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Results and lessons learned from the ESReDA's Accident Investigation Working Group
Introducing article to "Safety Science" special issue on "Industrial Events Investigation"

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ABSTRACT

The European Safety Reliability and Data Association (ESReDA) established in year 2000, a Working Group on Accident Investigation (WGAI) that ended in the year 2008. With the objective of improving the quality of accident investigation and as a consequence the learning from experience process and the safety performance, the working group tasked itself at two levels: the first one, at a societal, institutional and legal level, on the public accident investigation issue; the second one, at a methodological and organisational level, on the conduct of accident investigation. The underlying process that the working group followed was firstly to establish a state of the art of accident investigation practices and secondly to foster exchanges and dissemination of best practices through issuing guidelines, reports and by organising scientific seminars.

This article summarises the working group achievements made visible in editing three reports and organising two ESReDA seminars in the area of safety investigation of accidents. The article presents a synthesis of the approach and main results, the lessons learned, some dilemmas and conflicts, several future challenges, recommendations and suggestions for action to the main stakeholders involving European and member state authorities, industrials, research centres and universities, and professionals of the rising accident investigation community.

1. Introduction

The Learning From Experience (LFE) or operational feedback process is acknowledged as one of the pillars of the modern approaches of risk management (Dien and Llory, 2004). Thus, regulations were established to require that Investigations after Accidents (AI) or post-Event Investigation (EI) are conducted and that the LFE is properly ensured. Many industries also take into account events having minor consequences (e.g. equipment malfunctioning) in their LFE policy. In theory, an event and its learning process reveal the socio-technical system failures to which it is consequently possible to handle, for – according to the devoted expression – "not repeating the same errors". In addition – and not least – LFE may add more generalised measures to the safety management process and thus raise the total level of safety.

This is why, the investigations and analyses of events are seen as valuable sources of information relating to safety, and through this constitute important insights towards improvement. Lessons for risk prevention and reduction of consequences (crisis manage-

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ment, stakes vulnerability reduction...) are generally drawn from the analyses of several types of single events (disasters, accidents, incidents, near-misses, and even weak signals...) and series of events (trend analyses, statistical analyses, etc).

Thus, safety information collected and produced by and for the LFE process started to accumulate before being organised through the database management. Given the size and the duplication of industrial systems with the mass production, databases and the exploitation of the LFE data developed more or less quickly depending on industrial sectors.

This is one of the safety practices that contributed to the improvement of the safety performances over these last decades. However, many accidents and even catastrophes are still occurring in every industrial sector worldwide. They illustrate the multiple organisational failures of the risk management process and among them the deficiencies of LFE process (Dien and Llory, 2004; Llory, 1996, 1999; Dechy and Dien, 2007; Dechy et al., 2008). Accidents are repeating (like the accidents of the *Challenger* and *Columbia* space shuttles), and all the possible lessons that could have been drawn from a single accident, were not fully learned. Consequently, it was (and it is always) necessary to evaluate the quality of the event investigation which fuelled the LFE and risk reduction processes.

These rationales led the ESReDA Working Group on Accident Investigation (WGAI) to focus on:

- the societal, institutional and legal conditions of the countries, industrial sectors, public and private organisations, that are supporting the quality of accident investigations;
- the methodological and organisational tools for preparing, conducting the event and accident investigations and to disseminate their lessons.

This article thus synthesises approaches followed by the ESReDA WGAI from 2000 to 2008 in collecting, analysing and formalising its work. Main deliverables of WGAI were three reports and organisation of two seminars:

- the ESReDA inquiry (Valvisto et al., 2003) on accident investigation practices in Europe (2001–2003);
- the organisation of the 24th ESReDA Seminar (ESReDA, 2003) on "Safety investigations of accidents" in 2003;
- the ESReDA book (Roed-Larsen et al., 2005) "Shaping public accident investigations in Europe" (2003–2005);
- The organisation of the 33rd ESReDA Seminar (Dechy and Cojazzi, 2007) "Future challenges of accident investigations" in 2007;
- The ESReDA "Guidelines for safety investigation of accidents" (ESReDA, 2009).

Beyond findings and lessons, these deliverables focus also on the dilemmas, remaining challenges and recommendations related to AI.

In order to illustrate some of the WGAI findings, a number of articles being prepared for the 33rd ESReDA Seminar were selected and updated in order to be published in a special issue of the *Safety Science Journal*, dealing with "industrial events investigation".

2. Context, motives, objectives and approach of the working group

2.1. The European safety and reliability data association (www.esreda.org)

ESReDA is a European association which was established in 1992 to promote research, application and training in the reliability field. It comes from the merger of two associations (EuReDatA: European Reliability Data Association and ESRRDA: European Safety and Reliability Research and Development Association). It counts today more than fifty organisation members (which are Industrialists, Administrations, Universities, Research centres, Consulting companies) originating from all over Europe. The most visible activities of ESReDA are its expert working groups and the organisation of two annual seminars. In 2008, there were seven technical working groups: ageing, structural reliability, land use planning, maintenance, uncertainties, fire risk analysis, and accident investigations. The working groups are set up with some association members and also external experts. They have, in general, 2–3 years to implement their project which results in a deliverable such as a report sent to the association's members and which is also made available externally (www.esreda.org). The Association organise two annual seminars, most of the time in line with the activity of one of the working groups. Proceedings are accessible on request to the Joint Research Center (JRC) of the European Commission (EC) in Ispra in Italy (information on ESReDA website).

2.2. The ESReDA working group on accident investigation (WGAI): history, objectives and approach

From 1993 to 2000, the former ESReDA working group on "Accident analysis", focused on accident databases (data collection, database management, database use...) and "accidentology", and organised three seminars (1994, 1995, 1998). This working group published in 1994 a survey of the forces and weaknesses of accidents databases; in 1997 it performed a benchmark of accident databases and in 2001 it published a guide for design and use of Health, Safety and Environment databases (information available at www.esreda.org). The WGAI was formed by former members of this working group and integrated new participants. In the end, more than twenty experts took part in the different work processes through the 8 years.

When initiating the WGAI, on one hand, some issues were raised as mentioned in introduction about limits of accident databases, investigations findings and accidents repetition, and on the other hand, some rising demands were observed from the legislation and the companies about AI and EI and the implementation of LFE policies. Indeed, EU integration brings on harmonisation issues by the regulatory and control lever (e.g. Seveso II Directive in the process industries). Also, in the eighties and the nineties, some countries and sectors mandated more public accident investigations, and even established accident investigation boards (e.g. the aviation sector was a precursor to this development). However, little or no comprehensive research studies have been done to map the extension of accident investigation and to measure the effectiveness of such investigation systems or procedures on a European level.

Based on these initial observations, the WGAI has initially setup four broad objectives, with the perspective to improve safety with a scientific basis:

- to identify and describe the state of the art of the event and accident investigation in Europe (European, national, and company level);
- to identify and present general recommendations to the involved parties so as to obtain a better knowledge of accident mechanisms through the use and application of investigation methods;
- to present recommendations for involved parties with regard to the implementation of findings gained from accident investigations, with a view of improving overall safety management;

– to develop general guidelines for the accident investigation and the implementation of appropriate recommendations.

To do so, the WGAI relied on first hand information provided by its members coming from various EU/EEA countries and from several industrial sectors (fixed installations such as process industry, energy sector, transportation). Those safety and accident investigation experts had several positions from practitioners, managers, researchers from the industry and authorities, to consultants, researchers and professors from universities and research centres. They were able to identify most of the regulations, codes, standards, guidelines, publications and some of the AI practices in some organisations. One of the issue of this WG was to establish some generic frame of references, some common definitions in order to foster understanding of real similarities and differences despite several specific contexts.

Then, the WGAI launched an inquiry or survey to targeted organisations in order to establish a state of the art of accident investigation practices in Europe and offered cooperation with questionnaire responders and interviewed parties (see Section 3).

In a third step, with the triple objective to collect data on accident investigation practices and challenges, to disseminate and transfer knowledge on accident investigation to the safety community and to enhance fostering exchanges between stakeholders at different levels within EU/EEA and building an accident investigation community, the WGAI co-organised with the European Commission-Joint Research Center (EC-JRC) – two ESReDA seminars (see Sections 4 and 6).

The WGAI worked with ESReDA financial support and according to their operational rules. The main financial support came from the organisations (mostly member of the ESReDA) and from related projects which experts of the working group participated in a voluntary basis.

3. The ESReDA inquiry on accident investigation practices in Europe

3.1. Context, objectives and description of the inquiry

This inquiry had the objective to clarify and if possible establish a state of the art of the practices and main differences (regulatory, institutional, organisational, tools and methods...) according to the various countries, industrial sectors, the position of the organisation (authority, industrial...) and to assess the need to share information and "best practices". In our view, the added value of a European expert group within ESReDA, coming from different cultures, industrial sectors and with different positions and perspectives (research, improving practices in an organisation or develop competencies to provide to industries and authorities), is to provide and foster a hub for exchange and debates to facilitate inter-organisational learning (Dien and Llory, 2004; Dechy and Dien, 2007; Dechy et al., 2008) and even to contribute to EU issues of harmonisation of regulations and practices.

In order to collect data on the state of AI and EI practices, it was decided to go beyond knowledge and practice area of the working group members, and to conduct a larger inquiry by questioning and interviewing several actors. A questionnaire was developed and sent out in 2001 to 136 targeted organisations. The WGAI received 59 responses and kept 49 for its analysis (non-European excluded). Fifteen EU/EEA member state were represented in the survey with five countries totalling 75% of the responses: Sweden (11 responses), Norway (10), The Netherlands (6), Finland (5) and France (5). Results could be impaired by a "Nordic countries bias". Main categories of responding organisations were authorities (27), industrial companies (15), research centres, universities and consulting (7). A little more than 50% of the questioned organisations were in the transportation sector (air, rail, water, road), and a little less than 50 % were in fixed installations (production and storage in oil refining, gas, chemicals, offshore and energy production). Thus, this sample cannot be considered as robust from a statistical perspective but it provides a picture of the state of the art that may prove interesting for high-risk industries and large organisations.

3.2. Main results and lessons from the inquiry

One of the main outcomes of the inquiry (Valvisto et al., 2003) was to remind that regulations have a major impact on the decisions to undertake EI and AI, and on how to conduct AI and EI, being private or public actors.

Thus, most of the organisations agree on the definition of an accident as an unexpected, unwanted chain of events, with consequences (on Health, Safety, Environment or equipment damages) and refer to a regulatory definition (national, European and international legislation). The definition of an incident, however, proves to be much more fuzzy and is often considered as a near-miss or near-hit, mostly dependent from internal criteria but also to some regulatory criteria.

The issue of accident and incident definitions has some implications in the event notification policy to internal and/or external authorities. Thus the authorities do trigger investigations primarily based on the criteria of severity of the consequences of an event. The companies use in addition other criteria related to risks and learning potential. In two thirds of the cases, the organisations announce that it is compulsory to provide information to the investigators (quasi systematic for the authorities and a fortiori for justice).

The existence of permanent investigation services (such as investigation boards) in their industrial sector is thus announced by three quarters of the responders and confirms the tendency being observed on the development of these organisations. These investigation boards function with permanent investigators and/or with a board supervision of consultants and contractors. Authorities and research centres usually create ad-hoc committees with safety specialists. Companies and the consultants more often appoint temporary teams with safety specialists, shop floor operators and managers. The principal criteria to be selected within an investigation team are: to be a multidisciplinary safety specialist, a specialist recognised in safety in general (ex: transport), an expert specialised on a system or sector (ex: ammonia installation), an expert on human reliability. A member of top management, local managers and event witnesses are also often part of the investigation team. We could note that in 2001, the absence of qualified investigator and/or specialist in the AI and LFE processes was frequent.

The respondent organisations indicate that the main goal of the AI (being public or private) is to collect the facts and to identify the immediate and direct causes. The secondary objective is to prevent the repetition of a similar event. Other objectives being quoted by the organisations, are the supply of recommendations, the development of new procedures and regulations, the verification of the violation or conformity to the law, the taking stock of a learning opportunity and the issue of information dissemination. The large majority of the answers asserted that the main objectives of performing an investigation are to reveal the causes, and to generate the provision of recommendations and prevention measures. Nevertheless 40% replied that the first aim was to identify the facts.

On the use of AI procedures, 69% of the questioned organisations indicate the use of an internal procedure, an instruction or a rule. An international or national procedure is announced by

10% of the organisations. The majority of the organisations mention that they do not have any particular investigation method. A specific method is recommended by 20% of the organisations, and half of them quote the cause-consequence method. It was mentioned 14 different names of methods, with eight by only one organisation. The principal quoted methods are the fault tree analysis, human error analysis, probabilistic risk analysis, and root causes analysis.

In conclusion, in 2001, formal investigation practices (methods, trained investigators) were not often used yet. There is no dominant method and it was decided by the WGAI to look for comparative studies. In 2002, the WGAI had come up with the idea that for a safer Europe, a European research program on AI and EI should be launched, and could focus on the sharing of best practices and on the need for harmonisation of investigation tools and performance measurements: definitions, legal requirements (objectivity, independence, competence), institutions, notification and routines, procedures and methods. In this perspective, the WGAI invited practitioners, scientists and EC officials at the 24th ESReDA seminar (ESReDA, 2003) to share their views and debate those findings.

4. The 24th ESReDA seminar on "Safety accident investigation

Preliminary findings from the inquiry about the state of the art of investigation practices in EU and EEA, clearly showed the need for an ESReDA seminar on the topic of the safety investigation of accidents and events (as opposed to the legal investigations). It was held at EC–JRC Institute of Energy at Petten in The Netherlands in May 2003. It gathered 150 people of 25 countries with varied positions in many EU organisations (companies, research centres) but also from international organisations (IAEA, OECD, WANO[2]). About fifty presentations in the AI and risk management field were provided by speakers (ESReDA, 2003). Some EC representatives introduced the seminar and recalled the EU approach and vision on AI and its relation to risk and crises management.

The technical sessions were organised on the following topics: transversal to sectors issues, transport, process industry and energy sectors.

The main presentations and debates addressed:

- the scope of investigations;
- the nature of their immediate and root causes;
- the opportunity of near-misses for LFE systems;
- the investigation management with multiple stakeholders;
- the necessary distinction between justice litigation and safety investigation;
- the investigators' credibility;
- the long-term use of the knowledge learned by the investigation;
- the continual need for information exchange at international level;
- the comparative evaluation of the risks of technologies.

The remaining challenges underlined inter alia the need for information exchange on the methods and techniques of AI, and on the manner of scaling the recommendations to the various decision making and risk levels. More than 20 articles of the seminar were published in a special issue of the Journal of Hazardous Materials (No. 111 in July 2004) and among them an article summarising the ESReDA WGAI inquiry (Valvisto et al., 2003).

[2] IAEA: International Atomic Energy Agency; OECD: Organisation for Economic Co-operation and Development; WANO: World Association of Nuclear Operartors.

5. The ESReDA book "Shaping public accident investigation in Europe

5.1. Statements, motives and objectives of the book

For several decades, in the aftermath of major industrial pollutions and technological accidents, a strong and recurring societal demand for public and independent investigations has emerged. Thus in the United States, after the accidents of Three-Mile Island nuclear power plant in 1979 and of the space shuttle *Challenger* in 1986, ad-hoc presidential commissions were set up in order to bring the truth about these technological catastrophes. In the same way, in United Kingdom, Lord Cullen was mandated to conduct a commission established to carry out a public investigation about the Piper Alpha disaster in 1988 and again for the train accident in the Paddington area at Ladbroke Grove in 1999.

At the same time, international or national regulations were established to frame the Public Investigations after Accidents (PAI) with the aim to improve safety in particular in the aviation sector. Permanent investigation boards had been created for several years mainly in the transportation sector (air, then maritime and railway, like the US National Transportation Safety Board in 1967) or sometimes following major catastrophes (e.g. Paddington lead to the setting-up of 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 Board in 1998). Members of WGAI were experiencing this evolution in their own industrial sectors and also in their country in Europe. However, as stated before, 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, methods of PAI and investigation boards. In addition, the existing books essentially focused on catastrophes or investigation methods (technical methods, e.g. forensics, on the human error, etc.).

The study "Public Safety Investigations of Accidents in Europe" had two main objectives:

- to describe 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;
- to identify and discuss some of the main dilemmas and conflicts between an investigation commission and the environment, those that exist within a commission, the lessons to be drawn, together with outlining some main challenges for those investigations and some recommendations.

This collective work was geared in particular towards newcomers in the field of public investigations (new Member States of the EU, industrial sectors soon or recently regulated on this matter), but also to all actors in charge of these investigations, with the idea to feed the debate on the diversity of practices and to foster exchange of best practices between industrial sectors and EU countries.

5.2. Main results and lessons on public accident investigation in Europe

5.2.1. Defining the "Public accident investigation" concept

One of the subsidiary objectives of this work was to define the underlying concepts of PAI, if possible to achieving a consensus on a PAI definition, and otherwise, to determining criteria for the PAI.

This term or this concept is used by many actors who think they have the same definition, but a thorough analysis showed the ambiguity and the various uses of the term according to historical, cultural, sectorial and regulatory contexts. Indeed, "public inquiries or public investigation" is the term that seemed the most difficult to define in practice. To characterise this "public" concept, the WGAI identified criteria like:

- the nature of the authority in charge to trigger the investigation;
- the origin and power of the organisation in charge of the investigation;
- the composition of the investigation team with the participation of independent investigators;
- the investigation transparency to the public with consideration of flow and access to information throughout the investigation;
- and finally a focus on societal learning and safety and not to the necessary satisfaction of the social needs for search of responsibility and culpability.

A useful and strong distinction is made between public safety investigations and judicial inquiries. Indeed, the right to have access to all available evidence being useful for the PAI is often defined in regulations framing the coexistence of the two investigation types, which also take into account the secrecy of the legal instruction (in some countries), the medical secrecy or the professional secrecy.

Thus, this safety PAI aim at identifying the probable causes and the socio-technical system failures and at providing safety recommendations. The permanent investigation boards replace more and more the ad-hoc commission created in the aftermath of catastrophes. This represents more than one terminological change, namely the transition of an investigation entity, less integrated and dominated by the government and authorities, towards an investigation board (expected to be more professional and independent) focused on safety promotion rather than the investigation itself.

Criteria of frequency and severity of the accidents do influence the decision to launch these investigations which can be classified in three main categories (Rasmussen and Svedung, 2000): internal investigations for frequent events but with small scale consequences, technical or safety investigations for infrequent and medium sized accidents but significant for the sector or industrial system, and eventually PAI in case of rare and large scale events.

5.2.2. General and sectorial developments of public accident investigation and accident investigation boards in Europe

From a **general perspective**, and on the institutional and legal levels, there are many differences between countries, sectors and from a historical point of view. Many national regulations define requirements on AI and LFE e.g. labour, transport, technological and natural risks. From a historical perspective, one would notice the development of PAI and investigations in companies and the transfer of ad-hoc commissions to permanent investigation boards with the widening of their scope of investigation to multi-modal rather than sectorial. In addition, one raises an increasing attention of the public to the major accidents, a rise of the national and European legal specifications as well as the increasingly current use of procedures and standards even European and international. Sectorial European agencies with safety objectives were established in parallel.

At the European **civil aviation** level, the tradition of AI is quite old: the corrective actions in particular on the design are often implemented and the majority of the countries have permanent investigation boards. The first permanent AI commission was created in 1915 in United Kingdom for the military aviation sector (Accident Investigation Branch, AIB). At the end of the First World War, the AIB was attached to the Aviation Ministry and extended its action to the civil flight accidents. Since 1944, appendix 13 of the Chicago civil aviation convention specified a procedure and harmonised AI method that was integrated in 1951 by the International Civil Aviation Organisation (ICAO). In many EU countries, investigation boards were established before the Directive 94/56/EC of November 21, 1994 that contains the legal requirements for AI and explicitly asks for the creation of investigation boards independent of the control authorities.

In the **maritime sector**, despite a several centuries experience and many catastrophes, there is not a long accident investigation tradition in which the mission of learning lessons is separated from the allocation of blame and disciplinary action against the officers on board of seagoing vessels. Often, investigations focused on the questions of blame and liability. However the International Maritime Organisation (IMO) took resolutions (A.849 (20) on November 27, 1997 and A.884 (21) and amendments A.849 (20) on November 25, 1999) for AI and how to address human factors. Some EU countries have investigation boards or ad-hoc commissions (e.g. France has an investigation board since 1997, similar to the UK, The Netherlands, Norway, Sweden and Finland).

In the **railway sector**, AIs have been managed in-house for a long time especially within the state owned companies. A rare exception has been The Netherlands, which established an independent railway safety board already in 1959. This board merged into the Transportation Safety Board in 1997. During the nineties, the International Union of the Railways (UIC) advocated without success for an accident database. The sector was marked by several accidents in the British railway system and among them the Paddington accident in 1999. The 2004/49/EC Directive of April 29, 2004 on railway safety contains the legal requirements for AI and requires the creation of investigation boards, independent in, their organisation, their legal structure, their decision-making processes, and independent from any actor in charge of the infrastructure, the owner, the railway control authorities, or safety authorities.

In the **road sector**, no country but Finland has a permanent investigation board.[3] The sector did not have (in 2005 ESReDA, 2003) specific investigation boards. However several countries have multi-modal investigation boards that cover these accidents (e.g. the Norwegian Accident Investigation Board and the Dutch Safety Board). As this transportation means causes the most human consequences within the EU, a White Paper and a European program (COM 311 (2003)) for road safety were developed and mentioned LFE as a safety tool.

For the **tunnels**, the fires (1996, 2006, 2008) which have occurred in the Channel Tunnel (France/United Kingdom), in the Mont Blanc (France/Italy) and the Tauern (Austria) tunnels in 1999, as in the Gothard tunnel (Switzerland) in 2001 made obvious the human and economical consequences of these kind of accidents: tens of fatalities and injuries and some major European roads closed during months, even years. Some tunnels were designed at a time when the technical possibilities and the transport conditions were very different. Thus the Directive 2004/54/EC of April 29, 2004 defines the minimal safety requirements applicable to the tunnels of the trans-European roads network, and in particular, it sets the times for handing-over the AI by the owners. In France the investigation board for ground transportation accident is in charge of PAI in tunnels.

The **pipelines industry** in charge of the hazardous materials transportation was recently marked by the Ghislenghien catastrophe in Belgium in 2004. A European Directive has been in discussion for several years, in the aftermath of its exclusion from the

[3] This board sponsored by the insurers was established in 1968.

Seveso II regulation scope. The multi-modal Dutch Safety Board has in its field of competence the PAI involving pipelines.

Process industries and hazardous materials sectors were shocked by many catastrophes and disasters in Europe (Seveso in 1976, Basel in 1986, Enschede in 2000, Toulouse in 2001, Buncefield in 2005) and regulations aiming at controlling major hazards were implemented and revised in the aftermath of new catastrophes (Seveso I Directive in 1982 and Seveso II in 1996). These regulations define requirements for the investigations initiation, for the implementation of a LFE policy (for the Seveso high threshold sites) and for the notification to the authorities and Member States in case of major accidents (according to the criteria defined in appendix VI of the Directive 96/82/EC). There are no requirements for the PAI. The AI are carried out by the companies, by the third-party experts and the ad-hoc commissions (Dechy et al., 2004). A report is transmitted by the authorities (e.g. in France the BARPI) to the Major Accidents Hazards Bureau (MAHB/JRC/EC) that manages the MARS database. In Europe, some countries (The Netherlands, Sweden) that have multi-modal investigation boards or commissions have the major accidents in their investigation scope.

European **offshore oil and gas industry** saw the occurrence of platforms catastrophes such as Alexander L. Kielland in Norway in 1980 and Piper Alpha in 1988 (Lord Cullen ad-hoc commission). Strict regulations in the Health, Safety and Environment exist. Accidents are analysed by the companies and if necessary by the control authorities. There are neither a permanent investigation board nor a commission addressing this issue.

In the **energy production and transmission field**, several energy sources are to be considered (fossil, nuclear, hydraulic, and renewable). Recently, blackouts affected several EU countries at the same time and were the subject of learning from experience studies. With the Three-Mile Island accident in 1979 (Llory, 1996, 1999) and the Tchernobyl accident, in 1986, the nuclear power sector has several safety regulations and an international scale to classify accidents (INES) which relate to notification criteria and a specific procedure. Accident and incident investigations are performed by the operators and controlling authorities, and there were no requirements on PAI and no investigation boards.

In the **space sector**, the European Space Agency (ESA) is in charge of AI, along with the CNES and the French authorities if the accident occurs at the launch pad in French Guyana. The sector was especially shocked by the disintegration of the Challenger and Columbia space shuttles whose investigations were carried out by ad-hoc and independent commissions (presidential for Challenger and specific board for Columbia).

6. The 33rd ESReDA seminar "Future challenges of accident investigation

The second seminar organised by the WGAI aimed at gathering a community of interest on the AI, at delivering a status on the latest best practices, at communicating the results of the WGAI work and at exchanging about the remaining challenges faced by AI. The 33rd ESReDA seminar was organised in co-operation with the Institute for Protection and Security of Citizen (EC/JRC/IPSC), in Ispra (Italy), in November 2007. There were 60 participants of 14 countries (12 European countries, the United States and Australia). There were 24 presentations,[4] divided into nine technical sessions and three invited keynote lectures (Dechy and Cojazzi, 2007):

- Carolyn Griffiths, Director of the Railway Investigation Branch (RAIB) from UK who described her role in establishing an investigation board, in organising the training and the operations, and she also described some feedbacks after 2 years of operation.
- Pietro Carlo Cacciabue of the Italian committee for the safety of the flights which pointed out the safety management foundations : investigation, data collection and analysis.
- Bill Hoyle, investigation manager at US Chemical Safety Board who presented the lessons of the investigation performed by US CSB on the Texas City Refinery explosion of March 2005.

The nine technical sessions have enabled presentations, discussions and debates about the following topics (www.esreda.org).

- Accident investigation and safety management.
- New methods to investigate accidents.
- US Texas City 2005 (BP refinery) major accident investigations.
- Near-misses, weak signals and safety management.
- Safety trade-offs versus availability and justice.
- Managing accident investigation.
- Dealing with accident data.
- Analysing and learning lessons from crises events.
- Future challenges for accident investigations.

7. The ESReDA "Guidelines for safety investigation of accidents

7.1. Statements, motives and objectives of the guidelines

The WGAI members tasked themselves to develop a guide on accident investigation. This objective was reinforced by the findings of the inquiry (Valvisto et al., 2003) indicating a weak use of formal AI methods and even of AI procedures. The WGAI considered that its added value was not to be found in the development of an additional new method with regards to the cultural differences, sectorial and constraints of the actors in charge of AI. Indeed, it is known that there are multiple specific methods or procedures which have been developed in some organisations and sectors with contingencies that we do not handle. Without claiming to replace them, the WGAI wished to offer an external glance to the practitioners in order to develop a cross – organisation/sector/country – learning.

Therefore, the goal of the WGAI was to map best practices, common methodological characteristics and differences, stages and general objectives regardless of the sectors, the methods used and the events to analyse. The aim was also to identifying selection criteria of available generic tools. These guidelines provide a review of the current best or recognised practices beyond a single sector, to conduct AI, and provide also useful recommendations and theoretical frameworks for the various AI stages. These generic guidelines were prepared for investigators, AI managers, directors and purchasers of AI, customers and responsible people who will have to learn from the AI results, victims and researchers.

7.2. Main findings of the "Guidelines for safety investigation of accidents"

One of the basic difficulties faced by the WGAI was to understand the different theoretical views of an event, and the drafting of the book (Roed-Larsen et al., 2005) had recalled the diversity of accident models and definitions according to the position of the actors, their history and the weight of the legal definitions. It is a key issue, as from this definition or accident model, AI and risk management approaches are developed to understand and prevent the accidental phenomena.

The WGAI finally agreed on the following definition which states that in-depth analyses of accidents, incidents and crises clearly showed that any event is generated by direct and/or imme-

[4] Eight articles of the Seminar are published in this special issue of the Journal "Safety Science".

diate causes (technical failure and/or "human error"). Nevertheless their occurrence and/or their development are considered to be induced, facilitated or accelerated by underlying organisational conditions (complex factors) Dien, 2006. A vast majority of events can be seen as the ending point of a process of safety degradation. An event is very rarely an "unexpected combination of circumstances" or an "act of God". Indeed, an accident happens at the end of an incubation period (Turner and Pidgeon, 1997), during which some events and signals (weak or strong) occur, but they are not perceived and/or not treated appropriately according to their potential threat to safety.

To support this accident definition, we can quote firstly to the Columbia Accident Investigation Board (CAIB) that made its basic methodological posture of it. The CAIB firstly states (CAIB, 2003) that: "*Because the events that initiated the accident were not apparent for some time, the investigation's depth and breadth were unprecedented in NASA history. Further, the Board determined early in the investigation that it intended to put this accident into context. We considered it unlikely that the accident was a random event; rather, it was likely related in some degree to NASA's budgets, history, and program culture, as well as to the politics, compromises, and changing priorities of the democratic process. We are convinced that the management practices overseeing the Space Shuttle Program were as much a cause of the accident as the foam that struck the left wing.*" Secondly, we can quote the US CSB findings (US CSB, 2005) on Texas City refinery explosion in 2005: "*The Texas City disaster was caused by organizational and safety deficiencies at all levels of the BP Corporation. Warning signs of a possible disaster were present for several years, but company officials did not intervene effectively to prevent it. The extent of the serious safety culture deficiencies was further revealed when the refinery experienced two additional serious incidents just a few months after the March 2005 disaster.*"

This accident model implies to deal with causalities of different nature, mechanistic and deterministic in the technical installations, to more complex (with positive and negative feedback loops) in the human and social systems. In fact, it is necessary to call upon multiple competencies (hard sciences, to engineering and social sciences) to investigate, to make sense of multiple socio-technical (Rasmussen, 1997) dimensions (physical, chemical, cognitive, psychological, collective, organisational, financial, power and relationships with the authorities, political and societal, etc.) and then to learn from the accident in order to define corrective actions.

We had the occasion to point out the multiplicity of the reasons and the objectives for which AI are conducted depending on the stakeholders (e.g. companies, authorities and public parties). The AI purposes depend on the investigator's aim (e.g. search for responsibility and culpability, safety, reliability, to understand with common sense or scientific perspective (Rasmussen et al., 1994)) and underlying worldview or cultural paradigm (technical, behavioural,...). Also there may be several AIs started in the aftermath of accidents and managed simultaneously implying different interests that can lead to operational conflicts for the access to the site, to the witnesses, for the collection of facts and the evidence preservation, for the findings and their communication. Thus the cultural, political, organisational, financial, managerial contexts will shape the AI framework. An important stage for the investigator in charge and the stakeholders is the definition of the terms of reference that must address topics like the AI scope, the investigation into the immediate and/or root causes, the requirements for the report, the communication of urgent recommendations, the deadlines and the recipients of the AI.

Despite this diversity of contexts, constraints and configurations in which the AI are conducted, safety AI (versus a blame investigation) does obey to a certain number of general principles: protocols, coordination, competence, data and facts, formalisation and reporting, follow-up of the recommendations and communication. In the same way, AI obeys to a common process that can be described in several stages: definition of the terms of reference, establishing an investigation team, data collection, hypotheses generation, analysis, findings, lessons, and recommendations. Connection between the stages is not a linear but an iterative process (e.g. the terms of reference can be redefined with regards to first data collected, the investigator team can be reinforced when necessary with additional expertise...).

Moreover, each investigator brings his/her background knowledge and know-how that influences his/her initial representations and thus the way in which he/she a priori will collect the data and will conduct the investigation (as represented in Fig. 1).

With a similar issue, methods were developed to facilitate investigation tasks. Those methods use normative steps, qualitative or quantitative approaches, use different logical construction, call upon various underlying models, aim at clarifying phenomena at various levels of the socio-technical system, and have different purposes (to define what happened, how and why, and/or the corrective measures to prevent this type of events...). The idea to keep in mind is "*investigation tools in context*" (Frei et al., 2003), meaning that each method was developed in a context and with a particular purpose that the investigator should be aware of before making their in situ choices (Frei et al., 2003; Sklet, 2003).

Contrary to the accident development, AI must go back to the previous events that occurred within the socio-technical system and take into account, according to Reason (Reason, 1997), four different levels of phenomena: the principal elements of an event (danger source, defence barriers and controls, target loss), the individual level (unsafe action), the workplace (conditions which caused the error) and the organisation (with three dimensions according to Dien and Llory (2005): the vertical and hierarchical network, the inter-organisational network and the historical dimension).

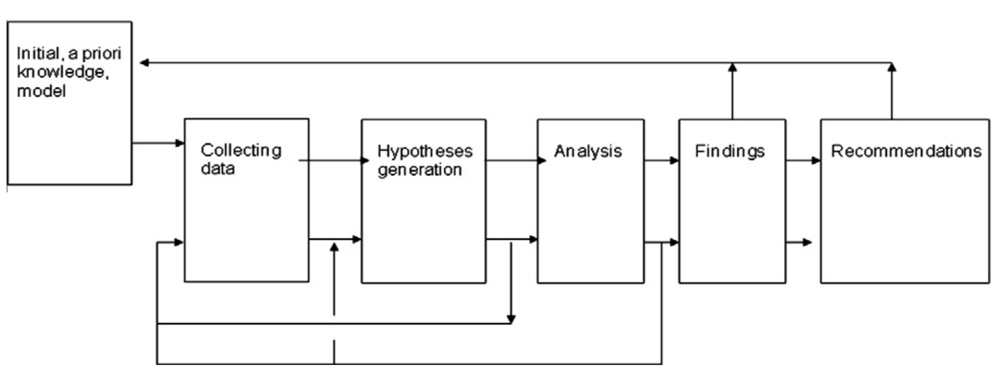

Fig. 1. Initial knowledge and accident investigation generic steps.

Among a number of remarkable AI with these principles, we would quote the following AI: the 1999 Paddington train collision investigation by the Lord Cullen Commission (Cullen, 2000); the 2003 CAIB investigation (CAIB, 2003) into the *Columbia* space shuttle disintegration; and the US CSB investigation into the 2005 Texas City Refinery explosion (US CSB, 2005). Indeed, the CAIB investigation has had a strong impact not only for its findings but also for its methodological developments (investigation scope and accident model) as stated by US CSB when investigating the BP Texas City refinery March 2005 accident: ''*This investigation was conducted in a manner similar to that used by the CAIB in its probe of the loss of the space shuttle. Using the CAIB model, the CSB examined both the technical and organizational causes of the incident at Texas City*''. [...] *Due to the significance of the disaster, the US CSB investigated not only BP'S safety performance at Texas City, but also the role played by BP Group management, based in London, England. The CSB further examined the effectiveness of the Occupational Safety and Health Administration (OSHA), which has primary US federal government oversight responsibility for worker safety*''. (US CSB, 2005)

With this background, it is recommended that the organisations establish a programme (ESReDA, 2009; Kingston et al., 2005) to prepare AI protocols and to train their investigators before the accident occurs so as to be effective on the ''D-day''.

Once the AI is completed and often before that, it is necessary to communicate to the stakeholders about the AI in course, about preliminary and final results in order to initiate and facilitate the learning process. For public investigations, the investigation boards developed public hearings where information about the event and its investigation are discussed and can provide feedback to the investigation process or its finalisation (see hearings procedures of US National Transportation Safety Board).

We wanted to pay attention to the stage of the recommendations design (after analysis, findings and lessons learned stages) that requires specific knowledge of the organisational network (actors, stakes, and political dimensions) and behaviour of the socio-technical system. The permanent investigation boards' set-up devoted teams to the design and follow-up of the implementation of the urgent or final recommendations. In addition, in the organisations where corrective actions are being implemented, a particular follow-up must be set up in order to control their effects in the short and long term and to observe any unexpected effect or even detect adverse effects.

8. Main lessons learned by the WGAI

The first lesson is that the WGAI had to deal with a very strong diversity of the cultural, historical and institutional contexts in Europe with regards to societal risk acceptability and societal risk management. Each country has a particular history (with regards to democratic history and societal experience of major hazards, pollution and catastrophes). Each industrial sector carries the marks of its technological developments (carved by its successes and its failures), and each organisation could be shaped more or less by serious failures. In the aftermath but not only, organisational, institutional and cultural processes were built up and explain a part of this AI diversity.

This diversity is bound to persist to a certain extent for the historical and political reasons presented above, but also to be reduced by several global processes affecting the AI directly. These are reactive and pro-active processes of convergence, harmonisation, integration, industrial concentration, information sharing, best practices and even transversal LFE (Dien and Llory, 2004; Dechy and Dien, 2007; Dechy et al., 2008) that can be observed at several levels:

- *At the societal and global level*, by an increased information accessibility and sharing with the modern means of communication (e.g. on the accidents).
- *At the economic, financial, political, institutional and legal level*, by the European and international harmonisation processes in particular to reduce the competition distortions in the market economy (e.g. International and European standardisations, safety directives, permanent investigation boards creation).
- *At the industry level*, with the technological developments, the concentration of the industrial tools with the rise of the multinationals, the experience sharing of the sector professionals (e.g. developments of investigations standards and procedures, crossed audits, sharing of the LFE).
- *At the control authorities' level* (e.g. cross inspection of the IAEA, procedures and methods sharing between inspectors of the Seveso sites within IMPEL network).
- *At the scientific and professional level* (e.g. scientific publications, European research projects, European and international professional networks in the field of the safety and reliability and in the investigation community).

With the development of modern human and industrial societies, of market economy, of functional specialisation of the organisations and with development of the formalised LFE process, an accident may trigger multiple (to sometimes much more than ten) investigations conducted by various actors (top management, Labour, Health and Safety Committee, customers, suppliers, subcontractors in cascades, several control authorities, insurers, justice, investigation boards, researchers...) with common purposes but also competing aims that can drift in conflict (Dechy and Dien, 2007; Dechy et al., 2008; Roed-Larsen et al., 2005; ESReDA, 2009). Indeed, these stakeholders will inquire with various rationales such as engineering, safety, economic and contractual, managerial, legal. This diversity of contexts and frameworks implies several investigation configurations, various uses of approaches and methods but also some common features (facts and event chronology collection, consequences evaluation, causality evaluation and judgement construction, determination of responsibilities and corrective actions). Thus, the AI organisational and managerial conditions remain strongly contingent to the stakeholders' context and are likely to keep competing on political level, on purposes, on findings and on corrective actions issues despite possible harmonisation on some issues (methods, legal definitions...).

In addition, in case of a severe accident or series of accidents with a major learning opportunity for a specific technology and sector, ad-hoc investigation commissions are launched in most countries and sectors with various means in several historical and political contexts. An emergent societal need for ''supra organisational'' safety was born with the introduction of the PAI concept, and its independence from the main stakeholders. This reactive concept, which is focused on the transparency and the causes, is dominated more and more by a prevention goal with the institutionalisation of safety investigation in permanent investigation boards. From technical AIs with strong relations with engineering many years ago and still, one sees a transition towards socio-technical approaches with multidisciplinary teams in safety boards. The chairman of the Dutch Safety Board and the International Transport Safety Association, Peter Van Vollenhoven, held this speech (Van Vollenhoven, 2001) in The Hague in 2002 titled ''*Independent accident investigations: every citizen's right, society's duty*''. He points out that the independence and the impartiality are seen like a pre-requisite to obtain the cooperation of the stakeholders to ensure collective learning. Hence, PAI faces an historical conflict with the responsibility issues of the justice litigation, and that is the reason why PAI are accompanied by legal developments to position the societal need for safety beside the one for justice.

Consequently, a huge variety of AI approaches, methods and positions is observed at the present time and is expected also for the future. A priori, one could argue that it does not constitute a problem in itself: taking into account the specific needs for each actor and sector, and could even be interpreted as a healthy sign fostering safety debates with the necessary multiplicity of the lenses on safety issues, and/or it could possibly generate at most some problems of co-operation and communication. However, with a more normative glance with regard to the knowledge obtained by the WGAI and other scholars, it seems that the problem is much more serious than inter-organisational or methodological. Indeed, to support this point of view, the WGAI survey showed a very limited use of formal methods and involvement of AI and LFE experts takes place. Few investigators and LFE experts have general training in conducting AI, and even less on the systemic and organisational approaches, to the extent that we could wonder about the weaknesses of the analysts and their approaches as a contributing factor to the repeated failures of the LFE (Dechy and Dien, 2007; Dechy et al., 2008; Dien et al., 2007). In addition, few organisations (except for some investigation boards and industrialists) adopted the socio-technical and organisational paradigms in their approaches and methods. Thus, the technical dominant paradigm with the engineering culture and the human error paradigm remain very dominant despite many scientific statements since the eighties and nineties (Llory, 1996, 1999; Turner and Pidgeon, 1997; Rasmussen, 1997; Reason, 1997).

In addition, the AI and LFE processes bring interesting findings for accident prevention that remain sometimes insufficient. Although some safety performances results are convincing over the last 50 years, Amalberti (Amalberti, 1996) speaking in 1996 about "*ultra-safe systems*" and Frantzen (Frantzen, 2004) diagnosing in 2004, despite minor yearly statistical variations, an asymptotic trend to the improvement of safety ("*tango on an asymptote*"), major accidents and disasters underline the failures of the LFE (Llory, 1996, 1999; Dechy and Dien, 2007; Dechy et al., 2008) and of other organisational factors (Dien and Llory, 2004; Llory, 1996, 1999; Dechy et al., 2004; Dien, 2006; Turner and Pidgeon, 1997; CAIB, 2003; US CSB, 2005; Reason, 1997; Cullen, 2000).

On the investigation board level, a great diversity was also noticed in legal contexts and on several issues such as the organisational structures, the investigations procedures and techniques in use. On the legal and procedural level, a harmonisation trend was noted with the ICAO, IMO and EC directives in particular in the transportation sector. The independence and the clear distinction with the judicial inquiries are often stated in the legislation. With different constraints, several organisational models coexist and have similar performances, but for the majority of the investigation boards, the following four elements of organisational structure are observed (Roed-Larsen et al., 2005):

- A managing Board which is small in size and comprises of ordinary members, supplemented by extraordinary members who provide specific knowledge, quality control and support from the relevant sectors.
- A professional bureau that combines the experience and expertise in the relevant sectors with the methodological elements of safety investigations.
- Experts available on call, who can be appointed in when specific expertise or capabilities are required.
- An information structure that can be used to obtain information for the design and performance of the investigation and which serves as the basis for the comparison of facts determined during investigations.

9. Dilemmas and conflicts

Whether it is a public or in-house AI, a number of dilemmas and conflicts have to be handled in the organisational framework and daily conduct of AI. For the PAI that can be managed by ad-hoc commission or investigation boards, external factors, like the relationship to the environment, the structural and legal framework, the administrative and financial resources, the political influence, the transparency degree, the reputation and the legal role of the victims, can all be at the origin of these conflicts. They can also originate from internal factors such as the organisational model, the role of independence, the material and financial resources, the teams competencies, the school of thought or dominant paradigm, the methods in use, the innovation capacity, the safety management, the contact with the victims and their families (Roed-Larsen et al., 2005).

Similar conflicts and dilemmas are present for company investigations: independence of the actors to the causality of the accident and dependence to the witnesses, blame culture and transparency on the causes, human error versus managerial and organisational deficiencies, internal competence and external expertise, resources, evidence collection and other conflicting activities such as rescuing, cleaning and repairing, investigation duration, and delay to re-start under production pressure… the unavoidable trade-offs have consequences on the AI and LFE quality.

One of the issues that animated the WGAI (Roed-Larsen et al., 2005) as well as many actors (Van Vollenhoven, 2001; Kahan, 1998; Stoop, 2000; Henrotte, 2000; Kahan et al., 2001) is the question of the multi-modal investigation boards compared to the sectorial and modal boards. Indeed, two strategies (multimode, multinational) are under debate with an identical objective: achieving a legally based, independent position, professional credibility and public confidence, high quality performance and critical mass to ensure continuity. The two proposals coexist with other operating modes (sectorial investigation boards, ad-hoc commissions) also having advantages and drawbacks (Table 1).

Advocates of multimodality believe that the test of time is on their side. None of the present multi-modal boards wants to go back to a single-mode concept (Van Vollenhoven, 2001).

The other proposal is the multinational concept. The ATAIC (Air Transport Accident Investigation Commission) consists of 12 Member States of the former Soviet Union, and was charged to maintain the safety level in spite of the USSR disintegration. This modal culture is accompanied by the belief of a weak interest for transversal LFE from other sectors to the specific aviation sector. In addition, in the EU, European agencies with safety objectives were established. One possibility is the evolution of a national investigation board towards a unified institution such as the US NTSB (federal agency). Beyond cultural resistances, or from professionals, resistances of the Member States could be at work against this type of evolution.

For PAI, but to a certain extent also for internal AI, one of the most important and debated factor is **Independence**. This famous Independence factor is supposed to support the impartiality, the integrity, the objectivity, the credibility, the transparency and the confidence of the stakeholders. First of all, it is worth recalling that independence is a relative concept. A total independence of the political and cultural system does not exist. In addition, a total independence of the sector and operational practices can compromise the credibility of the investigation board and deprive it of information sources, knowledge and especially of up-to-date competencies. Unrealistic recommendations could be proposed by a too much independent board. On the other side, cultural and epistemological barriers can be hard to overcome and even lead to defensive postures. Thus several dilemmas, conflicts, paradoxes are to be handled and require trade-offs at several levels (institutional and

Table 1
Arguments in favour and against multi-modal investigation agencies (Roed-Larsen et al., 2005).

Arguments against multi-modal agencies	Arguments in favour of multi-modal agencies
A loss of in-depth modal expertise and credibility in the sector due to a dilution in focus by combining various modes and sectors	A critical mass in knowledge is required to maintain high quality performance. Skills are transferable in managing major accidents, reviewing reports, or support by non-modal specialists such as metallurgists and human factors
Absence of learning potential due to dominant substantive differences between modes which exceed apparent similarities	Sharing resources in administration, facilities, senior management, training may provide a critical mass and a defence against budget cuts and benefit economy of scale effects
A domination by outsiders with insufficient expertise and insight, focusing attention towards issues and solutions at a generic and aggregated level	A similar approach across all sectors provides similar quality of investigations, policy harmonisation and a single philosophy, leading to increased public confidence in investigations
An attitude of segregation and compartmentalisation within modes hampers a willingness to co-operate	Synergetic co-operation may emerge from methodological and procedural similarities, leading to harmonisation of investigative methodologies
Loss of required skills and expertise during fact-finding and analysis in single major-event investigations, especially relevant where a leading role in major investigations is required	Combined experience can improve transparency of organisational and managerial issues for senior staff; CEO's and Board members during conduct of major investigations, training needs, dealing with the public and press, quality of reporting, drawing up of recommendations, flexibility of resource allocation and other general issues at a senior staff level

legal, organisational, communicational, training and on the process of investigation). In practice, independence refers to the evaluation and assessment of facts and findings without direct interference from governmental agencies and authorities, or vested industrial interests, leaving the drafting of recommendations and reporting to the discretion of the investigation agency.

Many countries and sectors clearly distinguished in regulations the safety PAI from the justice inquiries. Thus, a witness' protection is framed in order to free speech and the findings of the PAI cannot be used for legal prosecution. It could be objected that the justice inquiries can end up with a truth. However, the investigations' aims and temporalities are different, opposed on some points but are still complementary, in particular for prevention. This protection of information sources, the absence of any legal constraining capacity (as the police), are favouring the information release, in particular the one that is subjective and individual. This transparency on the actors' practices (sometimes necessarily secret (Llory, 1996, 1999; Dejours, 2003), or even in the dark side of organisations (Vaughan, 1999; Llory, 2006), perceptions, rationalities is a pre-requisite to understand the accidental phenomenon. It must benefit from the integrity and impartiality of investigation.

These AI qualities can only be reached if the investigators have sufficient levels of competencies, performances and resources. An increased need for a wider field of competencies is required with the development of global approaches integrating technical, human, organisational and societal dimensions. Thus, the resources necessary to understand the accidental phenomena and to the supply the suitable recommendations can be in danger with regards to budgetary constraints, which is what happened to the US NTSB in the nineties. To conclude, independence is not the only factor for high quality investigations (that identifies at least organisational and societal causes). On the other hand with increasingly systemic and organisational approaches, independence is a powerful factor to struggle with managerial, administrative, budgetary and political resistances.

10. Future challenges

Several challenges were identified by the WGAI through the three studies and the two conferences (Valvisto et al., 2003; ESReDA, 2003, 2009; Roed-Larsen et al., 2005; Dechy and Cojazzi, 2007). Thus the safety added value of AI was largely pointed out and testified by some watchwords such as the one of the aviation investigators associations (ISASI) since 1964 "*safety by investigation*" and the one of investigators in the maritime field (MAIIF) since 1992 "*maritime safety through investigation and co-operation*". Moreover, the need for independent, in-house and public AI, was largely recalled and integrated by the ITSA in 2004 with the Van Vollenhoven doctrine (Van Vollenhoven, 2001) "*Independent accident investigations: every citizen's right, society's duty*". Their position, beside the justice inquiries, must continue to be institutionalised. There remain many legal and political challenges according to countries and sectors.

An evolution of the AI scope is expected for several reasons. Shouldn't the field of the accidents include the near-misses, the catastrophes, the crises, the natural disasters, the safety and security events? In addition, the word 'accident' refers to the industrial accidents and the man-made accidents not to the natural disasters. On one hand, this traditional border is disputed by the effects of the anthropic activities on climate change and natural disasters and on the other hand, the technological systems are defined in environmental constraints which will evolve probably faster. Some industrial accidents have natural causes (Na-tech events). In such cases, a widening of AI scope would be an opportunity to revise underlying models and methods to analyse causalities.

One of the LFE process issues is emerging from its intrinsic nature as a reactive process of generalisation with an accident which will not re-occur with the same pattern. It is a compulsory transformation towards preventive knowledge that is risky. Safety studies findings, comparisons with other events, along with the use of series of events can all help the building of a more robust process of generalisation. Thus, one could shift from AI to safety investigation initiated either in the aftermath of an accident, a near-miss or near-hit, a weak signal, or an organisational change. In addition, as a first step, this generalisation process is necessary when transferring between different sectors or organisational contexts but it implies in a second step a readjustment with the context where the lesson must be implemented (Koornneef, 2000). Moreover, the recommendations established on a reactive basis, will have to better integrate pro-active insights with the use of scenarios and forecasting. More generally, one could advise to shift from static analyses to dynamic analyses and follow-ups. In front of the human, organisational and systemic phenomenon complexity, with their unpredictability and their non-linearity, the analyses, findings and recommendations cannot be regarded as valid (or closed) in an absolute manner towards time. The corrective actions must be the object of a regular and systematic follow-up in order to detect unexpected and perverse effects. Cases and diagnoses are not fully closed, and the AIs and risks analyses must be re-opened within sight of new elements.

Within the WGAI, a broad consensus was reached on the need to adopt a socio-technical and inter-organisational vision (Wilpert and Fahlbruch, 1998) for high-risk industries and to refer to holistic, systemic and organisational approaches for AI. Several AI had the occasion to have convincing results for better understanding accidents and finally to better designing prevention measures. Here again, the CAIB pointed the challenges very clearly, "*Many accident investigations do not go far enough. They identify the technical cause of the accident, and then connect it to a variant of "operator error" – the line worker who forgot to insert the bolt, the engineer who miscalculated the stress, or the manager who made the wrong decision. But this is seldom the entire issue. When the determinations of the causal chain are limited to the technical flaw and individual failure, typically the actions taken to prevent a similar event in the future are also limited: fix the technical problem and replace or retrain the individual responsible. Putting these corrections in place leads to another mistake: the belief that the problem is solved.*[5]" In other words, as many accident investigations do not go deep enough in researching causes, they stay at the surface—thus leaving room for the same type of events to recur. Furthermore, weaknesses in investigation could block the capability of finding both generic characteristics from the analysis of the event and other characteristics of interconnected events. This epistemological (r)evolution, although known and advocated by scholars, is not yet strongly diffused within the industry. The dominant paradigms of the technical failures and the human error are still quite present. Thus transfer efforts are to be realised for the industry and the authorities where cultural (technique oriented), managerial and budgetary resistances are strong. New models and methods should be developed in that way.

Preferably before an event occurs, AI protocols must be designed by organisations and the training of competent investigators has to be carried out in order to develop the investigation and learning capacities. The LFE, investigators, or social sciences skills and professions remain unrecognised in these universes of engineers. These evolutions are already observed within the investigation boards (engineers towards risk specialists) and in some ad-hoc commissions like the CAIB one. Moreover, as we stated before, the diversity of the methods in use or the lack of their use, is the symptom of the current organisational failure of the AI and LFE process. Beyond the necessary developments, research and transfers to practitioners, the priority remains to speed-up the exchange of best practices within several networks. This diagnosis led the ESReDA WGAI to focus on this last priority.

11. Recommendations and suggestions for action

Several recommendations and suggestions for action were made to the stakeholders by the WGAI throughout its three reports (Valvisto et al., 2003; Roed-Larsen et al., 2005; ESReDA, 2009) at the following levels:

– *At the EU, EC and some institutions level*: they should develop safety AI directives in order to harmonise the requirements and procedures, and integrate best practices of high-risk industries ; the multi-modal AI agency concept should be studied; the EU should encourage co-operations on these subjects and develop an extensive research program on crisis and risk management including AI; this is a priority as it implies an imminent and necessary change of the present dominant paradigms and a development towards the socio-technical and inter-organisational paradigm.
– *At the EU Member States level, their Parliaments, governments and ministries*: a legal and institutional revision should be carried out to facilitate the implementation of new investigation boards in risky sectors, characterised by high degrees of transparency, independence, competence and resources.
– *At the level of control authorities in charge of AI*: public authorities that are in charge of accident and disaster investigation should engage in networking and promote better cooperation and coordination, the exchange of information and methodology, to satisfy the expertise requirements during investigations and to feed the development of knowledge with lessons learned; accidents and safety investigations should be seen as problem providers for knowledge developers.
– *At the level of National PAI Commissions or Safety Boards*: National investigation bodies in different fields should promote possibilities of better structural and operational cooperation, a system of exchange of experience, methods and personnel, and support R&D programmes and projects concerning accident investigation.
– *At the level of research centres, universities, qualified institutions*: they should develop research programmes in disaster and accident investigations, crisis and risk management in close cooperation with political and administrative institutions, industrials, emergency response organisations and victim groups; the methodological development requires a simultaneous development of the systemic and organisational models to identify the systemic deficiencies and the changes required for the system.
– *At the national and international organisations level*: they should identify and develop standards and procedures for AI, support the development of independent commissions, contribute to higher transparency of the reports and take active role in promoting competence, education and training in accident prevention.
– *At the level of industry*: they should adopt a pro-active attitude for the implementation of methodological, human and organisational resources (internal and external), for the improvement of the AI and LFE quality; these issues must be stimulated and integrated in the developments of the new safety management systems; the resources allocated for AI and LFE must be reinforced.
– *At the professional investigator associations level*: they should be created in some sectors such as the association of investigators as in the fields of aviation and maritime and encourage the development of competences.
– *At the level of investigators*: they should look for information, LFE and investigator qualification trainings; the investigator and LFE professional qualifications should be more recognised within organisations and receive some qualification by education programmes to be developed by universities and other institutions.

12. Conclusion

During 8 years, the WGAI promoted and enabled knowledge exchange, emergence and formalisation of scientific data and lessons on the current accident investigation practices in Europe, thanks to the organisation of two ESReDA seminars and the publication of three documents. The WGAI testifies an increased formalisation of the internal and public safety investigation of accidents (in opposition to the justice inquiries), illustrated by the set-up of permanent investigation boards. The great diversity of cultural, societal, institutional, organisational, epistemological, and methodological contexts was expected, and can be seen with a long term view as a potential richness for the EU and industrial safety. Nevertheless, it is also the sign of serious delays in many countries, sectors and organisations, and should be understood as a major weakness in the management of the accident investigation and learning process at all the levels of the socio-technical system. We can observe its adverse effects with the repetition of some

[5] Emphasis added.

accidents. However, powerful processes of convergence, harmonisation, concentration, best practices and scientific knowledge sharing at all the levels, in Europe and the world, in each country, sector, industrial group, will probably improve the accident investigation process and may also prevent accidents in the future. In the end, the only thing the WGAI could do and propose was to stimulate those processes. Starting with these WGAI findings and in order to close the learning from experience loop upon accident investigations, a new ESReDA working group is being formed to focus on the "Dynamic learning as a follow-up of the lessons learned from accident investigations". New participants and any contributions will be welcome. A triggering event of this new project group, the 36th ESReDA Seminar has been hosted by EDP, in Coimbra, Portugal in June 2009 on "Lessons learned from accidents investigations".

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