really work well for indirect causes, partly because of the challenges with graphic representation but also because the method does not give a satisfying way to describe complex causality of indirect causes	Excellent for understanding direct causes, especially in complex situations. It provides a solid foundation for further analyses of different types, e.g., human and organisational factors, the role of regulation, etc.	The cost of software and the need for training may make this method inaccessible to many inspectors.

3.3 The SWOT analysis

To complement the objective evaluation of methods, the participants also required teams to complete the SWOT evaluation, a qualitative evaluation on the methods used. **Table 6** displays the observations each team recorded in the SWOT table. The strengths cited most often related to ease of use (and understanding) and the way that the analysis supported discovery of deeper insights. Observations in terms of weakness were more diverse. Some methods were noted for limitations in dealing with certain issues, such as the inability to capture “positive actions” in ARIA3, and the awkwardness of the visual graphics associated with indirect causes in Tripod Beta and the time required for “mapping” the accident to the model was cited for some methods, for example, Accimap and Organisational Analysis of Safety. (See **Figure 3** below for an example of the Accimap illustration produced in Team 7.) The investment in training or software purchase was also indicated as a weakness for some methods.

The opportunities and threats generally built on the strengths and weaknesses identified. Opportunities associated with each method usually were in relation to the type of learning that could be achieved, e.g., “excellent for understanding direct causes”, “opportunity to understand the relations between actions within the system”, etc. Many methods were also identified as being helpful in combination with another method or as a foundation for additional analyses. (In discussions about methods in the follow-up workshop, the teams generally agreed that this was an attribute shared by all the methods.) The communicating power of the method was also highlighted as an opportunity for some methods, in terms of flowcharts, tables, and statistics that some methods generated. In terms of threats, the training investment, the time investment, and the lack of formalized training tools, were most commonly mentioned.

Figure 3 An Accimap of the Buncefield accident



Source: Team 7 Presentation

4 Applying the project results

After reviewing the results of the team exercise, participants of the 2018 workshop reflected on insights obtained from their experiences in conducting the accident analysis exercises for accident investigation and the lessons learned process in general. The aim was to understand how the project findings could be used to give guidance to practitioners to help evaluate various methods for use in an investigation or to shed light on how conclusions were reached in an investigation report. The discussion sought to

- Identify who is the community in need of more guidance in investigation and lesson learning processes
- What are the priorities, needs, objectives and competences of this community
- What could the AABE produce from its work that would support this community.

4.1 The inspector as a key actor

Early in the discussions, the group reached a consensus that the government inspector, particularly as defined in the EU Seveso legislation, represents one of the key targets for additional support in investigation and analysis in the community engaged in chemical accident risk management. Typically Seveso inspectors are, or become through experience, experts in process safety to varying degrees and with varying specialties. They often are not trained formally an accident investigation or analysis, but they are users of the lessons learned and may have responsibilities such as, overseeing or advising on investigations, reviewing investigation reports, and summarising lessons learned from these reports. Many safety staff in industry may also share this profile to some degree.

The JRC has the ability to reach a wide network of inspectors through which any guidance and recommendations could immediately be challenged. The JRC also has some influence in accident reporting and the dissemination of lessons learned through its eMARS chemical accident reporting system. For all these reasons, the government inspector was chosen as the target group of reference for discussion about needs and priorities.

Following this agreement, the group had a roundtable discussion on the numerous ways that government inspectors, in particular EU Seveso inspectors, are engaged in chemical accident investigation and analysis, The discussion sought to understand the motivations (coming from regulations, legal structures, and other influences, that would shape the specific responsibilities assigned to an inspector. In addition, what kind of competences would be associated with these responsibilities. **Table 7** summarises the conclusions from the exchanges. The exercise resulted in a list expectations and requirements in regard to the inspector's role in accident investigation from different perspectives. This collection of ideas helped the group to focus on what expectations and requirements were potentially not being met.

From the perspective of inspectors, the group surmised that most, if not all, of the items on the inspector "wish list" related to their relationship with the operator. In many cases there may be a desire to observe and learn from the operator during an actual investigation in a genuine spirit of mutual learning. Another wish might be the ability to validate the competence and the operational readiness of the operator in investigating accidents. It was though that prioritising increased competence and confidence of inspectors would be a significant benefit to inspectors. These qualities could possibly emerge from better or more training and education in accident investigation and the availability of user-friendly guidance and tools.

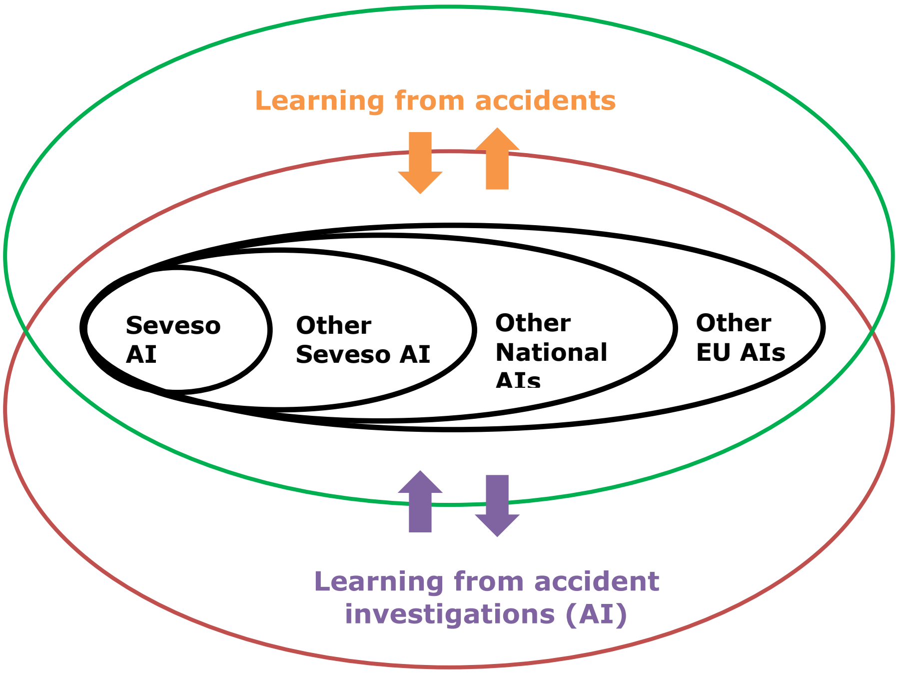
It was also recognised that that regular opportunities to practice these skills would help inspectors to maintain competence in major accident investigation. However, opportunities for Seveso Inspectors tend to be rare because largely it is the operator, under the supervision of the authority, who conducts the investigation into an accident. If the authority believes that an independent or additional investigation is required, then the authority will tend to contract out the task to a specialist third party.

With respect to the process of accident investigation it was felt particularly important for investigators to know when to stop an investigation and to continue with an investigation. It was recognised that this judgement depends greatly on the terms of reference for the investigation which should be fixed down from the start.

Table 7 Connecting to the world of major accident investigation

With respect to accident investigation it is important that inspectors	With respect to accident investigation, inspectors wish to	With respect to building inspector capabilities, action should be taken to	Accident investigators in general need to
• Understand the investigation process and are able to audit the process effectively. • Learn from the past (tools and data) • Understand deviations • Understand life-saving rules and barrier block & recovery • Know questions to be asked in the aftermath of an accident • Know when to stop and when to continue an investigation • Work to principles of good investigation practice and understand their input to analysis • Select right type of model for situation (what to use in investigation vs accident report) • Connect with the "big picture" of the process safety world, e. g., industry trends	• Influence operator to investigate accidents to prevent re-occurrence • Observe operators in investigation & feedback their insights • Join meetings of senior management in aftermath of accident • Have an answer to the question: Has operator engaged in accident investigation and lessons learning through accident follow-up procedures?	• Build inspector competence in accident investigation so that they can challenge operators • Provide the confidence for inspectors to present findings • Educate inspectors to be able to challenge specialists (raise status of inspectors) • Assist individuals to extract information from accident report for input into eMARS and national databases? • Recognise that the majority of inspectors have a role in accident investigations but it differs. • Provide lessons for inspectors • Provide reference sources • Offer training/mentoring/recognition	• Look at upstream factors • Divide the investigation into phases • Break up findings into digestible pieces of guidance/info • Possess independent critical thinking to understand complexity of causal chains • Understand that investigation is primarily about preventing event reoccurrence • Understand what went wrong to prevent reoccurrence • Have quick and easy way to structure data • Lead investigation to obtain as reliable, accurate and complete data as possible

Figure 4 Connecting to the world of major accident investigation



It was felt important for accident investigators to connect with the "big picture" such as developing knowledge and understanding the patterns and trends of an emerging technology such as the biogas sector. This sense of "big picture" could also apply to connecting to other major accident investigation processes such as illustrated in **Figure 4**. Sharing the learning from the accident investigation for instance with other Seveso accident investigators and national and European wide accident investigators in sectors such as aviation and nuclear sectors would appear to be of significant benefit.

4.2 Future work of the AABE group: Terms of Reference for an investigation

After brainstorming on the inspector's expectations and requirements, the group determined that a good starting point could be the establishment of Terms of Reference for accident investigation. Currently, very few tools exist in simple form that could help inspectors obtain a perspective on what a good investigation looks like. There is a need to have some guidance for those who have not been specially trained in accident investigation so that they have confidence in giving advice, in reviewing reports of lessons learned and root causes, and deciding what information can be more generically useful to other similar sites and even other industries. The group arrived at a consensus on what the basic elements of Terms of Reference could be. These elements are elaborated in **Annex 1**.

The group also considered the need for a systematic approach to organising the accident investigation. It was proposed, consistent with observations in **Table 7**, that an accident investigation can be divided into two phases, as follows:

- **The planning phase**. In this phase, the purpose and outcomes of the investigation are determined, resources and responsibilities are allocated, on which basis the Terms of Reference are established. The investigation will also make decisions regarding what method or methods will be used, providing a framework for identifying data needs and for organising and analysing data collected.
- **The implementation phase.** In this phase, the investigation has started, beginning with the collection of data through interviews, observation, and forensic studies. At various stages, investigation will need to begin directing decisions towards the output. Based on the story that is unfolding, the investigation will focus attention on certain lines of causality, collecting and examining data to shape

Figure 5 Key questions in the planning phase

PURPOSE

- ☐ Enforcement?
- ☐ Learning for the operators?
- ☐ Learning for the industry?
- ☐ Learning for the regulators?
- ☐ Data analysis/trend analysis?
- ☐ Learning from the accident investigation process?
- ☐ Preventing the same accident from recurring?
- ☐ Learning about possible future scenarios?
- ☐ Preventing the pattern from becoming an accident?

TERMS OF REFERENCE

- ☐ Are the terms of reference/scope of the investigation formally established?
- ☐ Are the investigation ToR tightly defined?
- ☐ Are the ToR sufficiently clear to determine the depth of the investigation?

OUTPUT

- ☐ What kinds of output?
- ☐ What will stop this accident from happening?
  - Lessons to be learned.
  - Data for analysis.
  - Improve the risk assessment, scenarios, SMS, safety report.
  - Compliance with regulations and standards.
  - Corrective and preventive actions

STRATEGY

- ☐ What methods or tools will be used?
- ☐ What kind of date is to be collected?
- ☐ How will the objectives be met?
- ☐ What resources are required, people, money, time?

RESOURCES, PEOPLE, CONSTRAINTS AND OPPORTUNITIES

- ☐ Individual and team competence.
- ☐ Conflicts of Interest
- ☐ Psychological health of inspector.
- ☐ Training, guidance, support
- ☐ Legal framework and constraints.
- ☐ Interactions with other investigations (e.g., police)
- ☐ Interaction with the media (if any)

RESPONSIBILITIES

- ☐ What kinds of models/tools/experts to use?
- ☐ Who to interview?
- ☐ What is scale of the investigation, e.g., complexity, time constraints.
- ☐ Who has what information?

COMMUNICATION PATHWAYS

- ☐ Working with the operator/controlling resources/working with experts.

Figure 6 Key questions in the implementation phase

INFORMATION COLLECTION AND RECORD-KEEPING

- ☐ Recording facts and findings
  - Physical – scene of the accident
  - Written - documents
  - Verbal – accounts of witnesses
- ☐ Creating sequence of events,
- ☐ Confidentiality
- ☐ How do you put it together? (aligns to the chosen analytical methods)
- ☐ Traceability of information (where did you get the information)

ANALYTICAL METHODS

- ☐ How do you identify critical information?
- ☐ How do you determine the loss of containment?

MAKING THE CASE

- ☐ Having the evidence to make your case.

FRAMING OF OUTPUT

- ☐ Perspective – upstream vs. downstream, the "big picture" systems, underlying causes, organisational factors, lessons to be learned for the operator, responders, industry, regulator, etc.

COMMUNICATING

- ☐ Results to operator/to your management/to a wider audience (e.g., eMARS, national authorities).
- ☐ Adjust the inspection plan.
- ☐ Implementing recommendations.
- ☐ Changing SMS, procedures, processes, risk assessment, scenarios, emergency plan, etc.

FINAL CHECK:

- ☐ What does success look like?
- ☐ Did you achieve your objectives?
- ☐ Did you have a plan?
- ☐ Did you execute your plan as you designed it?

REVIEWING THE INVESTIGATION.

- ☐ What will you do differently?
- ☐ What have you learned?
- ☐ What went well?
- ☐ What can you communicate to other inspectors-your organisation about what was learned?

some theories and discard others. After reaching final conclusions, the investigation then needs to identify effective means for communicating findings, crafting key messages (e.g., "breaking up findings into digestible pieces" as indicated in **Table 7**), identifying stakeholders, and recommending actions to be taken.

The group generated numerous ideas on what kinds of questions should be addressed in each of the two phases. **Figures 5** and **6** represent the results of this reflection. The checklist is intended to act not as a prescription but as options for the conduct of accident investigation, analysis and reporting that is expected to support progress towards better quality outcomes from Seveso accident investigations and improved reporting. The checklist provides a framework which would benefit from underlying support material and in turn would require review and validation from a working group of investigators, inspectors and analysts such as that established for the AABE.

The group then tentatively agreed to continue working together on a voluntary basis within the MAHB project to produce a simple guidance, or handbook, on the basis of these Terms of Reference and key questions starting in 2020. The proposed handbook would aim to be of value to inspectors who wish to

- conduct accident investigations
- supervise operators who are conducting accident investigations
- engage third party contractors to investigate accidents

It was proposed that the future work should be directed towards answering the needs of the inspectors as indicated in **Table 7** as a basis the checklist outlined in **Figures 5** and **6**.

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5 Conclusions

Learning lessons from accidents is a fundamental principle in preventing technological accidents and mitigating their effects. The principle has been well-recognised in the field of chemical process safety and enshrined in industry codes of practice for managing chemical accident risk, such as Responsible Care and in parallel legislation, most notably, the EU Seveso Directive. Nonetheless, it has been generally agreed that safety engineers and competent authority inspectors, who may one day be charged with running or advising on a chemical accident investigation, do not always feel sufficiently experienced or competent in all aspects of investigation and analysis to produce a thorough lessons learned analysis. While they diligently share lessons learned within such forums as the EU eMARS database, their reports may not always be reliable reflections of lessons that could have been learned from an incident.

The JRC organised the AABE project as a means to give greater support to operators and inspectors that are overseeing investigations or analysing the results of investigations, of chemical accidents that are reported into eMARS. The AABE began with the benchmarking of accident investigation and analysis methods because these tools tend to be one of the most important and least understood elements of a chemical accident investigation. Technological accidents tend to have complex causality and chemical accidents are a large subset of accidents of this type. This complexity is a challenging aspect of investigation and analysis of these events. For this reason, numerous accident investigation and analysis methodologies have been developed to generate investigators and analysts identify reliable learning lessons for avoiding future similar accidents.

As an outcome of the exercise, the participants produced tools for investigators to use to make decisions on what methods to use for their investigation. These same tools could also help analysts, reviewing investigation reports, to understand the methodology followed by the investigation and to apply their own methods to the data if necessary. These tools also include resources and examples to assist in learning about each method.

However, the benchmarking exercise also helped to reveal further potential tools that could be developed to support operators and inspectors in investigation and analysis of chemical accidents. Using the Seveso inspector as the typical user, the project participants generated a list of expectations and requirements for the inspectors involvement in the follow-up to a serious chemical. Based on these reflections, the group developed a framework for Terms of Reference, and key questions for planning and implementation of the investigation, around which a future handbook for Seveso inspectors on investigation and analysis could be produced. If resources allow, the JRC will begin organising this effort with participants of the AABE project starting in 2020.

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List of abbreviations and definitions

In this report:

- An **incident** is defined as:

  An occurrence that either resulted in, or had the potential to result in, a process upset with potential process condition excursions beyond operating limits, release of energy or materials, challenges to a protective barrier, or loss of stakeholder confidence in a company's reputation.

- An **accident** is defined as :

  An incident, that is, an unplanned event or sequence of events, that results in an undesirable consequence.

- A **near miss** is defined as:

  An incident in which an adverse consequence could potentially have resulted if circumstances (weather conditions, process safeguard response, adherence to procedure, etc.) had been slightly different.

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Annexes

Annex 1. A proposed accident investigation terms of reference (ToR)

D.1 Introduction

The purpose of an investigation is to establish the sequence of facts around the incident in order to determine what happened, why it happened and what actions are required to reduce the risk of recurrence and improve safety through shared learning.

Terms of reference (ToR) form the foundation stone for the commencement of an investigation. They should clearly and concisely set out the issues and scope of the review as well as the core people, boundaries and methods to be utilised. Defining matters that are in the scope of the review are particularly important in ensuring that the review stays within those bounds. The importance of spending time debating and developing terms of reference for an adequate and appropriate review should not be underestimated.

D.2 Benefits of a TOR

As well as establishing an understanding of what is required and by when, ToR can prevent such pitfalls as misunderstandings, unintended breaches of privacy and negative effects on relationships. Sound ToR provide the means by which emotive or biased considerations can be eliminated from the review and provide an excellent starting point for drafting an investigation plan.

When matters that have been investigated subsequently move into legal processes, ToR and constituting documents may be subject to significant scrutiny by courts or tribunals. The availability of a well-defined and expressed TOR in conjunction with evidence that the investigation applied was in line with these can mitigate against challenge at a later stage.

D.3 The contents of a ToR

The ToR typically contains the following elements;

Introduction

The introduction provides a brief overview of the background to the incident being reviewed e.g. this is the ToR in relation to <an incident> which occurred in XX location on XXXX date. It also identifies who is the commissioner of the investigation.

Purpose

The purpose of the investigation details the rationale and sets out what the investigation is required to examine. It may be described in terms such as:

"To establish the facts relating to <the incident>, to identify any factors which caused and contributed to <the incident> and to make recommendations which when implemented would reduce the risk of a similar incident occurring in the future."

Scope

The scope sets out the bounds of the review. Determining the scope is a critical component of the investigation. Defining and maintaining a clear understanding of the investigation's scope, and effectively conveying that to relevant parties, is essential to an effective review. Without a statement of scope, the investigation team may be tempted to take the investigation into areas that are not necessarily material to the original incident and the investigation may lose direction.

When determining scope, it is important to cast the net wide enough to ensure that the incident elicits all relevant facts. Therefore, the scope should be framed as broadly as possible around the central focus of the incident.

Membership of the investigation team

This should provide detail of the names and titles of the team and identify the investigation leader. It should also include detail of any experts or other persons to whom the team may access for advice.

Objectives

The objectives set out the actions and deliverables required by the incidents and should contain the following detail;

- The policy under which the incident is being carried out,
- The process and methodology to be applied
- The need to ensure that the investigation adheres to the principles of natural justice and fair procedures.
- The preparation of a report to the commissioner providing details of the incident, findings and recommendations

Timeframe for the completion of the review

This should include the expected timeframe for completion of the review and as well as establishing the need to advise the commissioner of any issues that might result in a delay to achieving completion within the stated timeframe.

Revisions to the ToR

Whilst it is not desirable, in some limited circumstances there may be a need to amend or modify aspects of the ToR during the conduct of an investigation, e.g., due to unanticipated events or the availability of new information. The availability of an amendment clause may therefore be advisable. If it is decided to include such a clause then the process attaching should be explicit, e.g., following discussion and agreement with the commissioner and that all parties will be informed of the change.

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