

# Fire investigation as learning tool

Audun Borg  
Norconsult AS  
Sandvika, Norway  
Audun.borg@norconsult.com

Ove Njå  
Seros  
University of Stavanger  
Stavanger, Norway  
Ove.njaa@uis.no

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## ABSTRACT

Fire investigation in Norway is an activity currently related to responsibilities, liability and Police investigation. This paper provides an initial discussion on concepts and methodologies for learning based fire investigations. Of special interest is potential benefits from fire investigations to fire safety engineering (FSE).

Available methodologies for conducting fire investigations are well established, but they lack learning perspectives. Learning is considered an inherent and natural part of the process. This is a flawed assumption. There is a gap in transferring the lessons learned from the fire investigations to target groups as well as to other related disciplines. For example, there is no methodology in place to ensure that the lessons learned from a police investigation related to fire safety is communicated to the fire safety engineering community. We postulate that fire investigations are about guilt. As a learning tool it is a ritual in society!

## BACKGROUND

Learning from incidents are an important part of developing the safety disciplines. As accident are rare events it is important to assess what went wrong to avoid it from happening again. In Norway the Police is required to carry out fire investigation of every fire incident, also where no suspicions of a crime has been committed. The Police is working with the local fire brigade and the local electrical authority to:

- Uncover the place of ignition.
- Uncover the cause of the fire and fire development.
- Assess whether a crime has been committed.
- Assess fire preventive measures and assess whether fire prevention acts have been followed.
- Find and identify fatalities.

Additionally, in the current regulations for fire prevention in Norway, there is a requirement that the local council investigate fires that have large consequences for lives, health, environment, or property. The evaluation is in this context defined as a systematic review and analysis of the fire preventive activities that may have influenced the fire incident.

## A. Kletz' frustrations

We draw experiences from the grand old pioneer, Trevor Kletz, who has collected information from several incidents and accidents in the plant industry [1]. Kletz describes causes and how the incidents could be avoided [1]. He is frustrated over the lack of learning, as he sees as change. Changes seen is far below his expectations [2]. Kletz sees incidents as education of experiences and he has identified 10 opportunities, which are often missed in terms of learning from the incidents:

1: *Accident investigations often find only one single cause.* Kletz states that accident reports often focus on a single cause, which is usually the last link in a chain of events. Since other links in the chain are not identified, we fail to explore all the opportunities of preventing future incidents.

2: *Accident investigation are often superficial.* Kletz claims that many of the root causes identified in accident reports are immediate causes. In learning from accidents, one should look beyond the cause of the accident to identify ways of avoiding the hazard.

3: *Accident investigations list human error as a cause.* Human error is a too vague term to be useful in an investigation.

4: *Accident reports looks for people to blame.* Focusing on finding people to blame could divert attention from what could be done to prevent similar fires, for example by improving design or methods of operation.

5: *Accident reports list causes that are difficult or impossible to remove.* According to Kletz more emphasis should be put on identifying the actions needed to prevent an accident from recurrence, rather than listing the causes.

6: *We change procedures rather than design.* Operational procedures are in many cases the last lines of defence against incidents. According to Kletz, a good prevention strategy starts in the early stages of the design.

7: *We may go too far.* Kletz claims that spending too much resources on preventing one accident may open for other incidents that loses priority.

8: *We do not let others learn from our experience.* To prevent accidents from happening again, it is essential that the message is distributed widely. Learning activities are rarely seen as practical strategies.

9: *We read or receive only overviews.* According to Kletz, many managers miss the opportunity to learn from incidents

because they do not have the time to read the accident report in detail.

10: *We forget the lessons learned and allow the accident to happen again.* Kletz claims that incident reports are often filed and forgotten. A good strategy to prevent this from happening is to include the reasons for the preventive measures when they are implemented.

#### B. Norwegian cases

Fire incidents in Norway over the last years have shown that there are more to be analysed after a fire than the cause of the fire and related responsibilities. The last 10 years have seen several fires that could provide knowledge beyond determining the initiating event, for example:

- Urtegata 31: Fire in a residential building in Oslo 2008, 6 fatalities - evacuation strategy in existing buildings.
- Gullskogen: Fire in a residential building in Drammen 2008, 7 fatalities - fire safety management and fire prevention in multiuse houses and residential buildings for guest workers.
- Lærdal, Flatanger og Frøya: 3 large wildland fires early 2014 due to unusual dry winter. No fatalities, but rapid fire spread due to strong wind which caused severe property damage - coordinating and leading of emergency organisations over large geographical areas and across disciplines.

#### C. Problem definition

The initiative to consider fire investigation in a broader context was initiated by the University of Stavanger and the civil protection centre in Rogaland (SASIRO).

SASIRO is currently involved in the Norwegian Tunnel Safety Cluster. An important aspect of increasing knowledge is fire investigation. As such, the concept and methodologies of investigations must be developed to extract important knowledge from incidents. SASIRO wishes to challenge current practices to fire investigation. Structures and techniques for accident investigation show little respect to the learning concept [3].

This paper is the first step towards developing learning concepts and methodologies to enhance the use of the knowledge produced. The focus of the paper is on FSE, in which the community receiving knowledge is put in the forefront rather than the accident or the investigator. Accident theories are important as premise for the investigation itself, but we emphasise that learning theories must also become part of the investigation methodology. As such the practices seen in many sectors are still poor. This paper explores some of these issues.

The important research questions in terms of learning from fire investigations in the FSE:

- Can knowledge obtained in a fire investigation be used within the current frames of FSE?
- What are the possible benefits?

- Are the current methods for fire investigation and identification of learning points adequate for FSE?

The scope of this paper is limited to provide an initial discussion on concepts and methodologies for learning based fire investigations from the perspective of FSE. We also make short comments on emergency response personnel's perspective on learning.

### LEARNING – A PREREQUISITE FOR INVESTIGATION

Learning is essentially about improving performance or making sure that chosen behaviour in the organisation is adequate, irrespective whether it is within the regulatory body, in the fire engineering company or in the fire department. Braut & Njå [4] developed a concept of learning based on accident investigations, which they sorted elements into three groups:

- Elements related to *content*, information, message, epistemological basis and desired cognitive structures.
- Elements related to relevant *context* and involved communities.
- Elements related to *commitment*, objectives and measures for learning, rewarding, motivation and evaluation.

Sommer, Njå and Braut [5] further developed a model for learning, cf. fig. 1. Learning places the individual at the centre of attention and focuses on the individual's need to learn. Their assumption is that there is a close relationship between the individuals and the organisational efforts to improve safety management. While addressing emergency services in their article, the notion of learning is general. Learning comprises more than change.

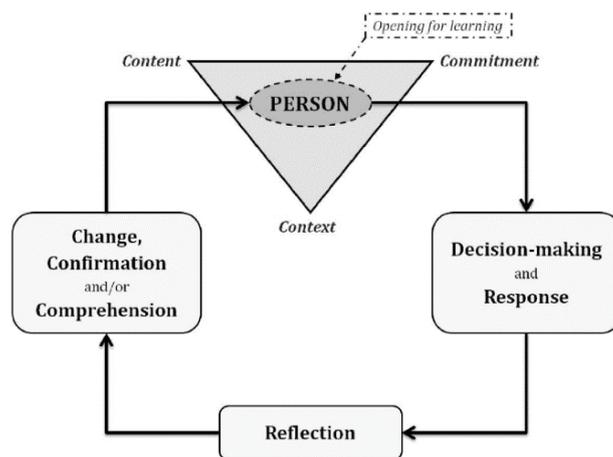


Figure 1. Model for learning, adopted from Sommer et.al. [5]

Learning is a continuous process consisting of four major features and no defined endpoint.

The person could be individuals or groups is the starting point for understanding learning. Content, context and

commitment are the elements that the person depends on in a combined approach to learning.

Decision-making and response corresponds to individuals' performance in their workplace activities (could be first responders, but not necessarily). Individuals' behaviour and "response" in fire safety engineering is a result of the decisions they make, which consequently form the outcome of the engineering designs.

Reflection is the very essence of learning. For individuals to learn from fire investigations they need to reflect on their performance (decision-making and response) and the suitability of their skills and knowledge. This include analytic reasoning either risk, performance or fire load assessments, understanding system behaviours and how building designs meet a span of heat loads. Gibbs' reflective cycle is a theory comprised of a six-stage cycle to guide reflection for learners [6]. For the learner from the fire investigation the cycle can be represented as follows:

**Description:** What happened in the passage you look into? Do not make judgements yet or try to draw conclusions. Simply describe.

**Feelings:** What were your feelings about the event. What were your thoughts? Do not move to analysing these yet.

**Evaluation:** What was in your opinion good in the event? What was bad? Make value judgements and relate them to your area of responsibility.

**Analysis:** What sense can you make of the situation occurred in the event? Bring in ideas from the outside of the described event. Were others' experiences similar or different in important ways?

**Conclusion:** What else could have been done in the event? What can be concluded in a general sense, from the contents of the event and the analyses?

**Action plan;** if a similar event, precursors or cues occur in your workplace what would you do? What could have been done different with respect to your tasks in this type of event?

The fire investigation should be prepared in a way in which Gibbs' reflective cycle may be facilitated for the actors deemed as learners, such as emergency response services, authorities or fire safety engineers.

Change, confirmation and/or comprehension are ways to categorise the outcome of learning. The reflection may result in change in engineering methods, behaviours or working methods. The learning could imply that the fire safety engineers have obtained confirmation of their existing knowledge and working practices. Alternatively, learning could manifest by the fire safety engineer comprehends that the estimated heat release rate has it shortcomings in forming the design scenarios for certain constructions.

However, this normative model for learning is a simplification, which does not reflect the system or workplace, of which the learning agent is being part. Additionally, it does not explore the contents of the various elements needed for investigators to understand how they must organise their fire

investigations. There is a need for further developing fire investigation methodologies placing learning at the forefront.

## LEARNING BASED FIRE INVESTIGATION ACROSS SYSTEM LEVELS

Focussing on learning from fire investigations, the investigator must clarify and adequately describe the system in which the fire occurred. Adopting the System Theoretic Accident Model and Processes [7] helps us to clarify relations between the actors and identifying and assessing the constraints established on each system level. A common understanding of the system involved in a fire investigation is hardly seen in any studies.

### D. Learning vs liability and blaming

Of course, the narrative is important and the investigations clarify observations about what happened. In every investigation a reception history will imply framing the history of the meanings imputed to the events. Observables, narratives and the reception history are formed in every fire investigation, either the investigation is structured as a learning investigation or a liability investigation, cf. figure 2.

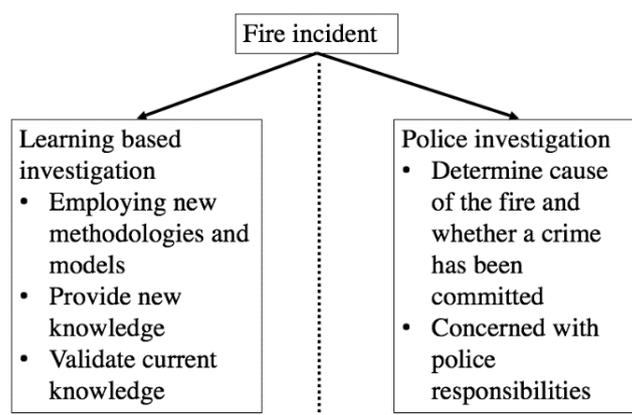


Figure 2. Learning based investigation vs. police investigation

Although the Police investigation might be used for learning, the issue of learning will never be its major goal. A learning-based investigation on the other hand contains a broad approach to the incident. The aim of the investigation is to increase safety. This could mean utilizing new methodologies and models to generate new knowledge and validate current knowledge. A learning investigation will encourage root cause analyses questioning the design principles and regulator's supervision activities, which will introduce uncertainties into the fire scenario model. Such an investigation shows respect to actors' contexts for learning, as well as their involvements in concert with new knowledge (contents) challenging current theories and methodologies.

Police investigations are purely retrospective as they must look back in order to find the true causes of the fire and responsible actors' behaviours. Learning based investigations on the other hand have a futuristic perspective. This means that the investigation must look for features to learn from the incident, which the actors and society could benefit from in the future.

### E. Accident Investigation Board Norway's methodology

The need for learning based fire investigations in Norway are identified by the Norwegian Directorate for Civil Protection (DSB), and reference is made to the methodologies employed by the Accident Investigation Board Norway (AIBN) [8]. Accident investigations conducted by AIBN are limited to the transport sector and focus on identifying safety problems and providing recommendations to reduce risk in the society. The strategy for identifying safety recommendations is:

1. Risk elimination
2. Manage risk and regulatory guidance
3. Consequence reducing measures and barriers
4. Reduce the probability for the event, or preventive measures such as organisational measures (training etc.).

The AIBN has conducted several investigations, which have resulted in safety recommendations to actors and structures, such as tunnels:

- Fire in Oslofjordtunnelen 2011 [9]
- Fire in Gudvangatunnelen 2013 [10]
- Fire in Gudvangatunnelen 2015 [11]
- Fire in Skatestraumtunnelen 2015 [12]

However, the AIBN has no system to follow up their recommendations and they have neither not knowledge about their impact on various actors' learning from their works. A report prepared by the Research Council of Norway claims that although there are several investigation methods for uncovering root causes of incidents, these are rarely used in the fire safety community [13].

### FIRE INVESTIGATION AND LEARNING IN EMERGENCY RESPONSE SERVICES

Evaluating incidents are deemed important aspects of learning in emergency response services. The DSB describes the process of systematic experience-based learning putting weight to "learning points" – cf. figure [8]:

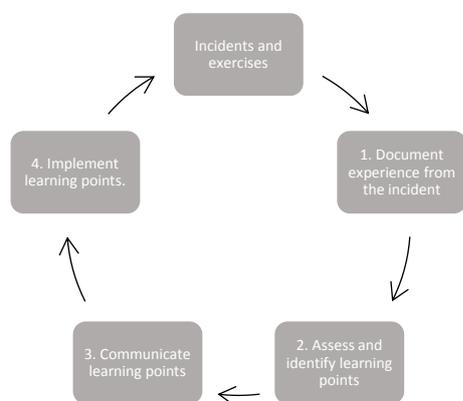


Figure 3. Process of experience-based learning

Sommer's PhD-dissertation revealed that fire investigations are rare and he concludes: "The lack of systemic knowledge accumulation and exchange of experiences hampers learning in emergency response organisations. Emergency personnel learn a lot both from stories about other emergency workers' experiences and from discussions with colleagues. However, with the exception of the JRCC (Joint Rescue Coordination Centre), exchange of experiences largely takes the form of informal storytelling and ad hoc discussions, thus making experience-sharing unsystematic and something that happens by chance. The emergency response organisations will therefore benefit from systematically storing and sharing experiences from responses" [14].

Sommer did not think of fire investigations outside the services involved as an extension to learning. The DSB's assumptions of learning points depicted in figure 3 is a naïve approach to learning.

### FIRE SAFETY ENGINEERING

The potential for learning from fire investigations are examined in terms on fire safety engineering. We restrict the assessment to consider fire safety engineering in terms of developing a fire safety strategy for a building or structure. When planning for fire safety the engineering is required to make assumptions and assessments of fires as future uncertain events. An important issue regarding fire safety engineering is the lack of knowledge from real fires. Many of the methodologies and models used in fire safety engineering is based on empirical correlations from small scale tests [15].

#### F. Prescriptive fire safety engineering

In the design phase of a building project, the fire safety engineer is concerned with developing a fire safety strategy for the specific building and occupancy. In the simplest case the fire safety strategy is developed in accordance with the relevant prescriptive fire safety code. This means that all fire safety measures such as fire resistance of structures, escape distance, active and passive fire safety measures are dictated by the code based on the building and occupancy characteristics.

Hence, for a fire safety engineer developing a fire safety design based on prescriptive guidance the learning from fire investigations is assumed embedded in the fire safety code. Wolski, Dembsey & Meacham [16] refer to continuous updating of fire safety codes in accordance with new knowledge, but at least in Norway this is rarely seen. However, parts of the prescriptive code is revised on the basis of large consequence fires, for example the catastrophic fire in the Grenfell Tower in London. Provision of formal practices for implementing new knowledge as addendum to the prescriptive guidance documents should be explored.

#### G. Performance based fire safety engineering

In performance-based fire safety engineering (PBFSE) the required level of fire safety and required fire safety measures are based on analyses. The purpose of performance-based engineering is to enable the engineers to tailor the necessary fire safety measures to the building in question. As such, PBFSE enables the development of innovative buildings and gives an opportunity to deploy new knowledge and

methodologies to obtain the required level of fire safety for the specific building. It is the motivation of the enforced self-regulation regime to deploy new solutions. However, it becomes difficult when fires are in fact rare events and technical solutions difficult to associate with occurred fires.

An opportunity for learning is fire risk assessments. Fire risk assessments are a mix of methodologies, where important information and recommendations from fire investigations easily could become implemented.

The fire safety engineering community's understanding of real fires is limited. Learning based fire investigations is an opportunity to provide validation of current knowledge and understanding of real fires. The reasons are that we must have a deep understanding of the phenomena before it can be translated into mathematical equations. When a new model or sub-model is developed it must be tested and validated to show that it accurately represents the phenomenon in question. This is an expensive and time-consuming task [17]. A well-functioning PBFSE-system would include informal and formal arenas for learning and development. Such arenas are rare.

#### *H. Learning in fire safety engineering*

There are potential benefits from implementing learning from fires in fire safety engineering. The structure of building projects do not encourage learning. Efforts to obtain knowledge from real fires are usually only triggered by large catastrophic fire events. An example of a catastrophic event that has led to a development of knowledge in the fire safety engineering discipline is the World Trade Centre. The event provided new knowledge into several scientific disciplines such as heat transfer, structural response and human behaviour [18]. Additionally, investigation and evaluation of fires can lead to development of new fire scenarios to be considered by the fire safety engineer. An example of such "new" fire scenario is the influence of travelling fires on concrete frames as investigated by the University of Edinburgh [19].

## **DISCUSSION / CONCLUSIONS**

We conclude this paper with considering the potential of learning-based fire investigations with regards to deployment in the FSE-community.

#### *I. Can knowledge obtained in a fire investigation be used within the current frames of FSE?*

There are currently no restrictions to the knowledge that can be included in an FSE-assessment. However, this implies that the design follows the path of PBFSE. Additionally, the investigations must be obtained and documented in a manner that can be transferred to design situations.

The prescriptive regime implies that relevant knowledge from fires is implemented in the fire code. Hence, it will be unlikely for the fire safety engineer to include learning points from investigations in his prescriptive design. The fire safety engineer must then recommend use of PBFSE.

#### *J. What are the benefits of learning based investigation for FSE?*

There are huge potentials for gaining knowledge from fire events into several aspects of FSE:

- Real fire experiences, heat loads, toxic substances and the influencing factors.
- Fire brigade intervention.
- Assess the effect and adequacy of fire and building codes.
- Knowledge about real buildings and structures in fire, including fire in complex structures such as long and steep road tunnels.
- Obtain a reflexive community regarding fire safety.
- Improve collaboration with other actors, for example fire departments.

Kletz frustrations are part of curriculum at universities. An improved interrelation between academia and the FSE community, for example the Nordic Fire and Safety Days, could lead to changes in FSE-practices. It will improve building designs and building operations. FSE will enhance its status as engineering discipline.

#### *K. Are the current methods for fire investigation, and identification of learning points, adequate for FSE?*

Current methods for fire investigations and we claim investigation methodologies in general are not adequate for learning in the FSE community. We think that the STAMP-model has its benefits as many other investigation techniques (ACCIMAP, MTO, STEP, Fault trees etc). These techniques differ in their views on accidents and how safety is managed. No technique so far has been developed on basis of learning theories. The structure of fire investigation must be changes and we need to define the contents of learning investigations.

Furthermore, changing practices in communities needs careful considerations. Stimuli, such as changes to the regulation regimes, key enterprises adopt learning practices, nominated learning agents etc, seem important.

#### *L. Summary and further work*

Fire investigations are important for recommending proactive fire risk preventing measures in society. The methodologies for conducting fire investigation is well established, but there are shortcomings. Learning must be properly included. We wish to follow up this paper by clarifying leading FSE-companies' attitudes and potentials for learning from investigations and how learning activities could be designed. This paper proposes additional research into the following areas for learning-based fire investigation for FSE:

- Establishing a system for identifying learning relevant for FSE. This includes a model for reflection, for example the Gibbs' reflection model presented earlier.
- Identifying possible arenas for knowledge transfer, and establish pilots and conduct trial research

- Structuring learning-based fire investigations and draw lines to the liability based investigations. We also need to explore the incentives needed to involve fire safety engineering companies to participate in learning processes.

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