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Past and future in accident prevention and learning: Single Case or Big Data?

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ABSTRACT

The European Safety Reliability and Data Association (ESReDA) has since 1993 set up a series of Project Groups dealing with the different angles of 'accident investigation' and 'learning from events'. With the 25th Anniversary of ESReDA now in 2016, the core of this group is still active, and has just initiated a new phase with its latest Project Group on 'Foresight on Safety'.

With the objective of improving the quality of accident investigation and the efficiency of learning from experience process and ultimately raising safety performance, the successive groups tasked themselves at two levels: the first one, at a societal, institutional and legal level, on the public accident investigation and societal learning; the second one, at a methodologicaland organisational level, on the conduct of accident investigation, the enablers and barriers to learning.

This article summarises the Project Groups' achievements (reports, books, papers and ESReDA seminars) on the various aspects of of accident investigations and dynamic learning from events. This article presents a synthesis of the approach and main results, the lessons learned, some dilemmas and conflicts, future challenges, recommendations and suggestions for action. Although varying in composition over time, the main participants remained involved in the development of the issue: participants from the European and member state authorities, industries, research centres and universities and professional practitioners represent a unique, voluntary cooperation across sectors, actors and disciplines that has lasted for almost 23 years now. At last, with the rise of 'big data' it is valuable to recall the interest of single case investigation and address the complementarity of the two approaches to learning.

1. Introduction

The European Safety Reliability and Data Association (ESReDA) has since 1993 set up a series of Project Groups dealing with the different angles of 'accident investigation' and 'learning from events'. The result is a multitude of publications and seminars of Europe's state-of-the-art in these areas. With the 25th Anniversary of ESReDA, these footprints of the consecutive 'accident' ESReDA Project Groups are summarized in this paper, and conclusions are drawn of the lessons learned from the years of working together. In addition, discussion on the trends of the future is raised.

To start from the reasons for the existence of these Project Groups, it is widely recognised that learning from experience is one of the pillars of risk management (Dien and Llory, 2004). To ensure learning, there are regulations concerning investigations after accidents have occurred. The objective of the learning process is to reveal the socio-technical system failures and to not repeat the same errors. In addition, learning from experience may add to the safety management process and regulatory controls and thus raise overall safety. This is why investigations and analyses of events are seen as valuable sources of information relating to safety that generate important insights towards improvement.

Learning from experience is one of the safety practices that contributed to the improvement of safety performance over the last decades. Safety information collected and produced by and for the learning from experience process started to accumulate before being organised through database management in the eighties and nineties when the computers use started. Compared to the increase in size and the duplication of industrial systems through mass production, databases and utilization of the data developed at different speeds, depending on industrial sectors. A new input since the 2010's is offered by developments in 'big data' and textual analysis.

Accidents and even catastrophes still occur in every industrial sector. Accidents are also repeating (like the accidents of the Challenger and Columbia space shuttles or the BP accidents at Grangemouth, Texas City and Prudhoe Bay), and all the possible lessons that could have been drawn from a single accident, are not fully learned. Consequently, it is necessary to evaluate the quality of the event investigation which fuels learning.

These rationales led consecutive ESReDA Project Groups to focus on the societal, institutional and legal conditions of the countries, industrial sectors, and public and private organisations that are supporting the quality of accident investigations and societal learning. In addition, focus was also given to the methodological tools and organisational provisions for preparing, for conducting the event and accident investigations and on the management of the learning process.

Since 1993, four ESReDA Project Groups have analysed the issue of accident prevention, event investigation and learning with different angles, and produced cumulative findings which are recalled before addressing the debate raised by big data developments. Can the 'big data' and other data mining opportunities replace the single and large scale investigation?

The Project Groups worked according to ESReDA's operating rules and with financial support from ESReDA. The main financial support, however, came from the organisations (mostly members of ESReDA) participating in the project group work. The article is written on the basis of the collective work of the experts of the Project Groups. All experts who participated are mentioned in the deliverables.

2. Project Group on Accident Analysis

After documenting for decades in paper reports the accident and event investigation findings and lessons, the technological offer with computers in the eighties and the nineties gave the adequate tool for setting up databases.

From 1993 to 2000, the ESReDA Project Group on ''Accident analysis", focused on accident databases (with issues such as data collection, database management, database use) and ''accidentology", and organised three seminars on these subjects (1994, 1995, 1998). In 1994 the Project Group did a survey of the strengths and weaknesses of accident databases. In 1997 it performed a benchmarking of accident databases. In 2001 it published a guide for the design and use of Health, Safety and Environment databases. More about the Project Group on Accident Analysis and about the group's objectives and approaches can be found in the Safety Science article "Results and lessons learned from the ESReDA's Accident Investigation Working Group" which was published in 2012.

ESReDA historical origin was partly driven by the safety improvement possibilities offered by the exchanges of data at a European level. However, one of the limits of the database approach and data analysis was raised, with the recurring lack of quality of data found in many databases across sectors and countries. It pushed the members of that Project Group to launch a new one to foster the quality of data recorded implying a better quality of investigation of accidents and lessons to be memorised.

3. Project Group on Accident Investigation

The Project Group on Accident Investigation was established by members of the previous Project Group and some new participants. In the end, more than twenty experts from 7 countries took part in the different work processes throughout the next 8 years.

3.1 Objectives of the project group

The Project Group's objectives were to 1) identify and describe the state of the art of the event and accident investigation in Europe (European, national, and company level); 2) to identify and present general recommendations to the involved parties so as to obtain a better knowledge of accident mechanisms throught the use and applications of investigations methods; 3) to present recommendations with regards to the implementation of accident investigation findings - and improve safety management; and 4) to develop general guidelines for accident investigations and the implementation of appropriate recommendations.

In order to achieve these goals, the Project Group relied on information provided by the multi-sectorial group members, launched a survey to establish the state of the art of investigation practices in Europe and organized two seminars in cooperation with the Joint Research Centre of the European Commission. The perspective was to improve safety on a scientific basis.

More about the Project Group on Accident Investigation and about the group's objectives, approaches and results can be found in the Safety Science article "Results and lessons learned from the ESReDA's Accident Investigation Working Group" which was published in 2012.

3.2 State of the art of accident investigation practices in Europe in early 2000

One of the main outcomes of the survey (Valvisto et al., 2003) was the identification that regulations have a large affect on the decision to investigate, on how to conduct it. Most of the organisations agreed on the definition of an accident, but the definition of an incident proved to be much more varying. The definition depended usually on internal criteria and most often it was considered as a near-miss or near-hit. The survey also revealed information on how and when accident boards and committees are formed, and on what basis.

The main goals of accident investigations are, according to the respondent organisations, to collect the facts and to identify the immediate and direct causes, and to prevent the accident from reoccurring in the future: to reveal the causes and to identify methods of prevention. Nevertheless, most of the organisations did not have an investigation method in use, and a specific method is recommended by only a fifth of the respondent organisations, with no particular method mentioned significantly more than others. It could be concluded that formal investigation practices regarding methods or trained investigators were not often used yet.

On the 24th ESReDA seminar on ‘Safety Investigation of Accidents’, held in 2003 at European Commission Joint Research Center (Institute of Energy) in Petten (The Netherlands), practitioners, scientists and European Commission officials shared their views and debated those findings. More than 20 articles of the seminar were published in a special issue of the Journal of Hazardous Materials in July 2004, among which the results of the survey (Valvisto et al. 2003).

3.3 A new concept to shape and promote: public safety investigations of accidents

After major industrial environmental catastrophies and technological accidents, for a long time there had been a strong societal demand for public and independent investigations. As an example, in particular in the transportation sector permanent investigation boards had been established, like the US National Transportation Safety Board (NTSB) in 1967, sometimes following major catastrophes such as the Paddington railway crash which lead to the setting-up in United Kingdom of the Railway Accident Investigation Branch in 2005, or Bhopal in 1984 in India with an American chemical company that led to the creation of US Chemical Safety and

Hazard Investigation Board (US CSB) in 1998. However, there were no progress reports on this evolution with the exception of some reports of the European Transportation Safety Council, on the legal conditions, institutional, organisational or methods of investigation. Existing literature essentially focused on catastrophes or investigation methods dealing with specific aspects, such as human error.

The ESReDA study ''Public Safety Investigations of Accidents in Europe" had the objectives of describing the origin, the development, the current situation and the observed trends in Europe concerning public investigation of accidents, including a comment of main objectives, organisational patterns, procedures, methods, basic and theoretical concepts, underlying paradigms, their legal and institutional frameworks, and of identifying and discussing the challenges faced by an investigation committee. (Roed-Larsen and al, 2005) This study was directed towards newcomers in the domain of public investigations and to actors in charge of investigations. The aim was to raise discussion on the diversity of practices and to promote exchange of best practices between industrial sectors and EU countries. Since the definition of 'public' varied, the Project Group defined the concept with the criteria of the identification of who is in charge or initiating the investigation, who are the members of the investigation team, the transparency of the investigation to the general public, and the aim of the investigation towards safety and learning. Thus a strong distinction is made between public safety investigations and judicial inquiries.

3.4 Methodological and organisational guidelines for safety investigation of accidents

Based on the findings of the survey (Valvisto et al., 2003), which indicated very little use of formal investigation methods or even procedures, the Project Group began constructing guidelines for safety investigations. The agreement of the group was, that there was no added value in developing a new method, especially when taking into account cultural and sectorial differences, and the other constraints of those in charge of accident investigation.

The goal of the Project Group was to write down best practices, common methodological characteristics and differences, investigation stages, objectives, methods used and which events to analyse. The aim was also to identify selection criteria of available generic tools. Eventually the guidelines provide a review of what are the current best or recognised practices beyond a single sector, on how to conduct accident investigations, and also on how to provide useful recommendations. In addition, the guidelines provide theoretical frameworks for the various investigation stages. The target group of the guidelines were not only those directly involved in investigations but also those who have the need to understand and learn from the investigations.

One of the challenges faced by the Project Group was to understand the different theoretical views of an event. Therefore the drafting of the guidelines (Roed-Larsen et al., 2005) put under discussion the diversity of accident models and definitions. A vast majority of events can be seen as the ending point of a process of safety degradation (Dien et al, 2006, ESReDA, 2009) and an event is very rarely an ''act of God". Indeed, an accident happens at the end of an incubation period (Turner and Pidgeon, 1997), during which signals occur, but they are not perceived and/or not treated appropriately according to their potential threat to safety.

In the guidelines the Project Group had the possibility to point out the multiplicity of the reasons and the objectives for which accident investigations are conducted. Despite the diversity of contexts, constraints and configurations in which the investigations are conducted, most safety investigations (versus blame investigations) follow a set of general principles concerning e.g. data, reporting, follow-up and communication. In addition, each investigator brings background knowledge and know-how that influences how the investigator conducts the investigation. On the other hand, each method was developed in a context and with a particular purpose that the investigator should be aware of before making in situ choices (Frei et al., 2003; Sklet, 2002).

The 33rd ESReDA seminar, which was organised in co-operation with the Institute for Protection and Security of Citizen (EC/JRC/IPSC), in Ispra (Italy), in November 2007 echoed three known accidents and their aftermath: the 1999 Paddington train collision public inquiry by the Lord Cullen Commission (Cullen 2000); the 2003 Columbia Accident Investigation Board analysis into the Columbia space shuttle disintegration (CAIB, 2003); and the US CSB investigation into the 2005 Texas City Refinery explosion (CSB, 2005). These three investigations have had a strong impact on methodological development of accident investigations. This second seminar organised by the Project Group aimed at gathering together a community of people interested in accident investigation, at delivering a status report on the latest best practices, at communicating the results of the Project Group's work and at exchanging information about the remaining challenges of accident investigation. It received important testimonies on the management of the Texas City accident investigation performed by US Chemical Safety Board (2007) and about organisational issues when establishing the new Rail Accident Investigation Branch in United Kingdom in the aftermath of the Paddington accident in 1999.

3.5 Lessons learned on accident investigation status in Europe

After several years of discussion and investigation into the matter, the Project Group had to draw several conclusions:

Despite a strong diversity of the sectorial, historical and national contexts in Europe about risk management and regulatory control, we can learn from each other and their good practices, and identify common features. A general trend to harmonisation is observed especially in the field of accident investigation.

An accident may trigger multiple investigations that are conducted by various stakeholders with different objectives and performance criteria. Nevertheless, similar principles can be applied (assumptions, data collection, biases,…).

Public safety investigation meets a societal demand especially after a disaster that can be summarised in *‘’Independent accident investigations: every citizen’s right, society’s duty” (*Pieter Van Vollenhoven, former chairman of the Dutch Safety Board, 2002).

The training and use of formal accident investigation methods was still limited as well as the involvement of professional investigator and in learning. It is as a contributing factor to the repeated failures of 'learning from experience'. (Dechy and Dien, 2007; Dechy et al., 2008; Dien et al., 2012, ESReDA, 2015).

From technical accident investigations with a strong relationship to engineering many years ago and still, a transition towards socio-technical approaches can be seen with multidisciplinary teams in safety boards.

The regulatory requests on public investigation board at international, European and national level are very diverse. With different constraints, several organisational models coexist. The following four elements of organisational structure are observed (Roed-Larsen et al., 2005): a managing board, a professional staff, experts available on call, an information structure to obtain information from design and performance of the entities under investigation. Some boards are multi-modal (ex. transportation, process), others are multinational (in aviation in the former Soviet Union); both have advantages and drawbacks (Roed-Larsen et al., 2005, Stoop, 2000).

For internal and external investigation an important performance criterion is the independence of investigators. Independence is supposed to support impartiality, integrity, objectivity, credibility, transparency and confidence of the stakeholders. However, it is a relative concept as nobody is excluded from a cultural context. This criterion must be balanced as it can compromise the credibility of the investigation board and deprive the investigation of information sources, knowledge and especially of up-to-date competences. In practice, independence refers to the evaluation and assessment of facts and findings, the drafting of recommendations to the discretion of the investigation agency without direct interference from stakeholders. With increasingly systemic and organisational approaches, independence is a powerful factor to struggle with managerial, administrative, budgetary and political resistances.

3.6 Project Group recommendations

In their conclusions, the Project Group addressed a series of recommendations to each stakeholder involved in the promotion of accident and incident investigations:

At the international level, harmonisation of requirements and procedures should be materialized in a EU Directive on conducting investigations, supported by an extensive research program focusing on changing present dominant paradigms,

At the national level, there is a need to establish networks between nations, industrial sectors, investigation boards and research communities to exchange experiences, to further harmonize and develop database systems, methods and models, and to identify and address systemic and knowledge deficiencies,

And at the organisational level, there is a need to promote adherence to safety culture and a proactive attitude towards implementation of new notions and concepts in industry. This should be accompanied by e.g. establishing investigator qualification training in educational programmes in universities of applied sciences.

4. Project Group Dynamic Learning as the Follow-Up from Accident Investigations

The Project Group on Dynamic Learning was established as a follow-up to the previous project. The idea was to find answers to the problem of accidents repeating themselves, lessons remaining unlearned, barriers to organisational and societal learning, and weaknesses in accident investigations that contributed to failure to learn. The main objective of the group work was to work out recommendations on how to capture, document, disseminate and implement insights, recommendations and experiences obtained in accident investigations. New members and their contributions were again welcomed to the group.

The results of the Project Group work consisted of two fruitful ESReDA seminars, three main outputs, and as a sideproduct a thought-provoking essay on the challenges of investigations. The three documents constructed during the project were a model - the ESReDA Cube - to facilitate dynamic learning, a document on barriers to learning and guidelines on what should be taken into account when conducting an accident investigation.

4.1 Seminars on learning

As a triggering event, the Project Group organised the 36th ESReDA seminars, which was hosted by Energias de Portugal (EDP), in Coimbra, Portugal in June 2009 on the theme of ''Lessons learned from accidents investigations". The seminar concentrated on discussions on the weaknesses of accident investigations, implementation and follow-up of safety recommendations, and improving learning as a process.

A few years, later, at the 45th ESReDA Seminar 'Bridging the Gap between Safety Recommendations and Learning', in Porto (Portugal) in 2013, and hosted again by EDP, the Project Group presented its first results on dynamic learning and barriers to learn in workshops where the audience had the possibility to discuss the results with the project group members. In addition, the seminar included sessions on e.g. learning from others, barriers and biases, and the challenges that exist in design, operations, and the interaction between them.

4.2 Exploring the learning space

One of the main results of the Project Group work was the "ESReDA Cube" (ESReDA, 2015), which is a method and a metaphor for exploring a learning space for safety. The metaphor is illustrated with five accident case studies. These accidents have occurred in high risk organizations, and are analysed with the model to identify learning barriers and opportunities at different levels. The case studies are: a pressure shock at a stainless steel manufacturing melt shop in Tornio in 2003 (Finland), the Toulouse ammonium nitrate disaster in 2001 (France), the crash of the ValuJet fligh 592 in 1996 (USA), the El Al air crash at Schiphol in 1992 (the Netherlands), and the Aasta train collision in 2000 (Norway). These cases were selected not only for their accident investigation interest, but also because the aftermath was well documented with several recommendations implemented or lessons forgotten. The idea was to have a bottom-up approach starting from the cases. The ESReDA Cube (see figure 1) is a tool to explore the learning potential of systems. It may be used to analyse a certain event or even a cluster of events, or to learn from past incidents by assessing accident investigation reports.

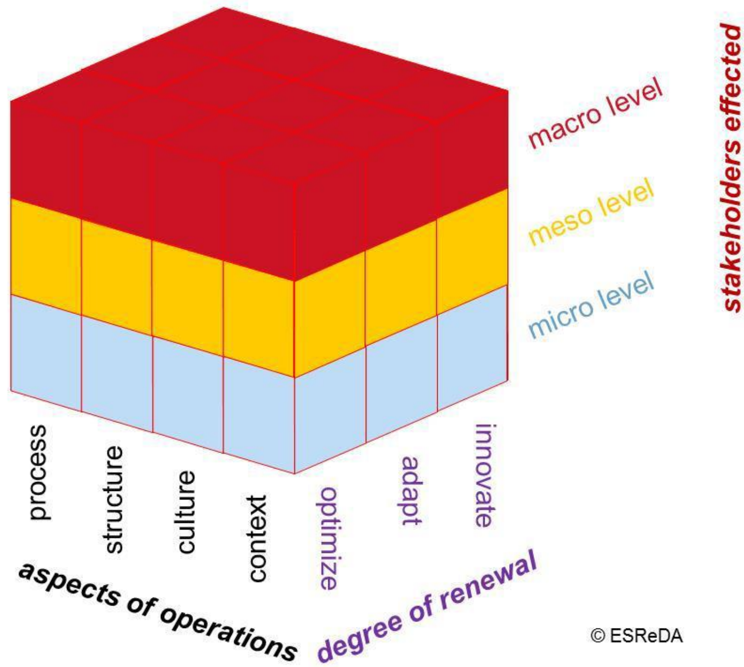

Figure 1 : the “ESReDA Cube” a metaphor to explore the learning space for safety

The world is full of models, methods and frameworks related to accidents and accident investigation. What sets the ESReDA Cube apart from most of them is the viewpoint of lessons learned. From the traditional viewpoint, the Cube is not necessarily the best way to identify what happened and why. Instead the model shows its strength when utilized in the 'last chapter' of the accident investigation report; in the recommendations on how to prevent such accidents in the future. Indeed, it may help the analyst to map the scope of its lessons to be learned, and where potentially some are missing. There the model can be used to identify both what went wrong and what went right when the accident occurred. This brings us to the next step of safety promotion: learning from success.

4.3 Barriers to learning from incidents and accidents

The ESReDA Project Group on Dynamic Learning compiled a document (ESReDA, 2015) on barriers which provides an overview of knowledge concerning the barriers which exist to learning from incidents and accidents. The focus of the document is on learning at an organizational level but it also takes into account a cross-organizational and societal or cultural level. The main idea was to provide a hierarchy in the failures and barriers to learn, from symptoms to pathologies and identify enablers to correct the root causes or mitigate the effects (see figure 2).

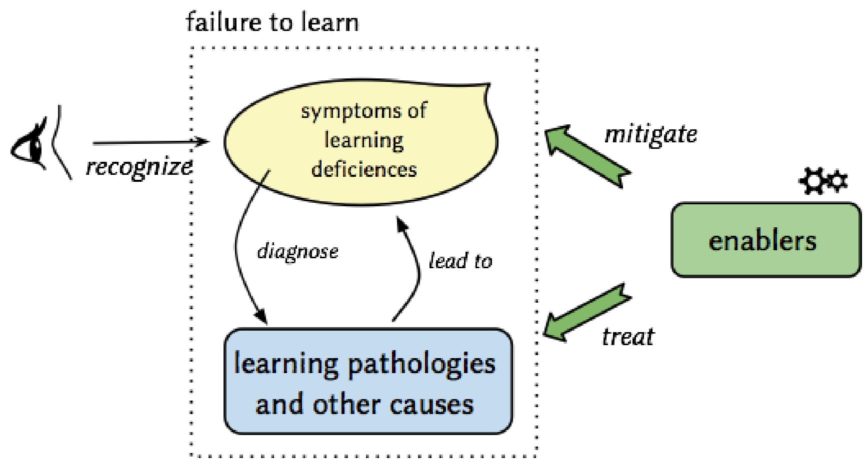

Figure 2 : *Categorising influence factors of the quality of learning (ESReDA, 2015).*

The final document is a straightforward list of how to identify failure to learn and what are the causes. The upside of this is that symptoms of failure to learn are possible to recognize fairly easily once you know what you are looking for. The devil hides in the pathogens: changing beliefs, assumptions and dilemmas that hinder learning. Nevertheless, the document also lists what enables learning, and although the task of promoting learning is not an easy one, with time and perseverance it is possible to improve learning, which is the key to preventing similar accidents in the future.

4.4 Guidelines for developing trainings on accident investigation and learning

The guidelines for developing training sessions were developed due to the need of putting together existing information on how to train investigators, database analysts and learning system managers but also safety managers. The target groups of the guidelines were distinguished in order to adapt the depth of training to the needs: ranging from a few hours to a few days or much more, especially between 'generalist' and 'specialists'. 'Generalists' are customers, users and assessors of the output but also resources providers of the processes of investigation and learning (e.g. safety manager while 'specialists' are in charge on the main process of investigation and learning, taking in charge the input and delivering the output (e.g. investigor, learning from experience manager, database analyst). In addition, 'experts' in some specific tools can be trained much more (e.g. forensics).

The content that could be transferred is proposed both for accident investigation training and dynamic learning, as well as how to use some case studies and some training sessions durations are suggested.To conclude, we studied not only the barriers in the system itself, but also the barriers in how to investigate.

4.5 Safety as a science seems to be in crisis

To learn from the positive, safety has been established as a science in the 1970's at several academia and within the R&D departments of major high-tech industries. To mention a few highlights: in the process industry, SHELL has taken the lead in safety management system development in occupational safety. In the nuclear industry, Electricité de France (EDF) has demonstrated its potential to safely produce nuclear energy for decades, based on probabilistic risk analysis and modelling. In aviation and the maritime, accident investigations have developed into a global network of independent safety investigation agencies. They have become non-plus ultra-safe systems.

However, with the emergence of new technologies, rapidly changing economic, social and market developments, globalization and privatization, new operating environment calls for a Next Gen approach. Such a call is heard in many industrial developments, stimulated by social awareness and acceptance of new risks and hazards, urging a need for a more sustainable and proactive society. Safety investigations provide a timely transparency in its factual functioning, disclosing both systemic and knowledge deficiencies and learning potential.

Unfortunately, major events have also triggered a sense of urgency to make a next step in safety:

- recent major accidents in the offshore, nuclear power and aviation sectors were unanticipated and remained unexplained
- discussions in a Special issue of Safety Science (October 2014) on fundamentals revealed theoretical and methodological dilemmas
- exploration of underlying fundamentals and notions seems inevitable to avoid disciplinary controversies and personal agonies
- several safety communities each independently explore paradigm shifts: researchers, consultants, designers as well as investigators
- academic and R&D safety experts and practitioners still have to rely on, to a large extent, 'on the job' training. A next step in scientific thinking and education seems to emerge.

The essay titled *Challenges to the investigation of occurrences* (Stoop, 2015), available on the ESReDA website, proposes an integration of perspectives and a transition from a factor-based event approach to a vector-based systems approach. It introduces new working relations between safety investigations and forensic engineering, resilience engineering, design methodology, transition management, simulation and gaming. It advocates a shift in thinking from 'human error' to transforming classic notions of Good Airmanship into a general applicable and substantiated Good Operatorship.

5. Project Group Foresight on Safety

Triggered by the findings of the Project Group on Learning, dissemination on learning experiences was discussed from a pro-active perspective. This led to the initiative to create the Project Group on Foresight on Safety. The Project Group on Foresight on Safety will consist of interested members, some of whom have been working together in previous project groups for many years already. This long history of collaboration has resulted in the synthesis and compilation of experiences and knowledge in the area of accident investigations, safety and learning. The influx of new interested members will further enhance the cross-fertilization of experiences and knowledge from one industrial sector to another. The Project Group plans to continue increasing the momentum of knowledge building and sharing. At present the Project

Group is drafting its working programme, covering issue of knowledge management, organisational learning, system change, scenario development, visibility of early warnings and validation of the ESReDA Cube model.

2. Conclusions

6.1 A long journey

This journey to systemic learning has not been a single and simple trip. It took about 25 years, and 3 completed Project Groups (and a starting one) and seven seminars (another one is expected in 2017) to compile discussions, experiences and (dis)agreements on how to proceed to enhance safety in complex and dynamic systems. The results have been compiled in books, papers and seminar proceedings on the ESReDA website. At the moment, as the operating environment of investigations is changing, several new perspectives challenge present investigations theory and practice:

- Harmonization across policy domains in the EU challenges interoperable paradigms and principles across different industrial sectors. This harmonization requires qualification of investigative training and skills, as well as methodological consensus across investigative domains
- Increasing complexity and dynamic behaviour of high technology systems requires sophisticated modelling, simulation and optimization efforts in enhancing the safety performance of such systems. Such efforts require real life data input for their validation and application
- Due to the increasing availability of large data sets, their on-line availability and open access nature, the abundance and structure of such data processing capabilities creates promising new and sometimes ecstatic perspectives. However, as demonstrated by experiences of the accident Malaysia Airlines Flight 370 that disappeared on 8 March 2014, we must remain realistic. Since the recovery of the CVR (Cockpit Voice Recorder) and FDR (Flight Data Recorder) will not provide usefull information due to the time delay in recording and crashing and the search area is overwhelmingly large, both approaches demonstrated their limitations. Investigator concerns on availability of data were expressed by the motto: "first find the haystack, then the needle".

6.2 Single Case or Big Data?

The current rise of ‘big data’ challenges the interest for detailed investigation as patterns could also be recognised with data mining and trend analysis to foresee safety degradation and prevent the next accident, not the previous one. Nevertheless, although 'big data' implies that there is a lot of useful data readily available, this is usually not the case, with too often a lack of rich data found in databases. In addition, the challenges of accurate analysis of the data remain. What does the data actually tell us, and what does it not tell us?

This historical overview on 23 years of accident investigation indicates that accident investigations –defined as exploring single case events- are unique and invaluable. First, contrary to event investigation (from which the poorer data is filling databases), the investigation of accidents and disasters provides more output with a more detailed account (sometimes more than 300 pages) of the story of accident degradation, root causes combination, early symptoms and warnings, than what is available in incident reports and event cases recorded in databases. Some accident investigations can be recognised as learning cases useful for teaching and safety training. The events can trigger individual, organisational and societal learning loops; their lessons can be generalised and introduced in regulations and even captured by other industrial sectors; this is less likely for lessons coming from 'big data' analysis. In addition, from the point-of-view of learning from the accident and preventing similar in the future, the analysis of a single event provides a more approachable human and organisational factors perspective of what has occurred and why, which will more probably affect safety system underlying dynamics in the future than 'cold statistics' of causality.

On the other side, 'big data' provides new opportunities, beyond the data treatment capacities of humans, to statistically recognise similarities, exceptions, and patterns. They can aid analysts, while they cannot substitute them. It should be noted though, that the existence of data does not automatically constitute improvement accordingly: the data has to be interpreted accurately - taking into account the uncertainties - and understandably communicated to the target group, e.g. the consumer, the company or the decision-maker.

Both approaches are of course complementary. Some authors (Dechy et al, 2013) have proposed to articulate multiple single events and accidents taking advantage of the medical metaphor, using the knowledge of pathologies to recognise the symptoms of diaseases. The idea would be that safety analysts use the knowledge of accidents to recognise earlier symptoms of safety degradation.

Perhaps most challenging is the question of how to use both big data and previous single accidents to promote safety proactively: without any further reminders of hindsight that the ominous data did exist or lessons that remained unlearned. This type of issues will be addressed in the next Project Group on Foresight on Safety.

Acknowledgements

The authors have summarised the results of the work done with around 50 experts participating to four project groups over 23 years. This paper is dedicated to their work that is continuing in the project group on 'Foresight in safety' and is written on their behalf. The detailed list of the participating experts is avaible in each ESReDA report, deliverable, report.

The authors would like to thank again ESReDA for its continuous support to these commitments, their organisations for support and interest to this collaborative work across European countries and sectors, and the organisations who hosted the seminars (Joint Research Center, Energias de Portugal).

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